April 19, 2024

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Maryland Department of the Environment
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Subject: Updated Evaluation of HydraSleeve Sampling Device for Long-Term Groundwater Monitoring Former Kop-Flex Facility Site, Hanover, Anne Arundel County, Maryland

Dear Mr. Stevens:

On behalf of EMERSUB 16 LLC and its parent company, Emerson Electric Co., WSP USA Inc. (WSP) is providing an updated evaluation for the continued use of the passive/no-purge (HydraSleeve®) sampling method for the long-term groundwater monitoring activities at the Former Kop-Flex Facility Site (the "Site") in Hanover, Anne Arundel County, Maryland (Figure 1). A field demonstration study of this sampler was conducted in 2016 to assess its performance in collecting representative groundwater samples for volatile organic compounds (VOCs) and 1,4-dioxane analysis.[1] Using a weight-of-evidence approach, the study concluded that constituents of concern (COCs) concentrations were similar in samples obtained using the HydraSleeve® sampler and both standard purge[2] and low-flow sampling methods, thus indicating the viability of this sampling method for the groundwater monitoring activities at the Site. The report of the 2016 HydraSleeve® field demonstration study was submitted to the U.S. Environmental Protection Agency (EPA) and Maryland Department of the Environment (MDE) for their review regarding the study's findings and conclusions. Based on the information in the report, USEPA an MDE provided, via electronic mail, conditional approval for the use of the HydraSleeve® sampler for the collection of groundwater samples in both onsite and offsite monitoring wells. However, USEPA and MDE noted that further evaluation of the comparability in the water quality data obtained using passive/no -purge and conventional sampling methods would need to be conducted following the completion of additional monitoring events using the HydraSleeve® sampler.

WSP initiated the use of the HydraSleeve® sampler for the long-term groundwater monitoring activities during the baseline (December 2016) sampling event. Given the continued use of this sampler through 2023, WSP believes that sufficient data has been obtained to allow for additional evaluation of the HydraSleeve® to provide representative water quality samples. The remaining sections of this updated evaluation report provide a discussion of the approach used to assess the applicability of a passive/no-purge sampling method, and an analysis and interpretation of the data obtained using both the conventional and HydraSleeve® sampling methods.

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[1] WSP USA Corp. (2016) *HydraSleeve Field Demonstration Study, Former Kop-Flex Facility Property, Hanover, Anne Arundel County, Maryland, Brownfield Master Inventory Number MD0286.* July 19, 2016.
[2] The standard purge sampling method involves the removal of a minimum of three well volumes prior to the collection of a groundwater sample for chemical analysis.

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OVERVIEW OF GROUNDWATER ASSESSMENT AND MONITORING

REVIEW OF GROUNDWATER MONITORING ACTIVITIES

PRE-RESPONSE ACTION PERIOD (2007 THROUGH 2015)

Groundwater monitoring to assess conditions at the Site were initiated as part of a Phase II assessment of the property in the late 1990's. These initial efforts focused on evaluating the hydrogeology and hydrogeochemistry in the shallow zone of the Lower Patapsco Aquifer (LPA) in the onsite area, A formalized groundwater monitoring program was developed in conjunction with the implementation of remedial activities in two areas of the Site in the early 2000's. The remediation monitoring activities involved the semi-annual sampling of the shallow zone wells using both standard purge and low-flow sampling methods. After the remedy implementation, supplemental investigations were conducted between 2006 and 2013 to further evaluate the horizontal and vertical extent of COCs and included the installation and sampling of new monitoring wells in both the shallow and deep zones of the LPA. These wells were incorporated into the existing groundwater monitoring program for the Site, and thus sampled using the same methods and at the same frequency as the other onsite wells.

Evaluation of the hydrogeochemistry in the offsite area began with the installation and sampling of monitoring well MW-24D on the adjacent Williams-Scotsman property in the spring of 2012. Based on the groundwater quality data obtained from this well and samples from private water supply wells further to the south, additional groundwater investigation activities were conducted in the summer and fall of 2014 to determine the presence and distribution of site-related COCs hydraulically downgradient of the former Kop-Flex facility. These investigation activities focused on the Severn area south of Maryland Route 100 and involved the installation of wells in both the shallow and deep zones of the LPA in five different areas. After completing the well installation activities, quarterly groundwater sampling was conducted using the low-flow sampling method to gather data on COCs concentrations in the aquifer.

HYDRASLEEVE® SAMPLER FIELD DEMONSTRATION STUDY (2016)

During the spring of 2016, WSP completed a study to evaluate the performance of a passive/no-purge sampling device - HydraSleeve® - in obtaining representative samples from monitoring wells for determining groundwater COCs concentrations at the Site. The study approach involved the collection of a single round of groundwater samples from select onsite shallow and deep monitoring wells using the HydraSleeve® sampler and comparing the analytical results for these samples with data from previous semi-annual monitoring events where samples were collected using either standard purge or low-flow purge-and-sample methods. An overall comparison of the analytical results for the different sampling methods indicated extremely minimal differences with respect to exceedances of the groundwater quality criteria, and thus no change in the inferred plume extent between the two data sets. An overall assessment of the sampling data for the primary site-related COCs – 1,1,1-trichloroethane (1,1,1-TCA), 1,1-dichloroethene (1,1-DCE), 1,1-dichloroethane (1,1-DCA) and 1,4-dioxane – was also performed using statistical and quantitative methods along with an evaluation of data plots where samples had been collected from wells using both passive/no-purge and purging methods. This evaluation indicated general similarity in the sample results for 1,1-DCE and 1,1-DCA, indicating concentrations in samples collected using the HydraSleeve® are consistent with historical monitoring data. Comparison of the sample data were also consistent for TCA, although in a manner that shows a difference between the sampling methods. For 1,4-dioxane, concentrations tended to be slightly higher in samples collected using either the standard purge or low-flow purging methods compared to the HydraSleeve® sampler. This difference between the conventional (purge-and-sample) and passive/no-purge sampler results was believed to reflect the high miscibility of this compound in groundwater and the fact that pumping, even at very low rates, could result in increased mass transport toward the well and thus higher concentrations in samples. A detailed discussion of the data evaluation methods and results can be found in the HydraSleeve Field Demonstration Study report (WSP 2016).

Using a broad weight-of-evidence approach, it was concluded that COCs concentrations in samples collected using the HydraSleeve® were similar to the concentrations detected in the standard purge and low-flow samples. Based on this conclusion, WSP recommended the use of the HydraSleeve® sampler for the long-term groundwater monitoring program at the Site.

RESPONSE ACTION PERIOD (2017 TO PRESENT)

Since early 2017, semi-annual groundwater monitoring has been conducted at the Site to gather data to evaluate the effectiveness of the implemented response action in accordance with the approved Groundwater Monitoring Plan. The monitoring program includes the collection of water level data and groundwater samples from monitoring wells in both the shallow and deep zones of the LPA.[3] For all monitoring events, including the baseline sampling round completed in December 2016, groundwater samples have been collected from the wells with single-use HydraSleeve® samplers.

In the offsite area, additional groundwater monitoring wells were installed in the spring of 2018 to supplement the existing well network used to assess the groundwater quality in the aquifer system. Most of these monitoring wells were completed in the deep LPA zone, which serves as the hydrostratigraphic unit for the offsite migration of COCs from the Site. Two monitoring wells were also screened in the deeper Patuxent aquifer that is separated from the LPA by the Arundel Clay confining unit. Prior to the 2018 well installation activities, groundwater samples continued to be collected from the existing monitoring wells on a quarterly basis. After augmenting the well network, the sampling frequency for the previously installed (2014) wells shifted from quarterly to semi-annual. The newly installed monitoring wells were sampled quarterly for four (4) consecutive quarters and then transitioned to a semi-annual sampling frequency consistent with the other offsite monitoring wells. Groundwater samples for all monitoring events were collected with single-use HydraSleeve® samplers.

CURRENT GROUNDWATER CONDITIONS AND RESPONSE ACTIONS

Groundwater investigation activities indicate the existence of Site-related COCs in both the shallow and deep zones of the LPA beneath the former Kop-Flex property and extending south-southeast past Maryland Route 100 (Paul Pitcher Highway) and slightly beyond Maryland State Route 174 (Reece Road). As noted earlier, the Site-related VOCs in groundwater primarily consist of 1,1,1-TCA and its biotic and abiotic degradation products 1,1-DCA and 1,1-DCE, respectively. Additionally, 1,4-dioxane, is present in groundwater and has been used to delimit the extent of contaminant impacts to the aquifer system due its high solubility and mobility in sediment-water media (Figures 2 and 3). In the shallow LPA zone, affected groundwater largely occurs on the former Kop-Flex property, with the highest COC concentrations present in the eastern portion of the former facility with levels decreasing westward in the direction of groundwater flow (Figure 2). The COCs detected in the deep LPA zone are consistent with those present in the shallow zone. Overall, COC-impacts in the deep zone extend from north of the former Kop-Flex property southward to the Andorick Acres community located west of Maryland Route 170 (Telegraph Road) and south of Reece Road (Figure 3).

Pursuant to the requirements under EPA Consent Order RCRA-03-2016-0170 CA and approved Response Action Plan, a hydraulic containment system (System) has been installed at the Site to control the migration of the site-related COCs in groundwater. The System involves the extraction of affected groundwater from three shallow recovery wells (RW-1S through RW-3S) screened within the shallow zone of the LPA, and two deep recovery wells (RW-1D and RW-2D) screened in the deep LPA zone. The extracted groundwater is routed via underground piping to a treatment building for the removal of VOCs and 1,4-dioxane using a specialty resin. The treated water is discharged to Stony Run, in accordance with the requirements specified in National Pollutant Discharge Elimination System (NPDES) Permit MD0069094 (corresponding to Maryland State Discharge Permit Number 15-DP-3442) issued by the MDE. The System has been in operation since mid-March 2017.

[3] A listing of the shallow and deep monitoring wells included in the monitoring program can be found in Section 3 of the following document: WSP USA Inc. (2015) *Groundwater Monitoring Plan, Former Kop-Flex Facility, Hanover, Maryland.* September 17, 2015.

HYDRASLEEVE® SAMPLER EVALUATION

METHODS

The technical approach utilized by WSP to further evaluate the applicability of the HydraSleeve® sampler to collect groundwater samples representative of the aquifer consisted of two components. The first step involved a detailed review of the Site conditions to ensure a passive/no-purge groundwater sampling method would be appropriate for the planned groundwater monitoring activities. For this part of the evaluation, WSP utilized the decision tool developed by the U.S. Geological Survey (USGS) and Interstate Technology and Regulatory Commission (ITRC) and published in the USGS Techniques and Methods manual.[4] The decision tool consists of a table with 10 questions that pertain to various characteristics of the site that have a bearing on the applicability of passive/no-purge sampling methods for groundwater quality monitoring. A copy of the decision analysis summary table provided in the USGS manual is presented below.

No.	Question	YES	NO
1	Is sampling being done for long-term groundwater monitoring?		
2	Has the groundwater chemistry at the site been fully characterized?		
3	Can the passive sampler being considered collect samples for all constituents of interest?		
4	Can the passive diffusion sampler being considered collect the sample volume necessary to analyze the constituents of interest given the well construction?		
5	Have hydraulic and chemical vertical profiling been done in the wells to be sampled?		
6	Are the monitoring wells to be sampled in an area where there is sufficient groundwater velocity (>0.5 ft/day)? Low groundwater velocity can result from either a low hydraulic conductivity (<10^{-5}cm/s) or a low hydraulic gradient (<0.001).		
7	Are the monitor wells currently free of dedicated pumps or other sampling equipment?		
8	Has a cost evaluation shown the passive sampler being considered offers a cost savings compared to current sampling techniques?		
9	Have you discussed the potential use of the passive sampler with site regulators?		
10	Are the site regulators familiar with the passive sampler technology, and will they allow the data to be used for the same purposes as those obtained by purge sampling?		

(From USGS 2020; modified from ITRC 2004)

Given that wells comprising the onsite groundwater monitoring network are screened in both sandy and clayey aquifer materials, separate decision summaries were completed for the wells completed in the different hydrostratigraphic units. A single decision summary was prepared for the offsite area because all groundwater monitoring wells in this portion of the Site with detectable levels of site related COCs are screened in predominately sandy sediments in the deep LPA zone.

After assessing the appropriateness of the passive/no-purge sampling method for the long-term monitoring activities, WSP utilized both non-statistical and statistical methods to evaluate the sampling data obtained using the HydraSleeve® and conventional sampling methods. The non-statistical method involved 1:1 graphical comparisons of the analytical data for samples collected using

[4] Imbrigiotta, T.E. and Harte, P.T. (2020). Passive sampling of groundwater wells for determination of water chemistry. *U.S. Geological Survey Techniques and Methods*, Chapter 8, Section D, Book 1, 80 p.
Interstate Technology and Regulatory Council (ITRC). (2004). Technical and Regulatory Guidance for Using Polyethylene Diffusion Bag Samplers to Monitor for Volatile Organic Compounds in Groundwater. Washington, D.C., ITRC DSP-3, 78 p.

the different methods. Given the non-paired nature of the sampling data, the following statistical tools were employed as part of the evaluation:

- Preparation of box plots showing the median, first and third quartiles, and the range (i.e., maximum, and minimum),
- Calculation of the relative percent difference (RPD) between median concentrations, and
- Performance of the Wilcoxon-Mann-Whitney Rank Sum Test on the two data sets

The Wilcoxon-Mann-Whitney Rank Sum Test is a non-parametric procedure that determines if the medians of the conventional and HydraSleeve® sampling data sets are significantly different. The selected statistical and non-statistical evaluation methods are consistent with those used during the 2016 field demonstration study (WSP 2016) and are cited in publications that provide guidance for transitioning from conventional to passive/no-purge groundwater sampling methods.[5]

SELECTION OF DATA FOR EVALUATION

Given the detection of site related COCs beyond the Site boundary, monitoring wells from both the onsite and offsite portion of the groundwater plume were selected for the updated sampler evaluation. For the onsite area, a major factor in determining wells suitable for inclusion in the evaluation was the extraction of impacted groundwater from recovery wells in the shallow and deep LPA zones. The initiation of remedial pumping in early 2017 also coincides with the transition from conventional to HydraSleeve® sampling methods at the Site. Given the high probability of concentration changes in response to groundwater pumping, monitoring wells located most distant from the recovery wells, and thus outside the immediate area of hydraulic influence, were deemed the most suitable for comparing data from pre-remediation (conventional) and remediation (HydraSleeve®) monitoring events. Given this determining factor, the onsite wells selected for the evaluation included shallow zone wells MW-04 and MW-09 and deep zone well MW-23D (Figures 2 and 3). These wells are also included in the data set for the 2016 HydraSleeve field demonstration study. In the offsite area, the monitoring wells selected for the sampler evaluation were (1) located within or just outside the inferred plume area within the deep zone of the LPA and (2) installed in the summer of 2014, when conventional sampling methods were still in use at the Site. Based on these criteria, the specific wells chosen for the evaluation included the deep wells at the MW-25 location (MW-25D-130 and MW-25D-192), MW-28D, and the deeper paired well at the MW-33D location (MW-33D-295) (Figure 3).

Data from previous sampling events was compiled to use as a basis of comparison of the conventional and HydraSleeve® sampling methods. Since initiating the Site groundwater monitoring activities, all samples have been analyzed for volatile organic compounds using EPA SW-846 Test Method 8260. Based on a request from the EPA and MDE, EMERSUB 16 started analyzing the onsite and offsite groundwater for 1,4-dioxane in 2011 using a modified version of the 8260-test method. A change to an analytically more accurate and precise 1,4-dioxane test method was implemented in 2022 for both the onsite and offsite groundwater monitoring programs. In order to further minimize the number of variables that could potentially affect the comparison of the monitoring data, results for groundwater samples collected after 2021 were not used in the graphical and statistical evaluation of the sampling methods.

The data from the selected onsite monitoring wells covers semi-annual sampling events between May 2007 and May 2021. Conventional well sampling methods were used to collect the onsite groundwater samples from May 2007 through June 2015. During this monitoring period, the sampling events were performed using a combination of the standard purge method, where three to five well volumes were removed from the well to ensure that the sample was representative of the water in the aquifer, and the low-flow purge and sample method. Even though both the standard purge and low flow methods were used, the majority of the samples collected during the 2007 through 2015 monitoring events utilized the standard purge procedure. The HydraSleeve® sampling method has been used to collect semi-annual well samples from December 2016 through May 2021 in accordance with the groundwater monitoring program for the onsite hydraulic containment system. For the offsite wells, the results from quarterly

[5] Naval Facilities Engineering Command (NAVFAC). 2013. *Fact Sheet – Transitioning from Conventional to Passive Sampling for Groundwater.* April 2013, 3 p.

monitoring events conducted at the selected monitoring wells between September 2014 and September 2016 constituted the conventional sampling data set. All sampling events completed during this 2-year period utilized the low-flow sampling method. The HydraSleeve® sampling data set consisted of the results for quarterly (December 2016 through February 2018) and semi-annual (May 2018 through May 2021) samples collected from the wells as part of the approved response action activity for the offsite area.

The evaluation of the sampling results focused on the primary COCs at the site, which include the following:

- 1,1,1-TCA
- 1,1-DCA
- 1,1-DCE
- 1,4-Dioxane

The historical analytical results (including duplicates) for the 2007 through May 2021 groundwater sampling events are provided in Enclosure A.

APPLICABILITY OF HYDRASLEEVE® SAMPLING METHOD FOR SITE GROUNDWATER MONITORING

Enclosure B includes completed versions of the USGS/ITRC passive sampler decision analysis summary table for the onsite and offsite areas. Overall, the largely affirmative answers indicated in the summary tables suggest that passive/no-purge samplers would be a technically viable sampling method for the Site. The only negative answers that require evaluation involve the low groundwater flow velocity for monitoring wells screened in the predominately silt and clay deposits of the shallow LPA zone and the lack of hydraulic or chemical profiling having been conducted in either the onsite or offsite wells. The following provides a discussion of these two factors as they relate to the applicability of using the HydraSleeve® sampler for the groundwater monitoring activities.

Technical concerns regarding the use of passive/no-purge samplers in wells completed in fine-grained aquifer materials are linked to low rates of groundwater flow into the screened interval and the potential for chemical reactions that could alter constituent concentrations within the water column in the well (USGS 2020). The Site contaminants do not consist of chemicals whose concentrations can be affected by changes in oxidation-reduction (*i.e.*, redox) conditions or pH, which could occur in wells with slow flushing times. Given the characteristics of the COCs and chemically inert nature of the PVC well material, the only chemical reaction that could potentially alter the concentrations of contaminants in the well water compared to their levels in the formation would be volatilization. This type of chemical reaction should have very minimal, if any, effect on 1,4-dioxane due to the relatively low Henry's Law constant (K_H) for this compound (5×10^{-6} atmospheres-cubic meter/mole [atm-m^3/mole]), which is a measure of the affinity of a compound to partition from the aqueous to the vapor phase.[6] However, the concentrations of chlorinated ethanes and ethenes could be influenced by this reaction process because of their ability to more easily transfer from the aqueous to vapor phase (K_H values of 10^{-2} to 10^{-3} atm-m^3/mole). Even though chlorinated VOCs could potentially move from the well water to the overlying, air-filled space within the PVC casing, it is reasonable to infer this partitioning would be limited because the inside of the well comprises a "closed system" that is not open to the ambient air when sealed with the well cap. Any potential volatilization of chlorinated VOCs would also be constrained by the small volume of the air-filled space due to small well diameter (2 inches) and shallow depth to the water level in the well. Since the HydraSleeve® sampler is removed immediately after accessing *(i.e.*, opening) the well, there would be no additional loss of VOCs from the water collected during the sampling activities. Given the above considerations, WSP believes the quality of the groundwater data obtained using the HydraSleeve sampler for wells screened in clayey layers is sufficient to meet the goals of the monitoring program for the site related COCs. As discussed in previous reports

[6] https://www.enviro.wiki/index.php?title=Chlorinated_Solvents; accessed on December 5, 2023.

for the Site, the permeable sand deposits constitute the primary pathway for contaminants to migrate and spread within both the shallow and deep zones of the Lower Patapsco aquifer. Thus, the sampling data from onsite wells screened in the sandy sediments will provide the most useful information regarding the performance of the hydraulic containment system and control of COC migration in the aquifer.

As indicated in the decision analysis summary tables, neither hydraulic nor chemical vertical profiling was conducted in the Site monitoring wells as part of the 2016 HydraSleeve® sampler field demonstration test. The reasons for not performing these profiling activities were due to (1) the relatively short (5 or 10-foot) screen intervals for all monitoring wells and (2) the absence of significant lithologic heterogeneity in the portions of the shallow and deep LPA zones that would be sampled by the wells. The /no-purge sampler guidance developed by the USGS states that wells with screens greater than 10 feet in length have "…an increased probability of intersecting zones of differing permeability and hydraulic head and, therefore, an increased probability of vertical flow within the well opening" (USGS 2020). Since horizontal groundwater flow predominates in short-screened wells, the constituent concentrations in samples tend to reflect the hydrogeochemistry of the aquifer formation coincident with the depth of the sampler.

The reason for conducting chemical profiling in wells designated for use of the passive/no-purge sampling method is to determine the appropriate depth(s) for sampler deployment and associated sample collection. In unconsolidated or porous media aquifers, this depth typically corresponds to the portion of the screen interval that intersects the layer with the highest potential for transport of the dissolved COCs in the groundwater. Since continuous coring of the aquifer material was conducted during advancement of all well boreholes except for 3 shallow onsite wells installed during the early investigation phase, the detailed lithologic logs developed from the field descriptions were deemed sufficient to identify the sand or gravelly sand layer that would have the presumed highest constituent mass flux in the screen/open interval. For the shallow onsite monitoring wells where continuous sampling was not performed – MW-01, MW-03, and MW-09 – the lithologic information provided in the boring log indicated minimal heterogeneity in the shallow zone of the LPA at these locations. Thus, WSP had a high level of confidence that the selected sampler deployment depths in these wells would coincide with permeable sand sediments that serve as the primary zone for constituent transport. A review of the field sampling information during implementation of the groundwater monitoring program indicates the majority of the samplers were placed at depths that would allow for the collection of water entering the well from a high permeability sand layer within the screen/open interval. However, at a very small number of locations – three in the onsite area and one offsite – the HydraSleeve sampler was being deployed such that more than 50% of the water would be collected from a depth interval associated with a fine-grained silt or silty clay layer in the aquifer. Given that most of the discharge and constituent mass flux into the screen/open interval would be from the permeable sand layers rather than the finer grained deposits, the water collected by the sampler should still be largely representative of the hydrogeochemistry within a high permeability flow zone for the well.

In summary, the results of the decision analysis indicate the HydraSleeve® sampling method would be applicable for the long-term groundwater monitoring at the Site. The use of the HydraSleeve sampler would allow for the collection of a sufficient volume of sample from the onsite and offsite monitoring wells for analysis of the COCs, and the monitoring activities could be conducted more efficiently and cost effectively than conventional purge-and sample methods. The effective completion of the field sampling is an important consideration for the onsite area due to a high degree of worker activity on the property as part of Catalent's operations. Given the short lengths for the well screens and detailed lithologic information gathered during drilling, performance of hydraulic or chemical profiling was not deemed necessary to successfully implement the use of HydraSleeve® sampler for the monitoring activities. All of the offsite wells and the majority (>80%) of the onsite wells are screened in permeable sand sediments that would contribute sufficient flow of groundwater through the screen/open interval. The lower flow velocities for wells completed in fine-grained, silt and clay materials should not impart detectable changes in the 1,4-dioxane concentrations between the formation water and the water sampled from the well. Given the well construction, it is believed any loss of chlorinated VOCs from the well water should be minimal and not detrimentally affect either the representativeness of the samples or their use in evaluating the groundwater quality in this portion of the LPA.

GRAPHICAL COMPARISON OF CONVENTIONAL AND HYDRASLEEVE® SAMPLER DATA

A graphical comparison of the data obtained using conventional and passive sampling methods is shown in the plots for the primary COCs provided in Figures 4 through 7. For these plots, each point compares the arithmetic mean concentration for the conventional (standard purge and low-flow purge) samples to the arithmetic mean of samples collected using the HydraSleeve® sampler. The plot for 1,1,1-TCA did not include the data from offsite well MW-25D-130 because one anomalously high concentration significantly skewed the mean value for the sample population.

Overall, the plots indicate generally good equivalency between the data obtained from each sampling method, although there is a general tendency toward lower COC concentrations in the HydraSleeve samples compared to the combined low-flow and standard purge samples. The only monitoring well that had mean COC concentrations that significantly deviated from the 1:1 equivalency line was offsite well MW-25D-130, which is located in the northeastern portion of the Harmans Woods development south of Maryland State Route 100 (Figure 1). For this well, mean COC concentrations in the samples collected using low-flow sampling methods were 7x to 8x higher than concentrations in samples obtained using the HydraSleeve sampler. A review of the well construction information for MW-25D-130 indicates the upper 6 feet of the screened interval is open to poorly sorted fine to coarse-grained sand and the lower 4 feet screens interlayered, fine to medium-grained clayey sand and silty sand. The HydraSleeve was being deployed at a depth such that groundwater flowing through both the sand and clayey to silty sand layers would be collected during sampler retrieval. Alternatively, the majority of the water extracted during purging of the well during low-flow sampling was probably derived from the fine to coarse-grained sand layer in the upper portion of the screened interval. Since this sand layer immediately underlies the confining unit for the deep LPA zone, localized area(s) of enhanced mass flux from the clayey aquitard to the more permeable sand below could develop during purging at even very low pumping rates, resulting in groundwater with elevated COC concentrations entering the well during sample collection using conventional methods. This facilitated, pumping-induced transport of contaminants across the clay-sand contact would not occur under normal (*i.e.*, non-pumping) conditions, which would exist during the use of passive/no-purge sampling methods. The mixing of waters from a shallower depth interval with water from the screen interval has been noted at other sites when comparing the results for samples collected using conventional and passive methods.[7] These studies concluded the passive sampler provided more representative data on the VOC concentrations of groundwater entering the well screen than methods that involved the pumping of water from the well.

STATISTICAL ANALYSIS OF CONVENTIONAL AND HYDRASLEEVE® SAMPLER DATA

GENERAL STATISTICS AND RELATIVE PERCENT DIFFERENCES

Table 1 provides the values for various statistical measures – mean, median, standard deviation and coefficient of variation – for the conventional and HydraSleeve® sampling data for each monitoring well. As mentioned in the previous section, the mean and median concentrations for samples collected using the standard purge and low-flow methods tend to be greater than the HydraSleeve sampler mean and median concentrations. This characteristic of the sample populations is shown by the box plots for the shallow and deep zone wells provided in Enclosure C. The only noticeable deviations apparent in the data are for 1,1-DCE in the samples from two deep LPA zone wells – MW-23D onsite and MW-25D-192 offsite. The 1,1-DCE concentrations in the HydraSleeve samples from deep offsite well MW-33D-295 are also greater than the conventional samples, although the difference is relatively small (0.65 µg/L). Both MW-23D and MW-25D-192 are characterized by the presence of one or more layers of fine-

[7] Vroblesky, Don A., Borchers, James, W., Campbell, Ted R., and Kinsey, Willey. 2000. Investigation of Polyethylene Passive Diffusion Samplers for Sampling Volatile Organic Compounds in Ground Water at Davis Global Communication, Sacramento, California, August 1998 to February 1999: *U.S. Geological Survey, Open-File Report 00-307*, 13 p.

grained silt and clay sediments within the screened interval. However, no clayey layers were noted within the aquifer sediments screened by well MW-33D-295.

The coefficient of variation, or CV, is a measure of the dispersion, or variability, of the data from the mean value. Based on the calculated values provided in Table 1, the data collected using the conventional sampling methods tend to have a smaller degree of dispersion than data for samples collected using the HydraSleeve® sampler. The only exception is for the data from shallow well MW-09, where the CV tends to be lower for the HydraSleeve® sampling method for most of the COCs. A closer look at this statistic shows the greatest difference in CV values is associated with (1) wells screened in the shallow LPA zone (MW-04 and MW-09) and (2) results for 1,1,1-TCA, which is the least mobile of the primary COCs, in both deep LPA zone wells. Minimal differences in the CVs exist for the more mobile contaminants – 1,1-DCA, 1,1-DCE and 1,4-dioxane – in the samples from the deep zone wells in both the onsite and offsite areas. Regarding the data variability for the shallow wells, the hydrogeochemistry in surficial water-bearing zones can be significantly influenced by spatiotemporal variations in the nature of water recharging the groundwater surface. Hydrologic data collected after completion of the property re-development in early 2017 show the stormwater management area in the east-central portion of the Site, where MW-04 and MW-09 are located, provides a localized source of recharge to the shallow zone (Figure 2). Thus, transient fluctuations in the groundwater recharge from this stormwater feature could result in variations in COC levels in the 2017 to 2021 groundwater samples collected using the HydraSleeve sampler from both of these shallow wells. This hydrogeochemical variability would not be present for samples collected using the conventional methods because this stormwater management area did not exist prior to 2017.

For the detected COCs at each well, the Relative Percent Difference (RPD) in the median concentrations for samples collected using conventional sampling methods and the HydraSleeve® sampler was calculated using the following equation:

$$RPD = 100*\{(A-B)/[(A+B)/2]\}$$

where:

A = median concentration for samples collected using conventional methods; and
B = median concentration for samples collected using the HydraSleeve® sampling method

A positive RPD value indicates the concentrations in samples obtained using conventional groundwater sampling methods is greater than the concentration in the HydraSleeve sample from the same well, while a negative value indicates the converse situation. Additionally, RPD values approaching zero indicate the different sampling methods will tend to provide similar results, whereas higher values indicate the results for one sampling method tend to differ significantly from the other method. For this evaluation, RPDs greater than +25% or less than -25% were considered to be indicative of a condition where the conventional sampling methods are likely to provide a significantly higher or lower concentration than the HydraSleeve® sampler. This value is similar to RPD criteria that have been used to evaluate bias in laboratory analytical data for groundwater samples. Given the conventional and HydraSleeve® samples were collected during separate time periods characterized by different activities at the Site, the use of a ±25% threshold value, as opposed to a lower value such as 10%, was deemed appropriate for the data sets.

The median RPDs for the primary Site COCs are provided in Table 1, with values less than +/-25% shown in green-colored type and greater than +/-25% indicated in red. The generally positive median RPD values indicate concentrations for these constituents are higher in samples collected using conventional sampling methods compared to the HydraSleeve sampler, which is consistent with other analyses of the data sets. Based on the 25% criterion, most of the values indicate the different methods provide samples with similar concentrations for the primary COCs. This sample comparability includes wells screened in both zones of the LPA and is most prevalent for the contaminants with the greatest mobility in the groundwater system. The RPD values indicate the greatest apparent discrepancy in sample concentrations occurred in the samples from shallow onsite well MW-09 and deep offsite well MW-25D-130. As discussed previously, the meaningful differences in the COC concentrations in the MW-25D-130 samples are believed to reflect the facilitated transport of contaminants under transient pumping conditions during well purging. The localized recharge associated with the stormwater management area could also factor into the discrepancy evident in the COC concentrations for the MW-09 samples. However, an additional mechanism(s) may contribute to the differences indicated by the relatively high RPD values.

WILCOXON-MANN-WHITNEY TEST

The Wilcoxon-Mann-Whitney Test for Uncensored Data without Non-detects (Wilcoxon-Mann-Whitney Test) was performed to determine if the mean analytical results for samples collected using conventional and HydraSleeve® sampling methods represent statistically different populations. This test is a non-parametric hypothesis testing procedure that can be used on data sets comprised of non-paired samples that have been collected at different times using different sampling methods. One advantage of the Wilcoxon-Mann-Whitney test method that is relevant to the sampler evaluation is the results are not affected by outliers in the data population.

Assumptions inherent in the Wilcoxon-Mann-Whitney test include the following:

- Measurements obtained using the different sampling methods are not correlated, and
- Probability distribution of the concentration data for each sampling method are similar.

The second assumption was evaluated by comparing the variances of the sample data sets. The equality of variances between the data populations is important when using the Wilcoxon-Mann-Whitney test because an incorrect conclusion may result if this assumption is not satisfied by the data.

The ProUCL statistical analysis software package (Version 5.1) was utilized for conducting the Wilcoxon-Mann-Whitney tests on the conventional and HydraSleeve® sampling data.[8] For this method, a two-sided null hypothesis (H0) was selected for each test, with H0 defined as mean/median for samples collected using conventional methods equaled the mean/median for samples collected by the HydraSleeve®. A 95% confidence level ($\alpha = 0.05$) was used in determining whether to accept or reject the null hypothesis of equivalency of the sample populations.

The results of the Wilcoxon-Mann-Whitney tests are provided in Table 2 for the shallow zone monitoring wells and Table 3 for the deep wells. As indicated in the tables, the validity of the test results for some wells is considered suspect because of non-conformance with the equality of variances assumption for the method. The wells in this category include onsite shallow well MW-09 and the paired MW-25D wells offsite. If we exclude these wells, the Wilcoxon-Mann-Whitney tests indicate the concentrations in samples obtained using the conventional and HydraSleeve® sampling methods tend to be statistically similar, particularly for the more mobile COCs in aquifer systems such as 1,1-DCA, 1,1-DCE and 1,4-dioxane. However, the results for 1,1-DCE and 1,4-dioxane at well MW-28D indicate an exception to this general conclusion regarding the similarity in sample concentrations (Table 3). The test results for MW-28D are supported by the median and concentration distributions shown in the box plots in Figures C-4 and C-5 in Enclosure C. Even though the statistical test concludes the sample concentrations are dissimilar, the actual difference in the median values is very small – 5.25 µg/L for 1,1-DCE and 1.75 µg/L for 1,4-dioxane. The reason for the apparent difference in COC concentrations is uncertain but may be related to contaminant mass from a specific transport interval/layer within the screened interval being incorporated into the sample collected via well purging but not the groundwater obtained using the HydraSleeve sampler.

CONCLUSIONS AND RECOMMENDATIONS

The results of a previous (2016) study found that groundwater samples collected using a passive/no-purge sampling device (HydraSleeve®) would provide data for COC concentrations similar to samples obtained using conventional sampling methods – standard purge-and-sample or low-flow sampling. The approach selected to assess the comparability of these two general sampling methods involved the use of "non-paired" data from onsite monitoring wells. However, the quantity of sampling data obtained using conventional methods was significantly greater than that available from passive/no-purge sampling events. Given the disparity in

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[8] U.S. Environmental Protection Agency (EPA). 2015. ProUCL Version 5.1 Technical Guide – Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations: Office of Research and Development EPA/600/R-07/041, 312 p.

the sample population sizes, the findings from the 2016 study were considered preliminary pending the collection of additional groundwater quality data using the HydraSleeve® sampler. For consistency, the updated sampler assessment presented in this report continued the use of non-paired data to evaluate the two sampling methods.

As part of this updated evaluation, WSP assessed the applicability of the HydraSleeve® sampler using a range of technical, implementibility, and regulatory criteria adopted by the USGS as developed by the ITRC. Overall, the use of the HydraSleeve® sampler would be appropriate based on consideration of these various factors. The only potential concerns identified involved the low groundwater flow velocities for onsite monitoring wells screened in fine-grained aquifer materials within the shallow zone of the LPA and the lack of profiling of COC concentrations within the screened intervals for monitoring wells. The slow movement of groundwater through wells screened in predominately silt and clay layers may experience some partial loss of CVOCs (*e.g*., 1,1-DCE and 1,1-DCA) via volatilization. Given the 'closed' nature of a capped monitoring well and immediate retrieval of the sampler upon accessing the well, the loss of volatile constituents should be limited and result in a minimal deviation regarding the accuracy of the CVOC concentrations detected during analysis. Unfortunately, no suitable onsite or offsite monitoring well currently exists to confirm this conclusion concerning the lack of significant CVOC loss in wells screened within clayey deposits and thus lower concentrations in passive/no-purge versus purged samples. The presence of vertical variations in COC concentrations in onsite and offsite monitoring wells is deemed unlikely because of the short (10-foot) screen lengths installed in all Site wells and absence of appreciable vertical heterogeneity in the aquifer materials that are in hydraulic communication with the screened interval. WSP has conducted vertical CVOC profiling at sites in the Atlantic Coastal Plan with paleo-depositional settings similar to the LPA in northern Anne Arundel County and found only very minor differences in constituent concentrations in wells with 10-foot screens.

An updated qualitative assessment was conducted on the historical sampling data collected using the conventional methods and HydraSleeve® sampler using graphical, quantitative, and statistical methods. The 1:1 data plots and RPD values show good correlation between the mean and median concentrations for samples collected using the different sampling methods. Significant deviations between the results for the different sampling methods are isolated and caused by locally anomalous conditions that do not reflect overall Site conditions. The presence of generally higher COC concentrations for methods that involve purging of water from the well prior to sample collection are believed to reflect the historical nature of the contaminant releases on the former Kop-Flex property. The release of solvents several decades ago would have allowed for the storage of contaminant mass in predominately silty and clayey layers and sandy lenses or beds isolated from the zone(s) containing the majority of the groundwater discharge within the heterogeneous aquifer zones. Under pumping conditions, these intervals could contribute contaminant mass via advective and diffusive processes to the groundwater flowing toward a well during the purging process. This enhanced, pumping-induced redistribution of contaminant mass would tend to show the greatest effect on the constituents with relatively low mobility, such as 1,1,1-TCA. This transient transport phenomenon may explain the higher RPD values for 1,1,1-TCA compared to more mobile COCs like 1,4-dioxane. Based on this line of reasoning, the analytical results for the HydraSleeve® samples would more accurately characterize the COC concentrations and mass discharge within the permeable portions of the shallow and deep LPA zones, which serve as the primary pathways for contaminant transport. The differences in the magnitudes of the median RPDs from this evaluation – high for low mobility constituents and low for high mobility compounds – are consistent with the findings from the 2016 HydraSleeve Demonstration Study.

Two-sample tests (Wilcoxon-Mann-Whitney Method) of the conventional and HydraSleeve® sampler data sets indicate statistically similar concentrations for the sampling methods at the 95% confidence level. This statistical equivalency holds particularly true for COCs like 1,1-DCE and 1,4-dioxane, which have relatively high mobility in the aquifer and have been used to delimit the extent of Site-related groundwater impacts. This conclusion mimics the findings from the previous study where sample concentrations of the mobile COCs were deemed to be statistically similar for the two sampling methods. The sampling data for offsite well MW-28D represents the only exception to the similarity in mobile COC concentrations for the different methods. Even though the two data populations are statistically dissimilar, the difference in the median 1,1-DCE and 1,4-dioxane concentrations for the conventional and HydraSleeve® samples is very low and would have minimal effect in defining the plume boundary in this area. The apparent discrepancy in the concentrations of these COCs could be due to slight variations in the contaminant mass flux within the permeable sand layers screened by this well.

In consideration of the above findings and using an overall weight-of-evidence approach, WSP concludes that COC concentrations in the HydraSleeve samples are similar to the concentrations detected in the standard purge and low-flow samples. Given this conclusion, WSP recommends the continued use of the HydraSleeve sampling device for the long-term groundwater monitoring program at the Site.

If you have any questions or comments regarding this updated sampler evaluation, please feel free to contact me at (703) 709-6500.

Kind regards,

Robert E. Johnson

Robert E. Johnson

Vice President
Earth & Environment

Encl.

K:\Emerson\Kop-Flex_Reports\Passive Sampler Evaluation – 2023\

cc: Mr. Brian Deitz, Site Assessment and Remediation Division, MDE
Mr. Oduwole Moshood, U.S. Environmental Protection Agency (EPA), Region III
Mr. Stephen Clarke, Emerson Electric Co.
Sheila Harvey, Esquire, Pillsbury Winthrop Shaw Pittman

FIGURES

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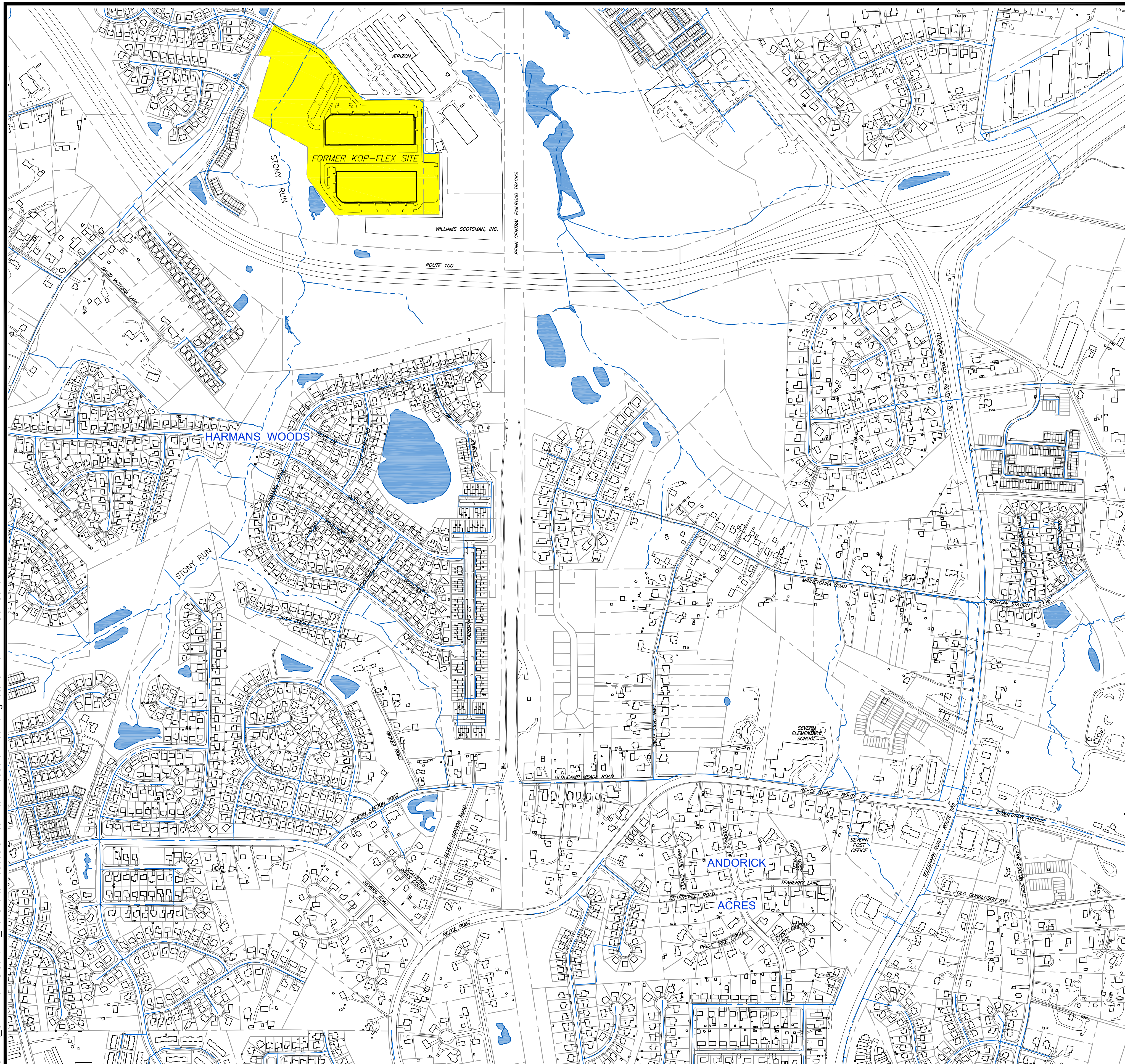

LEGEND

- PROPERTY LINE
- WATER MAIN
- WATER MAIN EXTENSION
- STREAM
- WATER BODY

N

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SCALE IN FEET

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REFERENCE: BASE FEATURES; ROADS, PARCELS, BUILDINGS, WATER FEATURES FROM ANNE ARUNDEL COUNTY WEBSITE. http://www.aacounty.org/departments/planning-and-zoning/research-and-gis/gis/

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Drawn By: EGC

Checked: 6/20/2023

Approved: 4/8/2024

DWG Name: 314V5608.011-037

FORMER KOP-FLEX FACILITY
HANOVER, MARYLAND

PREPARED FOR
EMERSON
ST. LOUIS, MISSOURI

FIGURE 1

LOCATION OF THE FORMER KOP-FLEX SITE IN HANOVER-SEVERN AREA

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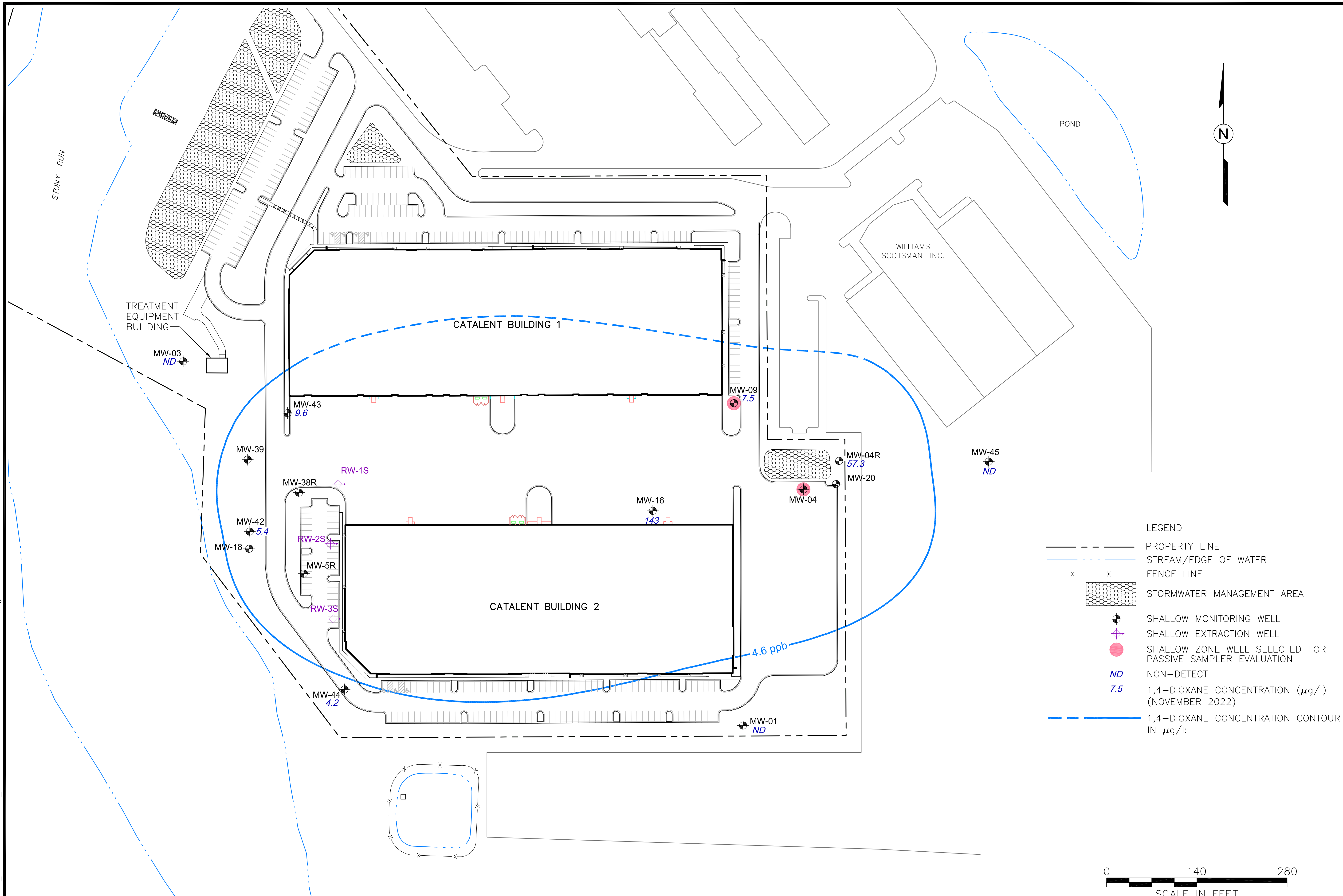
13530 DULLES TECHNOLOGY DR
SUITE 300
HERNDON, VA 20171
TEL: +1 703.709.6500



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Approved: 12/27/2023
DWG Name: 314V5608.010-052

FORMER KOP–FLEX FACILITY SITE
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EMERSUB 16 LLC
ST. LOUIS, MISSOURI

FIGURE 2

LOCATIONS OF SHALLOW MONITORING WELLS AND INFERRED 1,4–DIOXANE DISTRIBUTION IN THE SHALLOW ZONE OF THE LOWER PATAPSCO AQIFER

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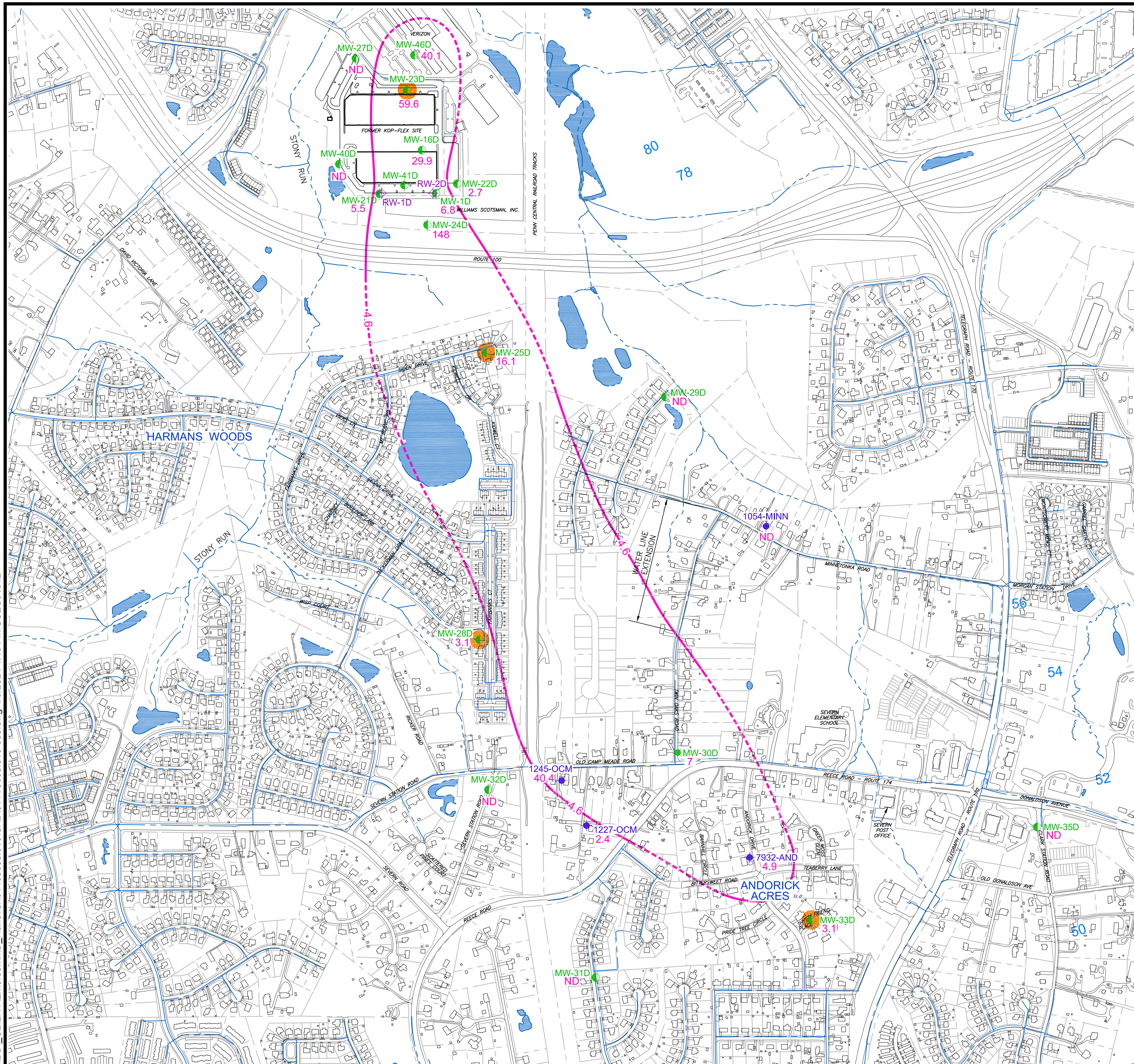

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REFERENCE: BASE FEATURES; ROADS, PARCELS, BUILDINGS, WATER FEATURES FROM ANNE ARUNDEL COUNTY WEBSITE. http://www.aacounty.org/departments/planning-and-zoning/research-and-gis/gis/ UPDATED WITH FEB 2021 DATA.

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LEGEND

- PROPERTY LINE
- WATER MAIN
- STREAM
- WATER BODY
- CONFINED LOWER PATAPSCO AQUIFER MONITORING WELLS
- CONFINED LOWER PATAPSCO AQUIFER AND PATUXENT AQUIFER MONITORING WELLS
- PRIVATE WATER-SUPPLY WELL
- DEEP GROUNDWATER EXTRACTION WELL
- DEEP ZONE WELL SELECTED FOR PASSIVE SAMPLER EVALUATION
- ND NOT DETECTED
- 76 1,4-DIOXANE CONCENTRATION (ppb) (NOVEMBER 2022)
- INFERRED 1,4-DIOXANE ISO-CONCENTRATION CONTOUR (ppb)
- INFERRED 1,4-DIOXANE ISO-CONCENTRATION CONTOUR (ppb) CHARACTERIZED BY HIGHER UNCERTAINTY GIVEN LOCATIONS OF SAMPLING POINTS

NOTE:
HISTORICAL DATA FROM SEVERAL PRIVATE WATER WELLS SAMPLED BETWEEN 2013 AND 2020 WERE USED TO GENERATE THE ISO-CONCENTRATION CONTOURS.

N

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SCALE IN FEET

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FIGURE 3

LOCATION OF MONITORING WELLS AND INFERRED 1,4-DIOXANE DISTRIBUTION IN THE DEEP ZONE OF LOWER PATAPSCO AQUIFER

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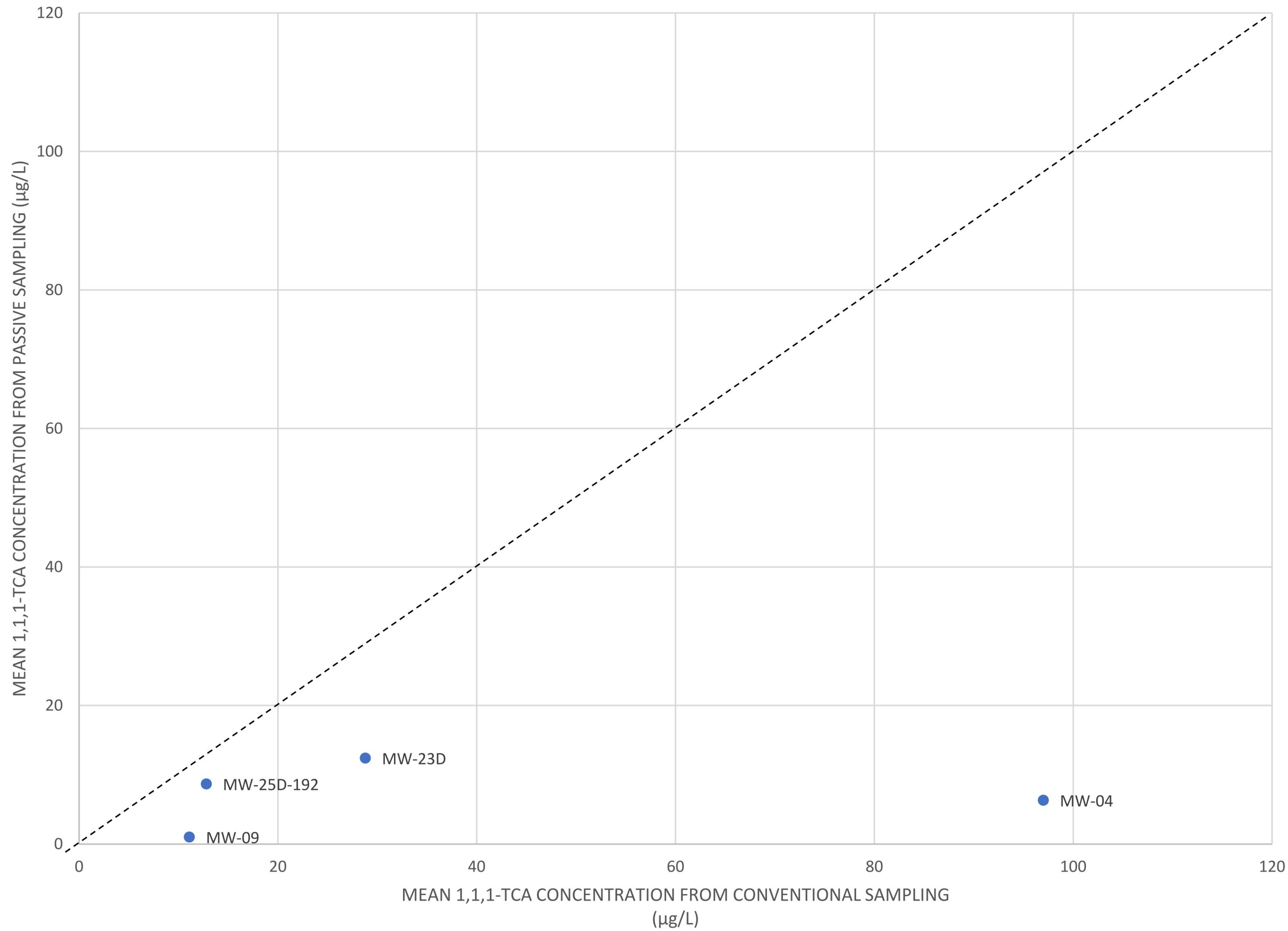

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FIGURE 4

COMPARISON OF 1,1,1–TRICHLOROETHANE IN GROUNDWATER SAMPLES COLLECTED USING PASSIVE AND CONVENTIONAL METHODS

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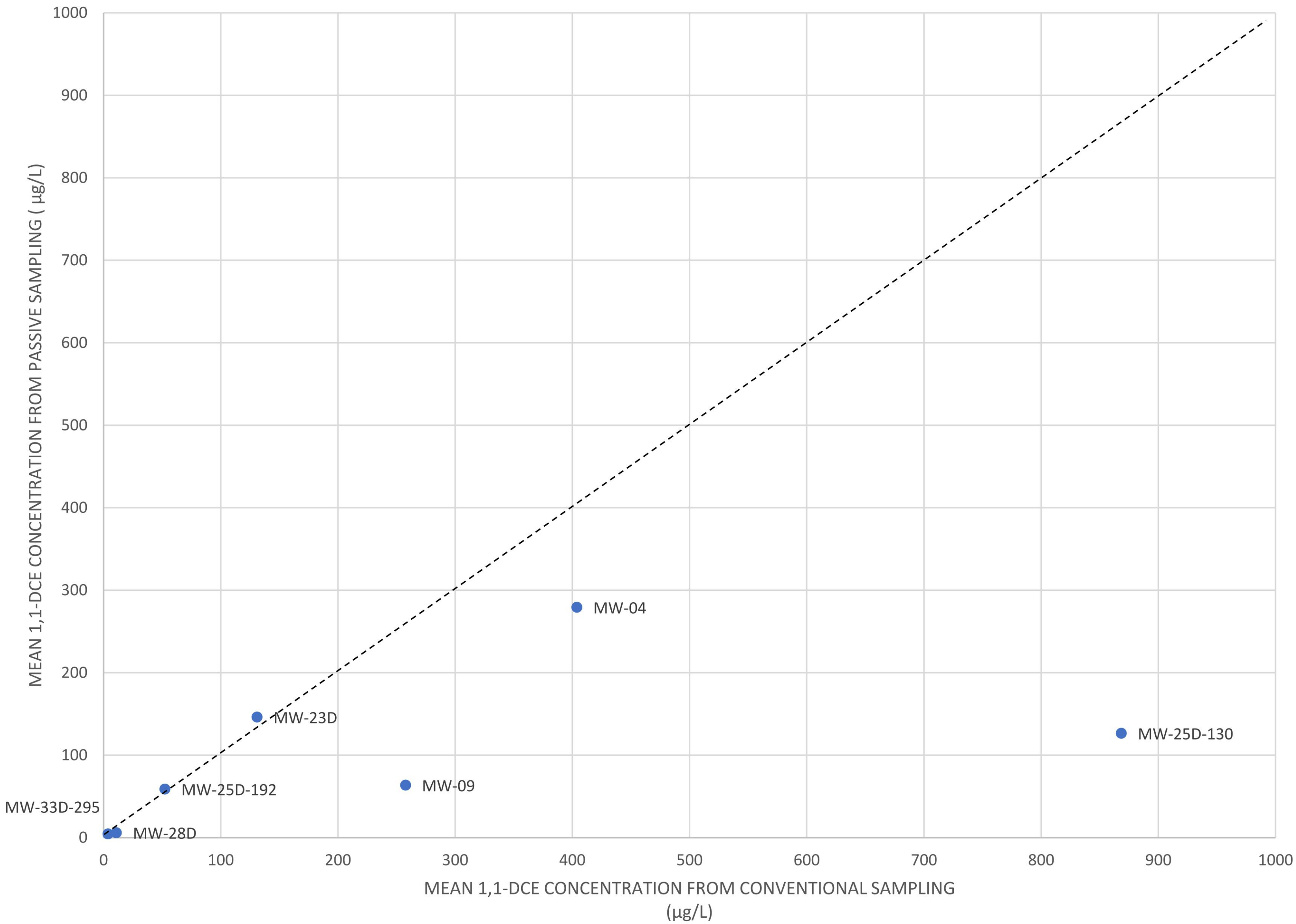

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FIGURE 5

COMPARISON OF 1,1–DICHLOROETHENE IN GROUNDWATER SAMPLES COLLECTED USING PASSIVE AND CONVENTIONAL METHODS

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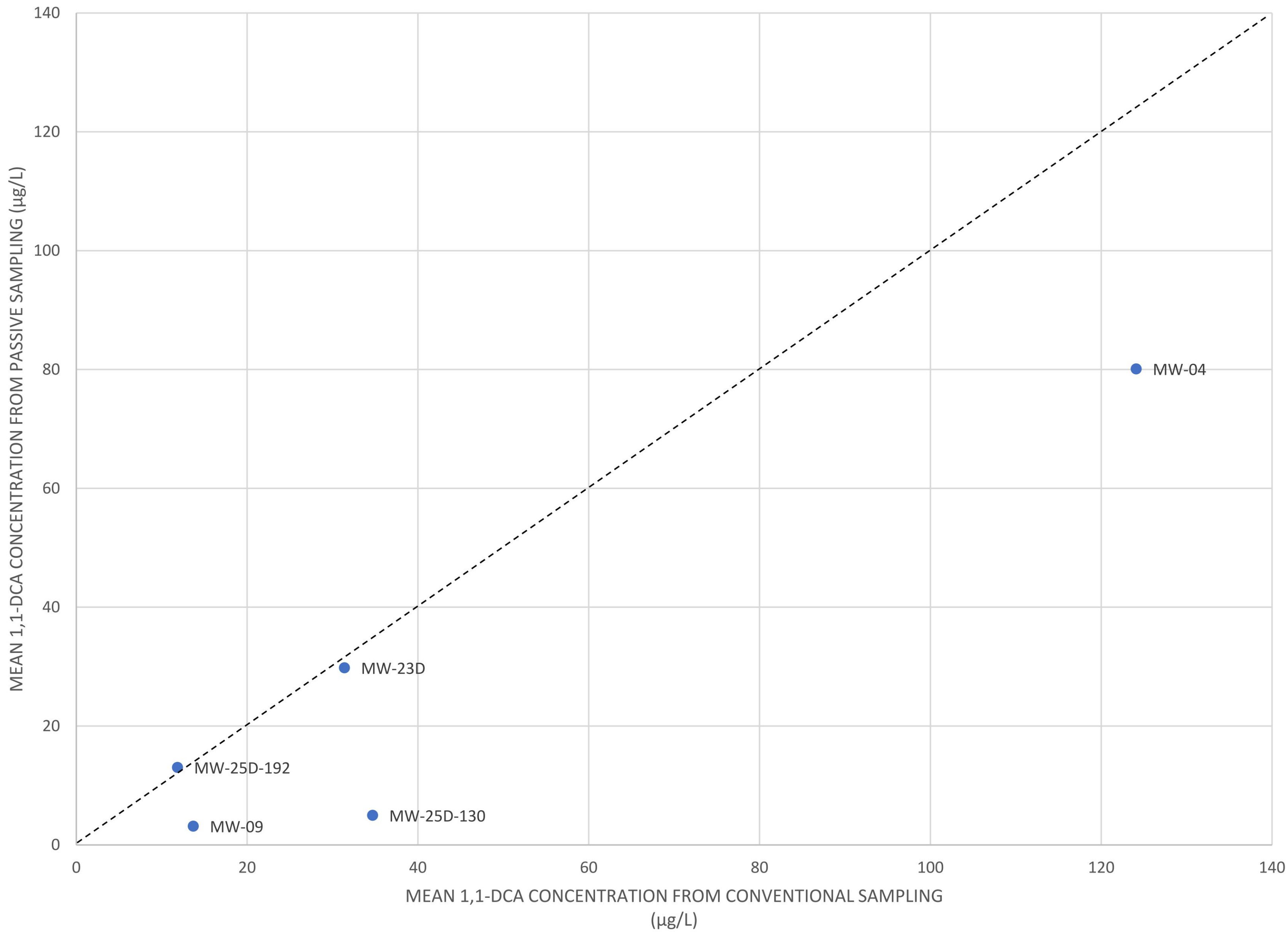

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FIGURE 6

COMPARISON OF 1,1–DICHLOROETHANE IN GROUNDWATER SAMPLES COLLECTED USING PASSIVE AND CONVENTIONAL METHODS

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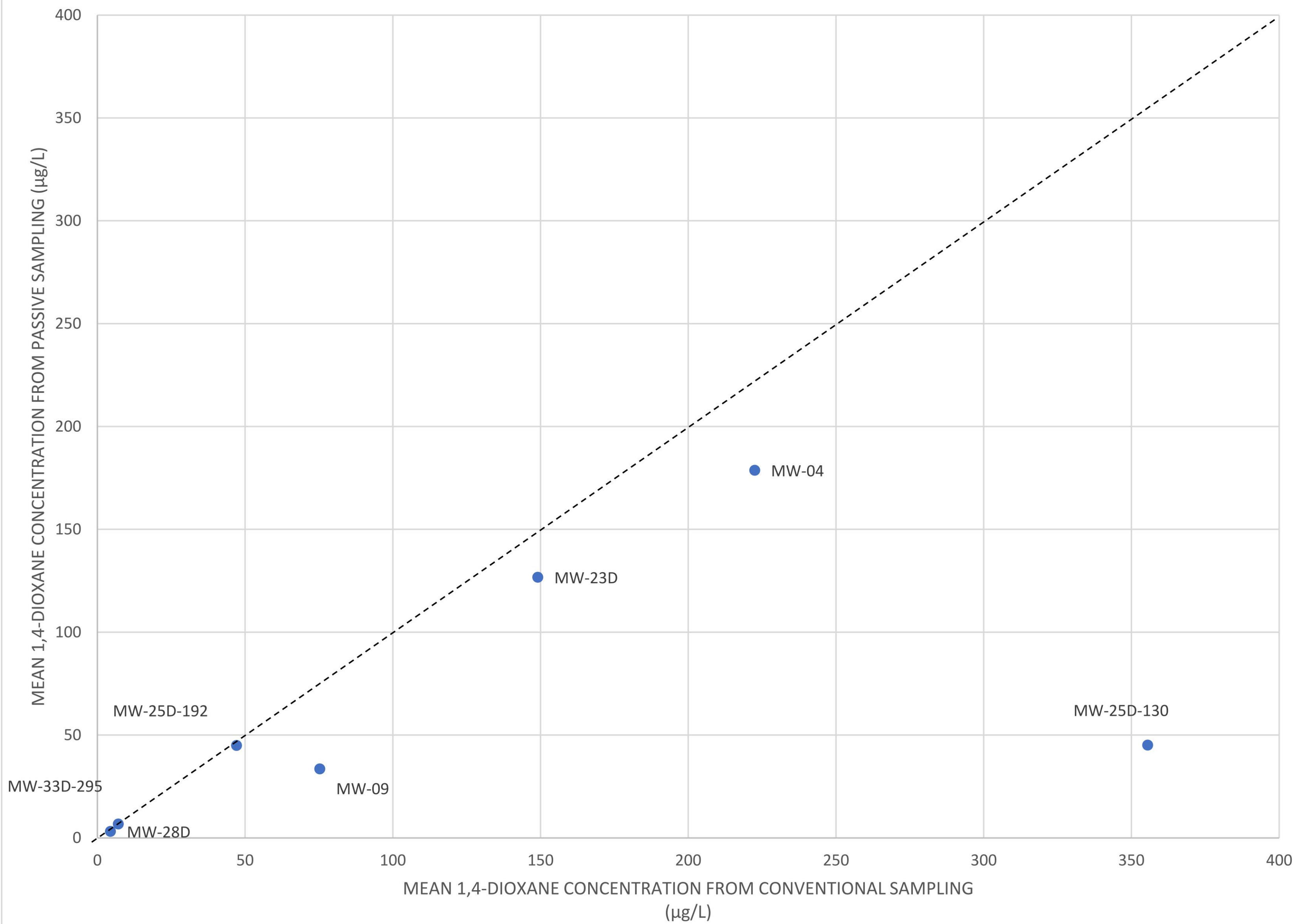

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FIGURE 7

COMPARISON OF 1,4–DIOXANE IN GROUNDWATER SAMPLES COLLECTED USING PASSIVE AND CONVENTIONAL METHODS

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TABLES

Table 1

Summary Statistics and Relative Percent Differences for Primary Constituents of Concern in Conventional and Passive Samples
Former Kop-Flex Facility Site
Hanover, Maryland

Well	Primary Constituent of Concern	CONVENTIONAL SAMPLING METHODS (a)				PASSIVE SAMPLING METHOD				Median Relative Percent Difference (b, c)
		Mean	Median	Standard Deviation	Coefficient of Variation	Mean	Median	Standard Deviation	Coefficient of Variation	
MW-04	1,1,1-Trichloroethance	97.02	61	109.4	1.13	6.31	2.55	9.61	1.52	45.99
	1,1-Dichloroethane	124.1	114	61.22	0.49	80.12	58.15	71.14	0.89	16.22
	1,1-Dichloroethene	403.9	320	285.8	0.71	279.2	150	285.6	1.02	18.09
	1,4-Dioxane	222.5	200	127.4	0.57	178.7	116	164.1	0.92	13.29
MW-09	1,1,1-Trichloroethane	11.13	9.7	7.39	0.66	1	1	0.13	0.13	40.65
	1,1-Dichloroethane	13.67	14	4.5	0.33	3.15	2.95	0.81	0.26	32.60
	1,1-Dichloroethene	257.7	220	138.1	0.54	63.58	58.3	16.84	0.27	29.05
	1,4-Dioxane	75.29	70.4	16.36	0.22	33.47	25.05	22.57	0.67	23.76
MW-23D	1,1,1-Trichloroethane	28.8	27.95	6.01	0.17	12.39	14.2	6.9	0.56	16.31
	1,1-Dichloroethane	31.36	30.55	4.29	0.14	29.78	30.8	6.37	0.21	-0.20
	1,1-Dichloroethene	131	125	32.79	0.25	146.1	141	38.24	0.26	-3.01
	1,4-Dioxane	149.1	149	20.83	0.14	126.7	129	33.76	0.27	3.60
MW-25D-130	1,1,1-Trichloroethane	1,146	34.65	3,145	2.75	4.55	6.4	2.32	0.51	34.41
	1,1-Dichloroethane	34.69	35.25	7.27	0.21	4.97	5	1.7	0.34	37.58
	1,1-Dichloroethene	868.5	827	193.9	0.22	126.5	144	51.47	0.41	35.17
	1,4-Dioxane	355.5	335	85.48	0.24	45.07	40.2	17.16	0.38	39.29
MW-25D-192	1,1,1-Trichloroethane	12.79	12.75	1.16	0.091	8.66	9.8	4.67	0.54	6.54
	1,1-Dichloroethane	11.86	11.7	1.13	0.095	13.04	13.6	2.68	0.21	-3.75
	1,1-Dichloroethene	52.28	52.6	5.15	0.099	58.85	61	12.6	0.21	-3.70
	1,4-Dioxane	47.11	43.6	8.9	0.19	44.87	44.3	8.96	0.2	-0.40
MW-28D	1,1-Dichloroethene	10.9	11.05	2.32	0.21	5.95	5.8	1.59	0.27	15.58
	1,4-Dioxane	4.44	4.75	1.09	0.25	3.13	3	0.73	0.23	11.29
MW-33D-295	1,1-Dichloroethene	3.83	3.75	0.6	0.16	4.44	4.4	0.69	0.16	-3.99
	1,4-Dioxane	7.09	7.3	0.91	0.13	6.73	6.3	1.05	0.16	3.68

a/ Includes both purge-and-sample and low-flow purging methods.
b/ Positive value indicates the median concentration in samples collected using conventional methods is greater than the median concentration in samples collected using the HydraSleeve samplers. Negative value indicates the median concentration in samples collected using conventional methods is less than the median concentration in samples collected using the HydraSleeve sampler.
c/ Values less than +/- 25% indicate similar sample populations and colored GREEN.
Values greater than +/- 25% indicate different sample populations and colored RED.

Table 2

Wilcox-Mann-Whitney Statistical Test Results
Shallow Zone Monitoring Well Samples
Former Kop-Flex Facility Site
Hanover, Maryland

Well ID	Constituent of Concern	Sampling Method	Evaluation of Sample Variance		Wilcoxon-Mann-Whitney Test Result
			Variance of Data Population	Equality of Variance	
MW-04	1,1-DCE	Conventional Passive	8,166 81,594	Equal variances	Conventional Sample = Passive Sample
	1,1-DCA	Conventional Passive	3,748 5,060	Equal variances	Conventional Sample ≠ Passive Sample
	1,1,1-TCA	Conventional Passive	11,979 92	Unequal variances	Conventional Sample ≠ Passive Sample
	1,4-Dioxane	Conventional Passive	16,224 26,924	Equal variances	Conventional Sample = Passive Sample
MW-09	1,1-DCE	Conventional Passive	19,072 284	Unequal variances	Conventional Sample ≠ PassiveSample
	1,1-DCA	Conventional Passive	20 0.65	Unequal variances	Conventional Sample ≠ Passive Sample
	1,1,1-TCA	Conventional Passive	55 0.02	Unequal variances	Conventional Sample ≠ Passive Sample
	1,4-Dioxane	Conventional Passive	268 509	Equal variances	Conventional Sample ≠ Passive Sample

Result indicates the concentrations for groundwater samples collected using the conventional and passive sampling methods are statistically similar at the 95% confidence level.

Result indicates the concentrations for groundwater samples collected using the conventional and passive sampling methods are statistically different at the 95% confidence level.

Result considered uncertain because the assumption regarding the equality of variances was not met by the data.

Table 3

Wilcox-Mann-Whitney Statistical Test Results
Deep Zone Monitoring Well Samples
Former Kop-Flex Facility Site
Hanover, Maryland

Well ID	Constituents of Concern	Sampling Method	**Evaluation of Sample Variance**		**Wilcoxon-Mann-Whitney Test Result**
			Variance of Data Population	**Equality of Variance**	
MW-23D	1,1-DCE	Conventional Passive	1,075 1,463	Equal Variances	Conventional Sample = Passive Sample
	1,1-DCA	Conventional Passive	18 41	Equal Variances	Conventional Sample = Passive Sample
	1,1,1-TCA	Conventional Passive	25 48	Equal Variances	Conventional Sample ≠ Passive Sample
	1,4-Dioxane	Conventional Passive	434 1,140	Equal Variances	Conventional Sample = Passive Sample
MW-25-130	1,1-DCE	Conventional Passive	37,612 2,650	Unequal Variances	Conventional Sample ≠ Passive Sample
	1,1-DCA	Conventional Passive	53 2.9	Unequal Variances	Conventional Sample ≠ Passive Sample
	1,1,1-TCA	Conventional Passive	9,893,281 5.4	Unequal Variances	Conventional Sample ≠ Passive Sample
	1,4-Dioxane	Conventional Passive	7,307 294	Unequal Variances	Conventional Sample ≠ Passive Sample
MW-25-192	1,1-DCE	Conventional Passive	27 159	Unequal Variances	Conventional Sample = Passive Sample
	1,1-DCA	Conventional Passive	1.3 7.2	Unequal Variances	Conventional Sample = Passive Sample
	1,1,1-TCA	Conventional Passive	1.4 22	Unequal Variances	Conventional Sample ≠ Passive Sample
	1,4-Dioxane	Conventional Passive	79 80	Equal Variances	Conventional Sample = Passive Sample
MW-28-210	1,1-DCE	Conventional Passive	5.4 2.5	Equal Variances	Conventional Sample ≠ Passive Sample
	1,4-Dioxane	Conventional Passive	1.2 0.54	Equal Variances	Conventional Sample ≠ Passive Sample
MW-33-295	1,1-DCE	Conventional Passive	0.36 0.47	Equal Variances	Conventional Sample = Passive Sample
	1,4-Dioxane	Conventional Passive	0.83 1.1	Equal Variances	Conventional Sample = Passive Sample

Result indicates the concentrations for groundwater samples collected using the conventional and passive sampling methods are statistically similar at the 95% confidence level.

Result indicates the concentrations for groundwater samples collected using the conventional and passive sampling methods are statistically different at the 95% confidence level.

Result considered uncertain because the assumption regarding the equality of variances was not met by the data.

ENCLOSURE A – HISTORICAL GROUNDWATER DATA FOR PRIMARY CONSTITUENTS OF CONCERN (2007 TO 2021)

Table A-1

Historical Groundwater Sampling Results (Convwetional + Hydrasleeve)
Former Kop-Flex Facility Site
Hanover, Maryland

Well ID	Sampling Method	Sample Date	1,1-Dichloroethene	1,1-Dichloroethane	1,1,1-Trichloroethane	1,4 - Dioxane
		Groundwater Quality Standard (µg/L)	7.0	2.8 (1)	200	4.6
ONSITE WELLS						
MW-4	**Conventional**	5/11/2007	**790**	**190**	**450**	**NA**
	Conventional	4/8/2008	**340**	**120**	180	**NA**
	Conventional	10/29/2008	**300**	**120**	140	**NA**
	Conventional	5/9/2009	**350**	**130**	100	**NA**
	Conventional	10/15/2009	**410**	**150**	100	**NA**
	Conventional	5/10/2010	**1100**	**290**	180	**NA**
	Conventional	10/25/2010	**360**	**130**	75.0	**NA**
	Conventional	6/7/2011	**200**	**81.0**	32.0	**NA**
	Conventional	12/11/2011	**250**	**87.0**	47.0	**212**
	Conventional	6/21/2012	**180**	**68.0**	25.0	**158**
	Conventional	12/14/2012	**210**	**100**	26.0	**188**
	Conventional	7/18/2013	**233**	**108**	27.9	**232**
	Conventional	12/13/2013	**188**	**67.0**	21.3	**178**
	Conventional	6/14/2014	**908**	**198**	104	**456**
	Conventional	12/4/2014	**128**	**38.2**	11.8	**23.7**
	Conventional	6/15/2015	**516**	**108**	32.3	**332**
	Hydrasleeve	12/7/2016	**1020**	**259**	31.7	**576**
	Hydrasleeve	5/2/2017	**459**	**103**	13.0	**252**
	Hydrasleeve	11/15/2017	**151**	**29.2**	4.3	**121**
	Hydrasleeve	5/30/2018	**153**	**33.3**	4.0	**92.7**
	Hydrasleeve	11/7/2018	**89.9**	**23.3**	1.6	1.0 U
	Hydrasleeve	5/21/2019	**142**	**57.7**	1.7	**111**
	Hydrasleeve	11/19/2019	**126**	**45.1**	1.0 U	**94.2**
	Hydrasleeve	5/13/2020	**149**	**58.6**	1.4	**84.6**
	Hydrasleeve	11/22/2020	**141**	**62.0**	1.0 U	**151**
	Hydrasleeve	5/9/2021	**361**	**130**	3.4	**303**
MW-9	**Conventional**	5/11/2007	**690**	**22.0**	33.0	**NA**
	Conventional	4/1/2008	**340**	**17.0**	13.0	**NA**
	Conventional	10/29/2008	**360**	**18.0**	16.0	**NA**
	Conventional	5/9/2009	**250**	**17.0**	16.0	**NA**
	Conventional	10/15/2009	**300**	**18.0**	13.0	**NA**
	Conventional	5/10/2010	**240**	**16.0**	10.0	**NA**
	Conventional	6/10/2011	**290**	**16.0**	10.0	**NA**
	Conventional	11/11/2011	**220**	**14.0**	8.0	**86.2**
	Conventional	6/1/2012	**160**	**8.0**	6.0	**71.3**
	Conventional	12/14/2012	**150**	**12.0**	5.5	**69.2**
	Conventional	7/18/2013	**170**	**10.9**	6.4	**69.5**
	Conventional	12/13/2013	**181**	**10.5**	4.6	**97.7**
	Conventional	6/14/2014	**193**	**8.5**	**ND**	**53.9**
	Conventional	12/3/2014	**179**	**11.1**	9.4	**96.1**
	Conventional	6/15/2015	**143**	**6.1**	4.9	**58.6**
	Hydrasleeve	12/8/2016	**104**	**4.5**	1.0 U	**95.5**
	Hydrasleeve	5/2/2017	**63.8**	**2.9**	1.0 U	**20.8**
	Hydrasleeve	11/15/2017	**60.2**	**3.1**	0.7 J	**32.4**
	Hydrasleeve	5/30/2018	**49.2**	2.2	1.0 U	**23.4**
	Hydrasleeve	11/7/2018	**75.9**	**4.5**	1.1	**37.4**
	Hydrasleeve	5/21/2019	**70.8**	**3.6**	1.2	**32.8**
	Hydrasleeve	11/19/2019	**48.7**	2.6	1.0 U	**24.4**
	Hydrasleeve	5/13/2020	**50.5**	2.6	1.0 U	**18.7**
	Hydrasleeve	11/22/2020	**56.4**	2.5	1.0 U	**25.7**
	Hydrasleeve	5/9/2021	**56.3**	**3.0**	1.0 U	**23.6**

Table A-1

Historical Groundwater Sampling Results (Convwetional + Hydrasleeve)
Former Kop-Flex Facility Site
Hanover, Maryland

Well ID	Sampling Method	Sample Date	1,1-Dichloroethene	1,1-Dichloroethane	1,1,1-Trichloroethane	1,4 - Dioxane
		Groundwater Quality Standard (µg/L)	7.0	2.8 (1)	200	4.6
MW-23D	Conventional	6/1/2012	120	29.0	36.0	149
	Conventional	8/27/2012	130	39.0	35.0	NA
	Conventional	12/14/2012	110	32.0	31.0	130
	Conventional	7/18/2013	131	32.7	28.6	186
	Conventional	12/13/2013	101	25.6	21.3	165
	Conventional	6/14/2014	101	29.1	24.7	132
	Conventional	12/2/2014	157	28.3	26.5	151
	Conventional	6/15/2015	198	35.2	27.3	131
	Hydrasleeve	1/2/2017	140	26.4	17.0	151
	Hydrasleeve	5/1/2017	208	39.1	19.9	177
	Hydrasleeve	11/15/2017	179	31.1	19.3	158
	Hydrasleeve	5/30/2018	172	30.5	14.8	148
	Hydrasleeve	11/7/2018	185	36.2	17.0	146
	Hydrasleeve	5/21/2019	96.4	18.5	8.6	70.7
	Hydrasleeve	11/19/2019	107	22.7	1.0 U	109
	Hydrasleeve	5/13/2020	142	35.2	13.6	112
	Hydrasleeve	11/22/2020	106	26.3	1.0 U	96.7
	Hydrasleeve	5/9/2021	126	31.8	11.7	99.0
OFFSITE WELLS						
MW-25-130	Conventional	9/16/2014	1140	47.0	64.2	492
	Conventional	3/19/2015	854	38.6	8930	446
	Conventional	6/24/2015	1030	37.1	46.3	303
	Conventional	9/23/2015	697	29.7	32.3	295
	Conventional	1/7/2016	800	33.4	5.0 U	398
	Conventional	3/23/2016	676	24.5	26.2	302
	Conventional	7/19/2016	1090	39.3	37.0	367
	Conventional	9/9/2016	661	27.9	25.0	241
	Hydrasleeve	12/8/2016	171	6.7	6.9	13.6
	Hydrasleeve	2/21/2017	194	7.2	7.0	69.1
	Hydrasleeve	5/2/2017	174	6.5	5.0	61.0
	Hydrasleeve	8/31/2017	193	7.4	6.9	57.9
	Hydrasleeve	11/14/2017	151	5.1	6.4	58.5
	Hydrasleeve	2/13/2018	154	6.3	6.4	67.1
	Hydrasleeve	5/30/2018	144	5.0	5.3	53.9
	Hydrasleeve	11/8/2018	109	4.4	1.0 U	40.2
	Hydrasleeve	5/22/2019	96.2	3.7	4.2	38.4
	Hydrasleeve	11/19/2019	62.1	2.7	1.0 U	31.0
	Hydrasleeve	5/14/2020	69.1	3.3	1.0 U	32.6
	Hydrasleeve	11/23/2020	76.0	3.3	4.9	32.4
	Hydrasleeve	5/10/2021	50.8	3.0	3.1	30.2

Table A-1

Historical Groundwater Sampling Results (Convwetional + Hydrasleeve)
Former Kop-Flex Facility Site
Hanover, Maryland

Well ID	Sampling Method	Sample Date	1,1-Dichloroethene	1,1-Dichloroethane	1,1,1-Trichloroethane	1,4 - Dioxane
		Groundwater Quality Standard (µg/L)	7.0	2.8 (1)	200	4.6
MW-25D-192	Conventional	9/16/2014	**52.2**	**10.8**	14.0	**65.1**
	Conventional	3/19/2015	**53.0**	**11.7**	13.7	**49.4**
	Conventional	6/25/2015	**59.4**	**11.9**	14.2	**39.8**
	Conventional	9/22/2015	**51.4**	**13.9**	12.9	**45.0**
	Conventional	1/7/2016	**47.2**	**11.7**	12.5	**41.7**
	Conventional	3/23/2016	**43.3**	**10.3**	11.3	**42.2**
	Conventional	7/20/2016	**54.9**	**11.7**	11.1	**54.4**
	Conventional	9/8/2016	**56.8**	**12.9**	12.6	**39.3**
	Hydrasleeve	12/8/2016	**64.6**	**16.1**	13.3	**51.3**
	Hydrasleeve	2/21/2017	**63.3**	**14.0**	11.6	**52.1**
	Hydrasleeve	5/2/2017	**81.0**	**16.9**	13.5	**53.1**
	Hydrasleeve	8/31/2017	**62.5**	**15.7**	13.1	**44.3**
	Hydrasleeve	11/14/2017	**67.2**	**13.6**	13.6	**56.7**
	Hydrasleeve	2/13/2018	**69.2**	**13.7**	11.0	**42.7**
	Hydrasleeve	5/30/2018	**58.3**	**10.8**	7.2	**50.8**
	Hydrasleeve	11/8/2018	**61.0**	**13.7**	9.8	**49.3**
	Hydrasleeve	5/22/2019	**51.7**	**11.8**	8.5	**36.7**
	Hydrasleeve	11/19/2019	**53.2**	**12.6**	1.0 U	**41.1**
	Hydrasleeve	5/14/2020	**58.0**	**12.8**	1.0 U	**41.1**
	Hydrasleeve	11/23/2020	**46.9**	**11.3**	5.8	**41.5**
	Hydrasleeve	5/10/2021	**28.2**	**6.5**	3.2	**22.6**
M2-28D-210	Conventional	9/17/2014	**6.8**	1.0 U	1.0 U	**5.1**
	Conventional	3/17/2015	**10.6**	1.0 U	1.0 U	**5.0**
	Conventional	6/23/2015	**12.8**	1.0 U	1.0 U	4.5
	Conventional	9/22/2015	**14.3**	1.0 U	1.0 U	4.4
	Conventional	1/5/2016	**11.5**	1.0 U	1.0 U	**5.5**
	Conventional	3/23/2016	**9.1**	1.0 U	1.0 U	4.0
	Conventional	7/19/2016	**10.1**	1.0 U	1.0 U	2.0
	Conventional	9/7/2016	**12.0**	1.0 U	1.0 U	**5.0**
	Hydrasleeve	12/8/2016	6.3	1.0 U	1.0 U	2.0
	Hydrasleeve	2/21/2017	4.6	1.0 U	1.0 U	3.0
	Hydrasleeve	5/2/2017	5.8	1.0 U	1.0 U	2.7
	Hydrasleeve	8/31/2017	5.0	1.0 U	1.0 U	2.7
	Hydrasleeve	11/14/2017	5.5	1.0 U	1.0 U	3.5
	Hydrasleeve	2/14/2018	4.3	1.0 U	1.0 U	2.8
	Hydrasleeve	5/30/2018	6.1	1.0 U	1.0 U	2.4
	Hydrasleeve	11/8/2018	6.9	1.0 U	1.0 U	2.3
	Hydrasleeve	5/22/2019	5.2	1.0 U	1.0 U	3.5
	Hydrasleeve	11/20/2019	6.1	1.0 U	1.0 U	3.9
	Hydrasleeve	5/14/2020	4.0	1.0 U	1.0 U	3.4
	Hydrasleeve	11/23/2020	**7.6**	1.0 U	1.0 U	4.2
	Hydrasleeve	5/10/2021	**10.0**	1.0 U	1.0 U	4.3

Table A-1

Historical Groundwater Sampling Results (Convwetional + Hydrasleeve)
Former Kop-Flex Facility Site
Hanover, Maryland

Well ID	Sampling Method	Sample Date	1,1-Dichloroethene	1,1-Dichloroethane	1,1,1-Trichloroethane	1,4 - Dioxane
		Groundwater Quality Standard (µg/L)	**7.0**	**2.8 (1)**	**200**	**4.6**
MW-33-295	**Conventional**	9/18/2014	3.3	1.0	1.0 U	**7.2**
	Conventional	3/18/2015	4.6	1.0	1.0 U	**8.0**
	Conventional	6/23/2015	3.3	1.0	1.0 U	**6.8**
	Conventional	9/21/2015	4.8	1.0	1.0 U	**6.8**
	Conventional	1/4/2016	3.7	1.0	1.0 U	**7.6**
	Conventional	3/21/2016	3.9	1.0	1.0 U	**7.8**
	Conventional	7/18/2016	3.2	1.0	1.0 U	**5.1**
	Conventional	9/7/2016	3.8	1.0	1.0 U	**7.4**
	Hydrasleeve	12/8/2016	5.4	1.0	1.0 U	**7.4**
	Hydrasleeve	2/21/2017	4.0	1.0	1.0 U	**6.8**
	Hydrasleeve	5/2/2017	5.3	1.0	1.0 U	**7.4**
	Hydrasleeve	8/31/2017	5.6	1.0	1.0 U	**6.3**
	Hydrasleeve	11/14/2017	3.4	1.0	0.49 J	**9.7**
	Hydrasleeve	2/13/2018	4.6	1.0	0.49 J	**6.9**
	Hydrasleeve	5/31/2018	4.6	1.0	0.49 J	**6.9**
	Hydrasleeve	11/8/2018	4.2	1.0	1.0 U	**6.1**
	Hydrasleeve	5/22/2019	4.5	1.0	1.0 U	**6.1**
	Hydrasleeve	11/20/2019	3.7	1.0	1.0 U	**6.3**
	Hydrasleeve	5/14/2020	4.4	1.0	1.0 U	**6.0**
	Hydrasleeve	11/23/2020	3.6	1.0	1.0 U	**6.0**
	Hydrasleeve	5/10/2021	4.4	1.0	1.0 U	**5.6**

(1) MDE GW Quality Standard changed from 90 µg/L to 2.8 µg/L in October 2018

a/ U = not detected above the method detection limit; J = estimated concentration between the reporting limit and method detection limit.
Bolded values indicate an exceedence of the Groundwater Quality Standards
All sample concentrations in micrograms per liter (µg/l)
NA = not analyzed

ENCLOSURE B - DECISION ANALYSIS SUMMARY TABLES, ONSITE AND OFFSITE AREAS

PASSIVE SAMPLER DECISION ANALYSIS SUMMARY

ONSITE AREA – SHALLOW ZONE, LOWER PATAPSCO AQUIFER

Number	Question	Yes	No
1	Is sampling being done for long-term groundwater monitoring?	X	
2	Has the groundwater chemistry at the site been fully characterized?	X	
3	Can the passive sampler being considered collect samples for all constituents of interest?	X	
4	Can the passive sampler being considered collect the sample volume necessary to analyze the constituents of interest given the well construction?	X	
5	Have hydraulic and chemical vertical profiling been done in the wells to be sampled?		X
6	Are the monitoring wells to be sampled in an area where there is sufficient groundwater velocity (>0.5 feet per day)?	X[1]	X[2]
7	Are the monitoring wells currently free of dedicated pumps or other sampling equipment?	X	
8	Has a cost evaluation shown the passive sampler being considered offers a cost savings compared to current sampling techniques?	X	
9	Have you discussed the potential use of the passive sampler with site regulators?	X	
10	Are the site regulators familiar with the passive sampler technology and will they allow the data to be used for the same purposes as those obtained by purge sampling?	X[3]	

[1] For wells screened in layers comprised of predominately coarse-grained (sand and gravel) sediments.

[2] For wells screened in layers comprised of fine-grained (silt and clay) sediments. The low groundwater flow velocity reflects the inferred very low hydraulic conductivity of the aquifer material.

[3] Conditional approval for use of the passive sampling method was provided by USEPA and MDE in the Fall of 2016.

PASSIVE SAMPLER DECISION ANALYSIS SUMMARY

ONSITE AREA – DEEP ZONE, LOWER PATAPSCO AQUIFER

Number	Question	Yes	No
1	Is sampling being done for long-term groundwater monitoring?	X	
2	Has the groundwater chemistry at the site been fully characterized?	X	
3	Can the passive sampler being considered collect samples for all constituents of interest?	X	
4	Can the passive sampler being considered collect the sample volume necessary to analyze the constituents of interest given the well construction?	X	
5	Have hydraulic and chemical vertical profiling been done in the wells to be sampled?		X
6	Are the monitoring wells to be sampled in an area where there is sufficient groundwater velocity (>0.5 feet per day)?	X	
7	Are the monitoring wells currently free of dedicated pumps or other sampling equipment?	X	
8	Has a cost evaluation shown the passive sampler being considered offers a cost savings compared to current sampling techniques?	X	
9	Have you discussed the potential use of the passive sampler with site regulators?	X	
10	Are the site regulators familiar with the passive sampler technology and will they allow the data to be used for the same purposes as those obtained by purge sampling?	X[1]	

[1] Conditional approval for use of the passive sampling method was provided by USEPA and MDE in the Fall of 2016.

PASSIVE SAMPLER DECISION ANALYSIS SUMMARY

OFFSITE AREA – DEEP ZONE, LOWER PATAPSCO AQUIFER

Number	Question	Yes	No
1	Is sampling being done for long-term groundwater monitoring?	X	
2	Has the groundwater chemistry at the site been fully characterized?	X	
3	Can the passive sampler being considered collect samples for all constituents of interest?	X	
4	Can the passive sampler being considered collect the sample volume necessary to analyze the constituents of interest given the well construction?	X	
5	Have hydraulic and chemical vertical profiling been done in the wells to be sampled?		X
6	Are the monitoring wells to be sampled in an area where there is sufficient groundwater velocity (>0.5 feet per day)?	X[1]	
7	Are the monitoring wells currently free of dedicated pumps or other sampling equipment?	X	
8	Has a cost evaluation shown the passive sampler being considered offers a cost savings compared to current sampling techniques?	X	
9	Have you discussed the potential use of the passive sampler with site regulators?	X	
10	Are the site regulators familiar with the passive sampler technology and will they allow the data to be used for the same purposes as those obtained by purge sampling?	X[2]	

[1] The calculated groundwater flow velocities in the offsite area ranged from 0.1 feet per day to 0.4 feet per day, with a mean value of 0.25 feet per day. The relatively low hydraulic gradient in this portion of the Lower Patapsco aquifer is the reason for the groundwater flow velocity being slightly below the optimum value of 0.5 feet per day.

[2] Conditional approval for use of the passive sampling method was provided by USEPA and MDE in the Fall of 2016.

ENCLOSURE C – BOX PLOTS OF PRIMARY CONSTITUENTS OF CONCERN

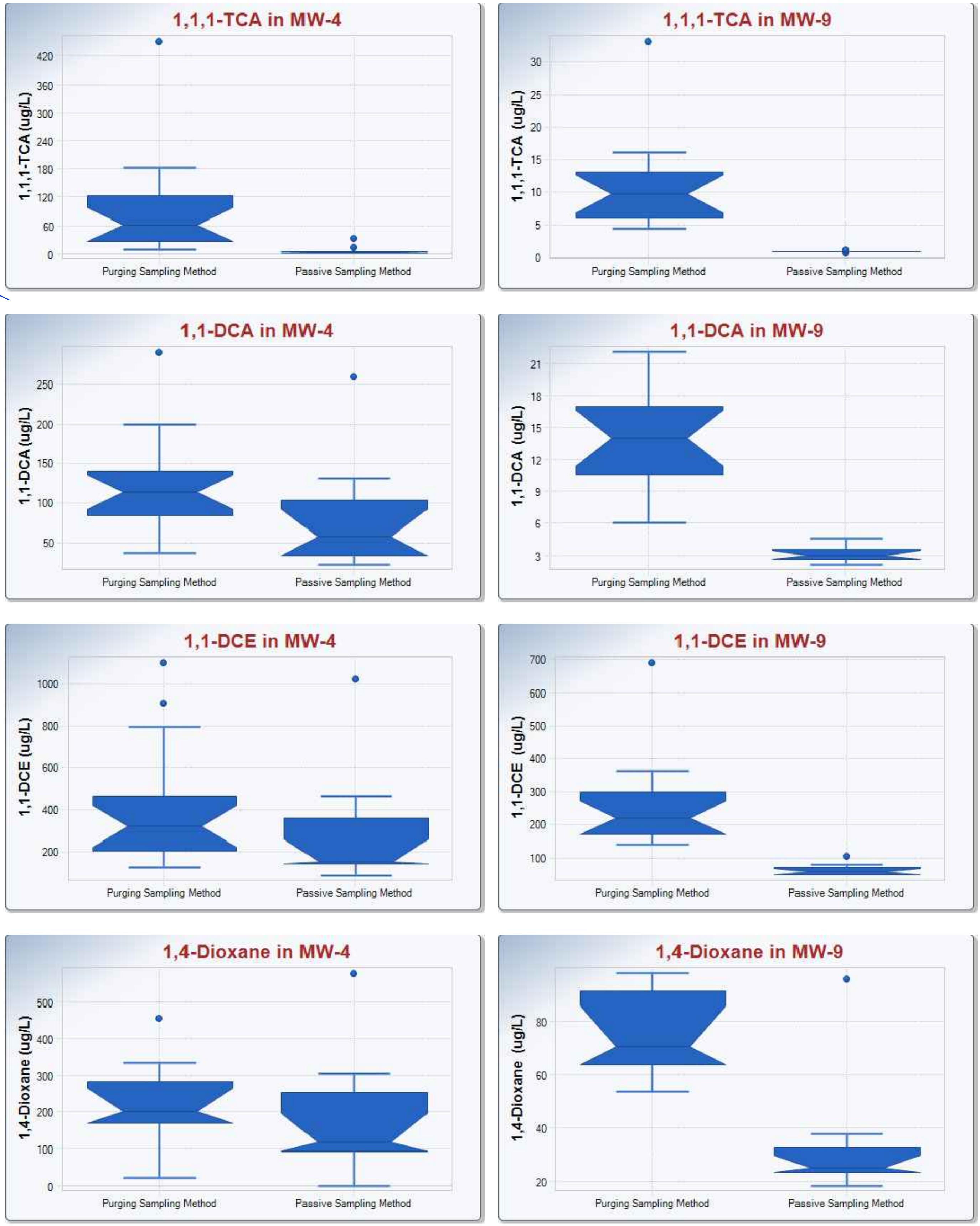

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FIGURE C–1

BOX PLOTS FOR
ONSITE SHALLOW ZONE WELLS

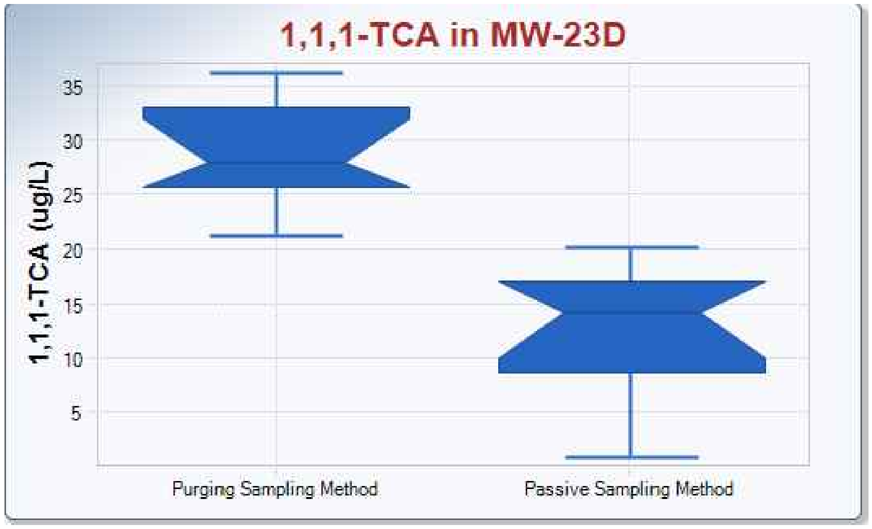
FORMER KOP–FLEX FACILITY SITE
HANOVER, MARYLAND

PREPARED FOR
EMERSON
ST. LOUIS, MISSOURI

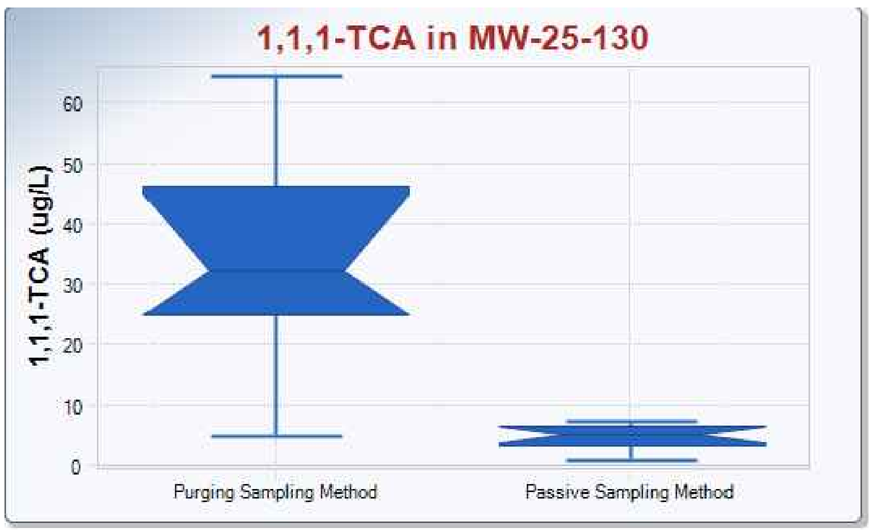
DWG Name: 314V5608.010–054
Checked:
Approved: RJ 1/3/2024
Drawn By: EGC
A

R:\ACAD\CADD_CLIENT\Emerson\MD_Hanover\31405608.010\CAD\314V5608.010-054.dwg 1/3/2024 1:13 PM USEC01012

Onsite Area



Offsite Area



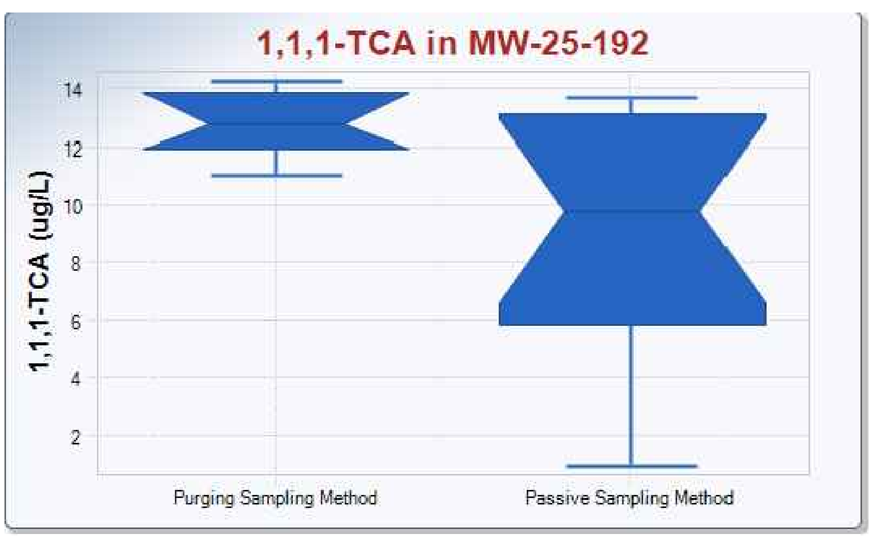


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FIGURE C–2

1,1,1–TCA BOX PLOTS
FOR DEEP ZONE WELLS

FORMER KOP–FLEX FACILITY SITE
HANOVER, MARYLAND

PREPARED FOR
EMERSON
ST. LOUIS, MISSOURI

A | Drawn By: EGC | Checked: | Approved: RD 1/3/2024 | DWG Name: 314V5608.010–054

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Approved: RJ 1/3/2024
Drawn By: EGC
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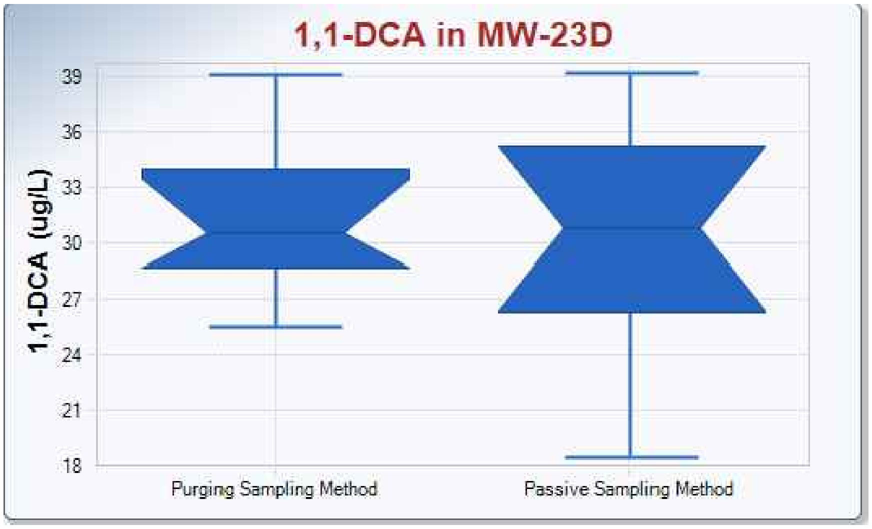

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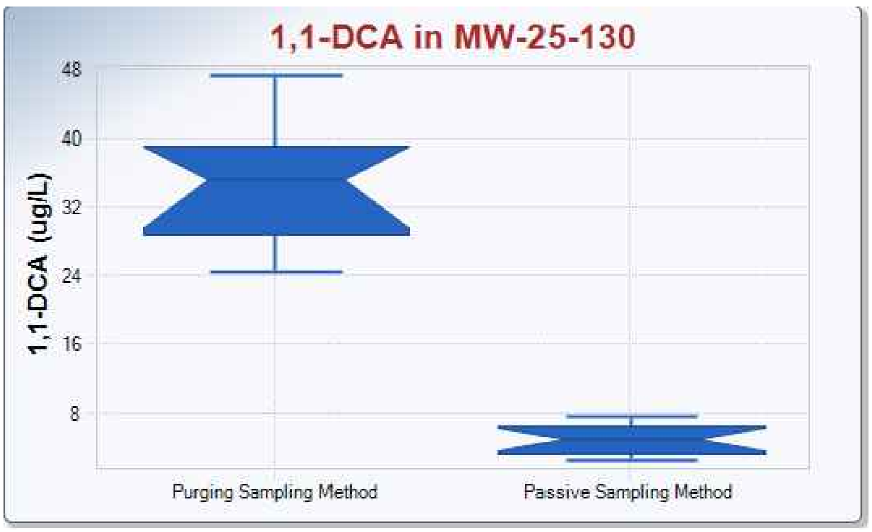

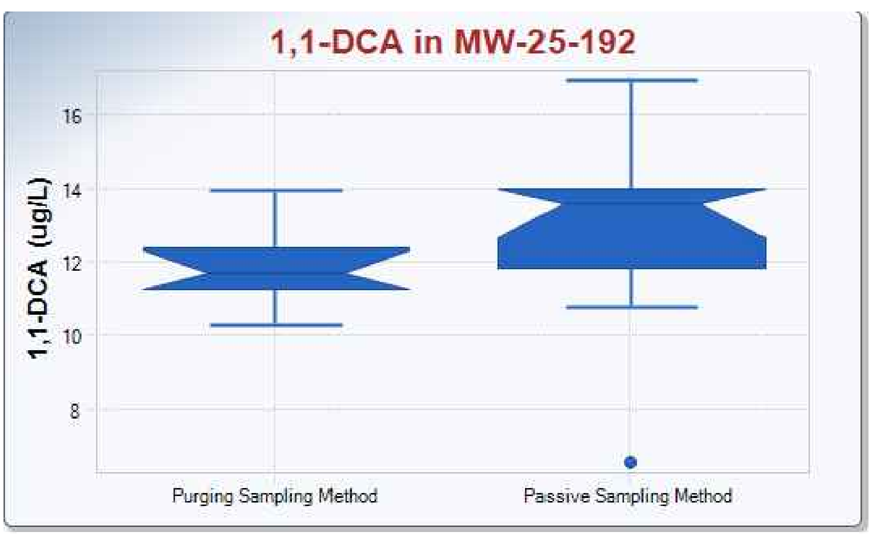

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FIGURE C-3

1,1-DCA BOX PLOTS FOR DEEP ZONE WELLS

FORMER KOP-FLEX FACILITY SITE
HANOVER, MARYLAND

PREPARED FOR
EMERSON
ST. LOUIS, MISSOURI

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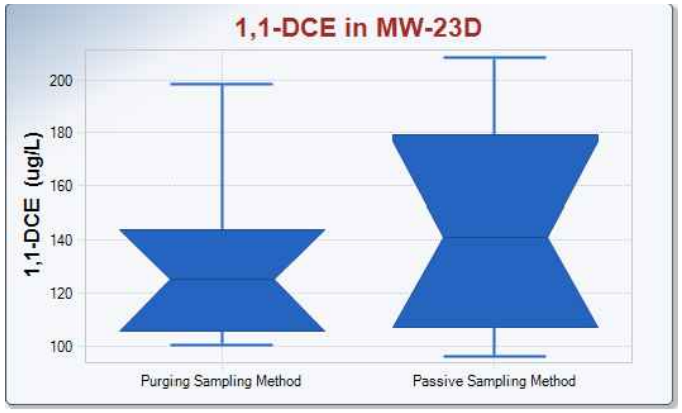

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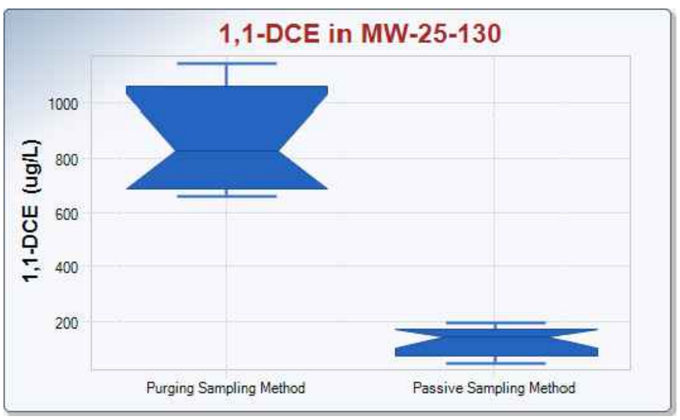

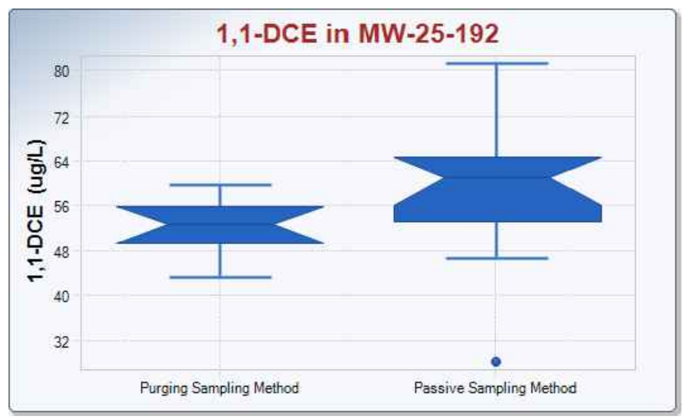

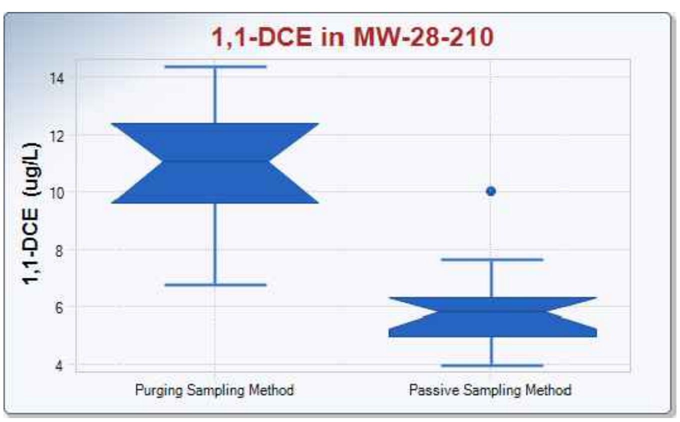

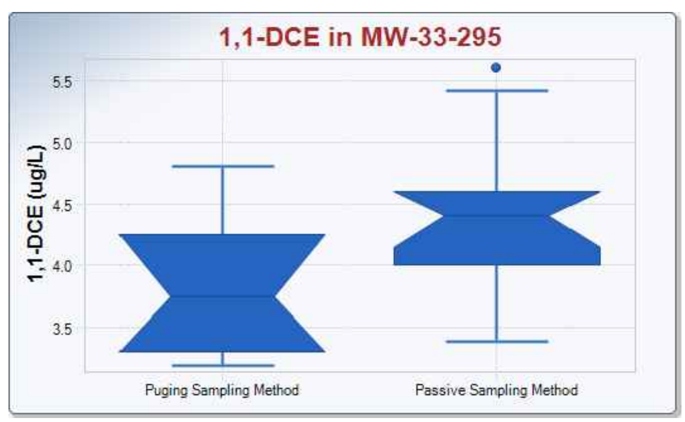

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FIGURE C-4

1,1-DCE BOX PLOTS
FOR DEEP ZONE WELLS

FORMER KOP-FLEX FACILITY SITE
HANOVER, MARYLAND

PREPARED FOR
EMERSON
ST. LOUIS, MISSOURI

DWG Name: 314V5608.010-054
Checked:
Approved: RJ 1/3/2024
Drawn By: EGC
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DWG Name: 314V5608.010-054
Checked: 1/3/2024
Approved:
Drawn By: EGC
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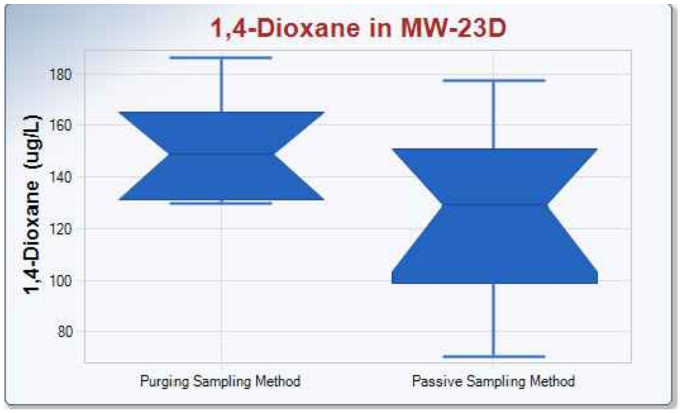
Onsite Area



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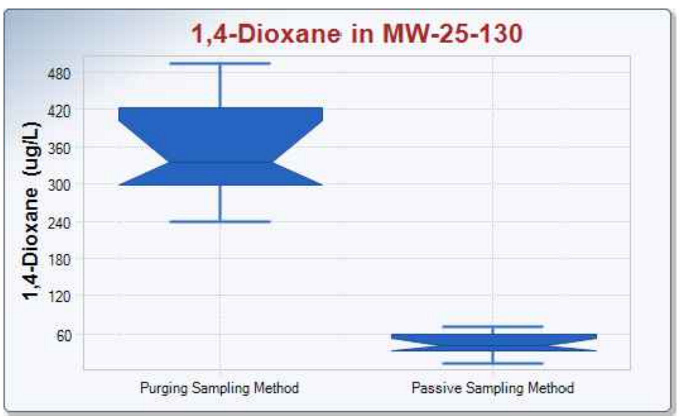

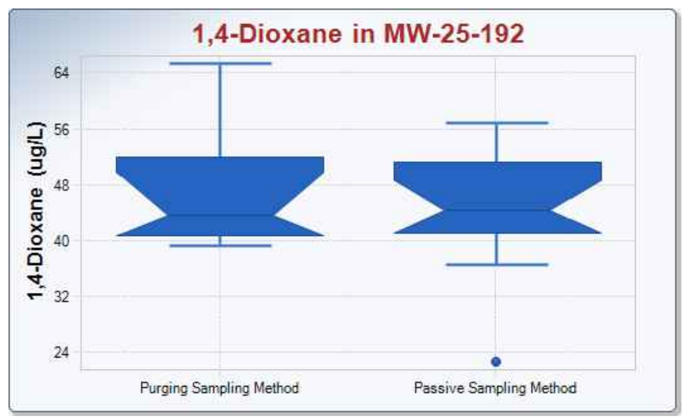

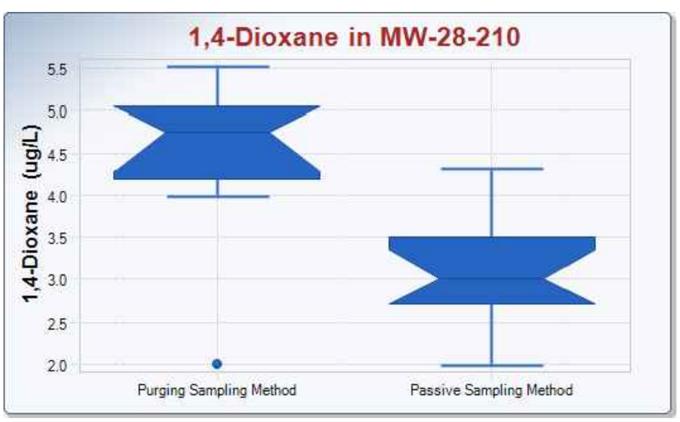

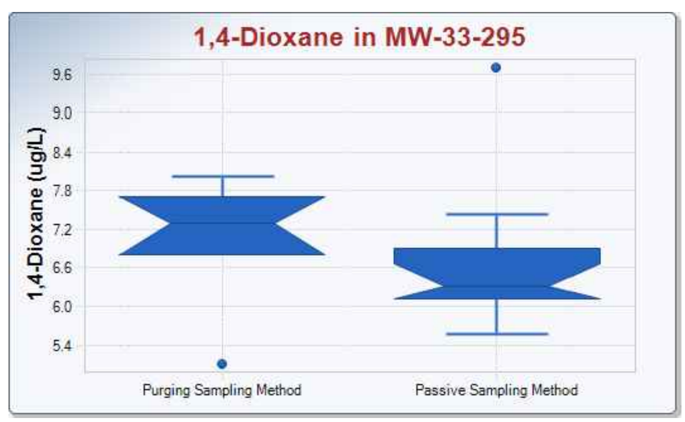

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FIGURE C-5

1,4-DIOXANE BOX PLOTS FOR DEEP ZONE WELLS

FORMER KOP-FLEX FACILITY SITE
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