8976 Wellington Road
Manassas, VA 20109

September 30, 2021

Gary Priscott
New York State Department of Environmental Remediation
1679 Route 11
Kirkwood, NY 13795

Re: Remedy Optimization Report
IBM Gun Club, Former Burn Pit Area
Robinson Hill Road, Union, NY 13760
NYSDEC Site # C704044

Dear Mr. Priscott:

This letter serves to transmit the Remedy Optimization Report for the above referenced site to the New York State Department of Environmental Conservation (NYSDEC). IBM elected to voluntarily commission the remedy optimization evaluation described in the enclosed report, which was prepared Sanborn, Head Engineering, P.C. on behalf of IBM.

If you have any questions regarding the enclosed report, please contact me at 720-397-5618.

Regards,

Stephen Brown

Stephen Brown
IBM Program Manager

Enclosure: Remedy Optimization Report

cc: Kevin O'Hara (Binghamton Country Club)
Eamonn O'Neil (NYSDOH)
Maureen Schuck (NYSDOH)
Harry Warner (NYSDEC)

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Building Trust. Engineering Success.

20 Foundry Street
Concord, NH 03301

September 30, 2021
File No. 3526.05

Stephen Brown, P.E.
IBM Corporate Environmental Affairs
8976 Wellington Road
Manassas, Virginia 20109

Re: Remedy Optimization Report
IBM Gun Club – Former Burn Pit Area
Union, New York
BCP Agreement #C704044

Dear Mr. Brown:

The attached document comprises the Remedy Optimization Report for the above-referenced site. The Remedy Optimization Report has been prepared on behalf of IBM by Sanborn, Head Engineering P.C. (SHPC) for submittal to the New York State Department of Environmental Conservation (NYSDEC) and Department of Health (NYSDOH), collectively the Departments, as part of a voluntary assessment of the current remedy and potential enhancements that could further improve remedy performance.

If you have any questions or comments, please contact us. We appreciate the opportunity to provide service to you on this important project.

Very truly yours,
SANBORN, HEAD ENGINEERING, P.C.

David Shea

David Shea, P.E.
Senior Vice President

Erica Bosse

Erica M. Bosse, P.G.
Project Manager

Bradley A. Green, P.G.
Senior Vice President

Encl. Remedy Optimization Report

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REMEDY OPTIMIZATION REPORT

IBM GUN CLUB

Former Burn Pit Area
Union, New York
NYSDEC Site #C704044

Prepared for IBM Corporate Environmental Affairs
File No. 3526.05
September 2021

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1.0 INTRODUCTION

This report presents the findings of an assessment of the current remedy for the former Burn Pit Area (BPA) of the IBM Gun Club property (the Site). International Business Machines (IBM) Corporation engaged Sanborn, Head Engineering P.C. (Sanborn Head) to conduct the remedy assessment and prepare this report. While the current remediation approach for the Site continues to be effective at meeting the goals established in the Site Management Plan[1] (SMP), IBM voluntarily elected to undertake an evaluation of the enhanced biodegradation component of the remedy after observing a change in the effectiveness of recent injection events.

Work at the Site is being conducted in accordance with the SMP under the New York State Brownfield Cleanup program (BCP) administered by the New York State Department of Environmental Conservation (NYSDEC) through BCP Agreement No. C704044. We understand that IBM will submit this report to NYSDEC and the New York State Department of Health (NYSDOH), referred to as the Departments. The report will also be provided to the Binghamton Country Club, the current owner of the Site.

1.1 Background

The Site is located in the Town of Union, County of Broome, New York, and it is part of Parcel 126.18-1-20 on the Broome County Tax Map. The Site is an approximately 15.591-acre area bounded by the former IBM Gun Club Shooting Range parcel to the north and west, Binghamton Country Club property to the south, Robinson Hill Road to the east (see Figure 1). Site ownership was transferred to the Binghamton Country Club in 2015. Remediation of Site groundwater is intended to address the presence of volatile organic compounds (VOCs) in groundwater, principally trichloroethene (TCE) and its biochemical breakdown products.

Site geology is comprised of 1 to 7 feet of glacial till underlain by moderately hard, well-cemented, fine-grained sedimentary rock, principally sandy siltstone with lesser amounts of shale and sandstone. The uppermost 40 ft of rock is characterized by a predominance of near horizontal bedding parallel fractures that conveys most of the groundwater flow through and away from the Site. A program of rock core sampling for VOCs during the remedial investigation defined areas of primary and secondary source rock. Primary and secondary source rock was defined as containing greater than 0.1 and 0.01 grams per cubic foot (g/ft^3) in rock, respectively.[2] Primary and secondary source rock isopleths are shown on Figure 2.

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[1] Sanborn, Head & Associates, Inc., Site Management Plan, Brownfield Cleanup Program, IBM Gun Club – Former Burn Pit Area, Union, New York, NYSDEC Site #C704044, BCA Index # B7-0661004-05, December 2013, last revised May 2017.

[2] Primary source rock refers to rock that has been impacted by the release of VOCs to the subsurface and acts as a primary source for groundwater contamination. Secondary source rock refers to rock containing VOCs believed to originate from historical downgradient transport of dissolved-phase VOCs that may act as a secondary source of VOCs to groundwater flowing through fractures via back diffusion.

An aquitard interval of unfractured rock that is relatively impervious to water flow is present at depths of approximately 15 to 20 feet in the main area of the plume. As a result, the majority of the VOC mass is found within the upper 15 ft of subsurface.

The depth to groundwater is about 10 feet in wells screened above the first substantial bedrock aquitard interval. VOC concentrations above 1,000 micrograms per liter (μg/L) in groundwater were found in primary source rock on the Site, while concentrations off-Site were generally below 100 μg/L in secondary source rock. This groundwater plume extended off-Site to the south onto the adjoining property being used as a golf course; however, concentrations greatly decrease, and groundwater standards are generally attained on the adjoining property.

During the remedial investigation, groundwater seeps were observed to break out along the southern slope of the Site in several discrete areas downgradient of the BPA. Some seeps contained low but detectable concentrations of VOCs.

1.1.1 Selected Remedy

To address the presence of VOCs in Site groundwater and sorbed mass within the rock matrix, a feasibility assessment of remedial measures was performed. The approved remedy includes a combination of enhanced in-situ biochemical degradation, an engineered soil cap, and phytoremediation. Following remedy construction and implementation during 2013 and 2014, a Certificate of Completion (COC) for the Site was issued on November 12, 2014 by NYSDEC. Thus, the remedy has been in place for about 7.5 years.

Figure 3 provides a summary of the remedy, which includes the following engineering control components (ECs):

1. **An engineered soil cap** constructed of low-permeability, clean soil fill that provides a minimum of 2 feet of cover over near-surface soils.

2. **Placement and compaction of engineered soil fill within a topographic depression south of the BPA ("Seep Area"),** where VOC-containing groundwater had historically been observed to breakout to the ground surface as seasonal seeps and springs.

3. **Phytoremediation -** Establishment and maintenance of grass and tree cover to limit infiltration recharge to groundwater and enhance direct uptake of VOC-containing shallow groundwater, a process known as phytoremediation; and

4. **Enhanced biochemical degradation (EBD) –** The injection into the subsurface of engineered amendments (edible soybean oil) shown to enhance biochemical destruction of VOCs in site-specific pilot testing. The EBD component included installation of two rows of injection boreholes, as shown on Figures 2 and 3.

Institutional controls (ICs) were also established as part of the remedy and included controls to maintain and monitor the ECs, prevent future exposure to remaining contamination, and limit the use and development of the Site to restricted residential uses only. The ICs continue to be adhered to and are not discussed in this report.

1.2 Remedial Action Performance Objectives and Measures of Success

The goals of the combined application of capping, phytoremediation, and EBD are to:

- Produce sustained EBD throughout the primary source rock;
- Limit mass flux out of the primary source rock area, in particular across the Site boundary; and
- Enhance the intrinsic biochemical degradation processes outside and downgradient of the primary source rock.

As outlined below, the performance objectives incorporate short- and longer-term measures of success. These measures are intended as broad measures of success, recognizing that the actual performance will vary from location to location and with time.

1.2.1 Short-Term Goals

The performance goals of the remedy established in the Remedial Work Plan (RWP), and carried through the SMP, include short- and longer-term measures of success that are expected to require decades to complete. While categorized as short-term goals, these performance measures continue to be evaluated in the long-term. The performance goals and measures of success to be assessed in the short term, defined as 5 years or less, are shown in Exhibit 1. Short-term measures of success were assessed as part of the 2019 Periodic Review Report (PRR).[3] The findings of that report indicated progress consistent with expectations for a decades long remedy, with some aspects of the remedy having opportunity for improvement.

Remedy Goals	*Short Term Measures of Success (Less than 5 years)*
1. Sustained enhanced biochemical degradation (EBD) throughout Primary Source Rock	*2 orders of magnitude sustained reduction in TCE concentrations in injection displacement zone*
2. Limit Mass Flux Out of Primary Source Rock	*Downgradient response without accumulation of toxic breakdown products*
3. Enhance biochemical processes outside primary source rock	

Exhibit 1 - Goals and Short-Term Measures of Success Outlined in the Site Management Plan

Areas of geochemical conditions conducive to biochemical degradation have been established and maintained throughout much of the primary source rock. However, those areas remain generally unchanged and have not increased since before the 2017 injection. Starting in 2017, areas most conducive to degradation (methanogenic conditions) were no longer present in between the rows of injection boreholes. The area of sulfate-reducing conditions has decreased to the south (not

[3] Sanborn, Head Engineering. P.C., January 20, 2020, 2019 Periodic Review Report IBM Gun Club – Former Burn Pit Area, Union, New York, BCP Agreement #C704044.

encompassing BP-38A and BP-39A) since 2019, and this area was not impacted or improved by the 2020 injection.

The metric of success of 2 orders of magnitude (Oom) reduction of TCE in groundwater from monitoring wells within the injection displacement zone has been achieved in some but not all locations. The injection displacement zone is defined as the area where groundwater volume within fractures is expected to be displaced by amendment during injections. A comparison of distribution of TCE in groundwater based on October 2013 and June 2021 sampling is shown on Figure 4.

One out of four routinely sampled monitoring wells in the injection displacement zone exhibits 2 Oom reduction of TCE since the start of monitoring (BP-2A), with the remainder exhibiting one half to 1 Oom reduction. As discussed in recently submitted reports, further downgradient increases in TCE, *cis*-1,2-dichloroethene (cDCE), and vinyl chloride (VC) concentrations at off-Site well BP-39A (see time series in Appendix C) have been observed, which is expected during the course of a long-term EBD remedy. The generation and increasing concentrations of ethene and ethane at well BP-39A suggest that destruction of VC and other VOCs is occurring in this area and the process is not stalling, and conditions remain favorable for EBD in the downgradient area. However, changes to the remedy may be able to improve conditions that could benefit this process further.

1.2.2 Long-Term Goals

The effects of the amendment injections should propagate from the emplaced amendment mass to downgradient locations. Site-specific modeling completed during EBD pilot testing indicated that it may take decades for the full effect to be reflected at the most downgradient seeps and springs in a wet area on the adjoining property about 1,000 ft downgradient from the BPA.

The long-term performance objectives (beyond 5 years) would include continuing to meet the short-term objectives and making progress towards reducing TCE concentrations on adjoining property, including:

- Evidence of sustained EBD beneath the wooded slope on Binghamton Country Club property just south of the property line following a shift to biochemical conditions more conducive to EBD. Success will be measured by decreasing concentrations of TCE and increasing concentrations of breakdown products; and

- On a 10-to-20-year timescale, we would expect the cumulative effect of reduced mass flux out of the primary source rock and downgradient migration of EBD to reduce concentrations at downgradient seeps and springs at points of shallow groundwater discharge.

In general, progress is being made toward long-term goals, with some aspects having opportunity for improvement. Evidence suggests that EBD is sustained at the property boundary and intermittently enhanced further down the slope. Downgradient monitoring well BP-9A, located just north of the property boundary, continues to exhibit sustained sulfate-reducing conditions conducive to EBD and has exhibited recent Oom increases in the terminal breakdown products ethene and ethane.

However, at further downgradient well BP-39A, total VOC concentrations are generally increasing, driven by increases of parent as well as breakdown and terminal breakdown products. Increase in total VOCs may indicate biodegradation is occurring, but at rates less than the rate of back diffusion from the primary and secondary source rock. Additionally, geochemical conditions conducive to EBD are not sustained at the location and have not been present since 2019.

The SMP also states that if diminished returns are observed from repeated injections, an evaluation of the EBD program should be performed. As noted in previous sampling reports, the response to the 2017 injection was muted, and after the 2020 injection, conditions improved for approximately 1 year.

1.3 Scope of Assessment and Report

Monitoring data, in aggregate, continue to support that degradation of VOCs is occurring. Both short- and long-term remedy measures of success are primarily being met and are generally on track as part of a decades-long process. However, as discussed in more detail in Section 2.0, there are aspects of the remedy that can be improved. The key areas of improvement are discussed in Section 3.0 and include injection timing, amendment delivery, and improving geochemical conditions. This optimization assessment evaluated several strategies for improving the remedy and making in-situ treatment more efficient. Recommendations for changes to the monitoring program and other conclusions are presented in Section 4.0.

2.0 EVALUATION OF CURRENT REMEDY

The Site remedy components include capping, phytoremediation, and enhanced biochemical degradation. The status and performance of each of the remedy components is summarized in the subsections below, and supporting data analysis, charts, and figures are presented in Appendix B.

The remedy evaluation discussion is presented in the following order: 1) Low permeability cap and phytoremediation, 2) effectiveness of amendment delivery, 3) frequency of delivery, and 4) status of conducive biogeochemical conditions.

2.1 Low Permeability Cap and Phytoremediation

The combined goals of the low permeability capping and phytoremediation components of the remedy are to limit infiltration through underlying VOC-containing rock, eliminate downgradient seeps, improve reduction-oxidation (redox) conditions in groundwater, and provide supplemental uptake of groundwater and VOCs via phytoremediation. Metrics of success outlined in the SMP include reducing VOC flux across the property boundary and the observation of the presence or absence of new or re-emerging seeps and springs along the hillslope and gravel access road north of the Country Club property boundary. An assessment of long-term trends in groundwater elevation and redox conditions pre- and post- capping and tree planting is presented in Appendix B and is summarized below.

The combined action of the low permeability cap and phytoremediation are meeting performance goals established in the SMP. While material changes to water levels because of capping have not been realized, the presence of seeps has been reduced and stable for several years. Geochemical parameters in monitoring wells within the capped area and away from the direct influence of injections are slightly improved since the installation of the cap, indicating that reduction of infiltration of oxygen-rich water is having a beneficial effect on redox conditions.

At the same time, tree mortality compared to initial planting has appeared to stabilize around 35% across the planted area. Tree measurements collected in June 2021 indicate continued growth progress, with tree height increasing on average to 25 feet and circumference to 1 foot.

2.2 Enhanced Biochemical Degradation

A summary of the effectiveness of the EBD portion of the remedy is presented below. Further details including the injection design, dosing, and frequency are provided in Appendix B. In addition to the design of the injections, an assessment of the current Site geochemistry is also reviewed. Interactive figures depicting geochemical conditions both before and after the most recent injection in September 2020 are included in Appendix C.

2.2.1 Effectiveness of Delivery

At a Site-wide scale, the EBD approach continues to be generally effective at meeting performance goals established in the SMP, but the effectiveness of delivery of the existing injection well network has decreased compared to the initial injection events in 2014.

Injection borehole performance has been tracked since the first injections in 2014. Several of the wells, including a cluster in the center of the A-line, as well as B-9, did not perform as well (they accepted less amendment under pressure) in 2020 compared to previous injections. Based on observations made during recent injections and the injection boreholes redevelopment in 2019, transmissivity in the injection boreholes has decreased, possibly due to the emplacement of oily emulsion in fractures, which has likely reduced the effective permeability. This is a common and expected observation at in-situ EBD sites.

Decreasing TOC concentrations, especially at locations in between the A- and B-line of injection wells, have been observed since 2017 and were not materially affected by either the August 2017 or most recent injection in September 2020. Offsite, no immediate effects of injections are observed, and long-term TOC trends are neutral, suggesting that carbon delivery may be limited in this area.

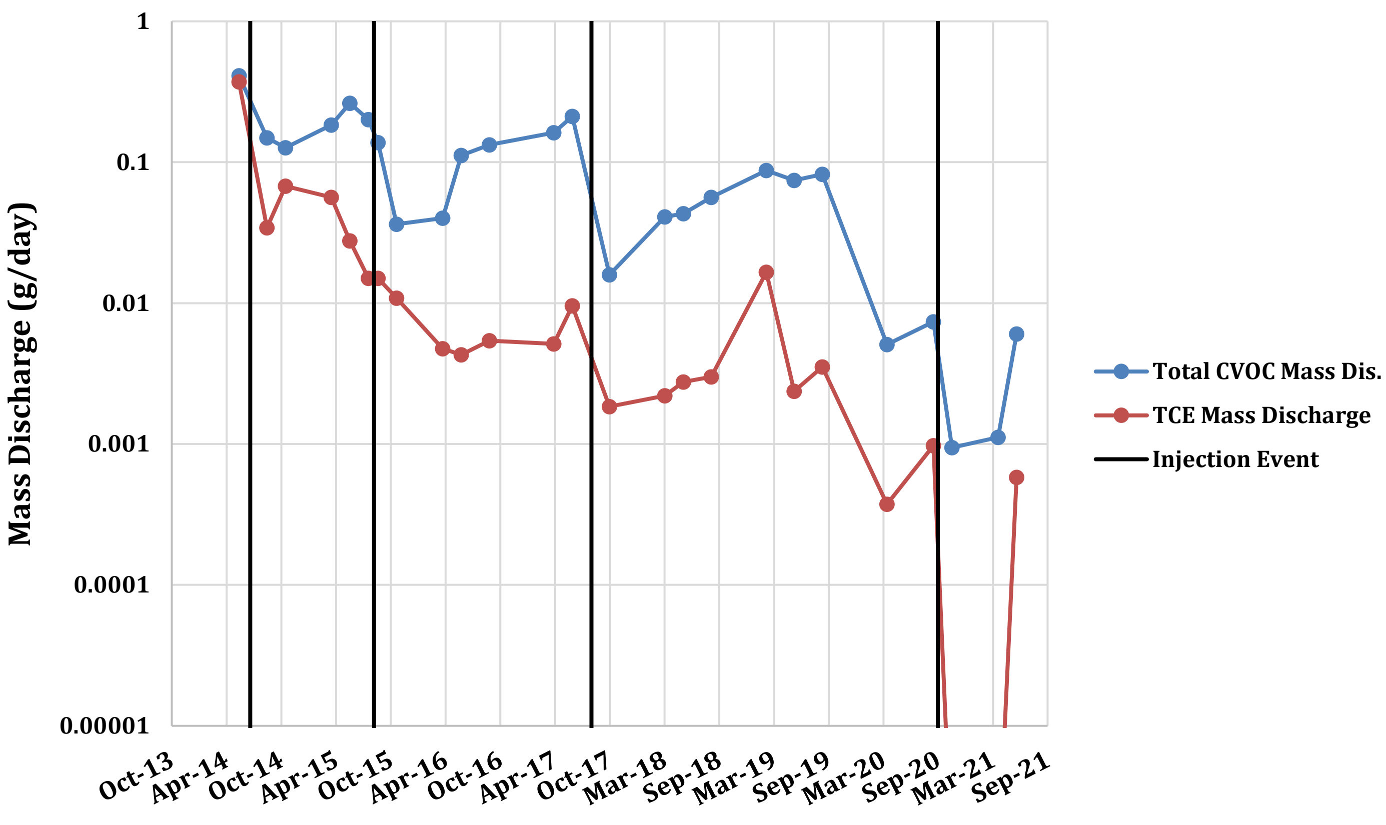
The distribution of TCE in groundwater in October 2013, before any site-wide injections, compared to June 2021 monitoring is shown in Figure 4. While there have been overall improvements in TCE concentrations realized since 2013, monitoring wells within the core of the plume through the primary source rock along a line from BP-6A southwest to BP-39A remain elevated, with concentrations in the thousands of micrograms per liter. Further improvements may be realized by the improved delivery of amendment to the main part of the plume in areas of highest VOC concentration in rock (red area of primary source rock on Figure 2).

2.2.2 Frequency of Injections

There is strong evidence that the aquifer responds favorably to injection events and that sustained biochemical degradation is occurring. However, the benefits of most recent September 2020 injection were most pronounced for a period of approximately 1-year with reduced effectiveness after this timeframe. Several lines of evidence support this analysis including VOC concentration and compound-specific isotope analysis (CSIA) data.

Reduction of mass flux out of the primary source rock is monitored as part of remedial performance objectives. Mass flux out of the primary source rock is calculated by estimating groundwater flow across the B-line of injection boreholes. Downgradient mass discharge estimates are derived from ongoing monitoring of VOC concentrations at three of the B-series injection boreholes (B-4, B-7, and B-9), which represent a range of transmissivities across the B-line. A record of VOC mass discharge estimated from sampling of these three boreholes is shown in Exhibit 2 below.

Exhibit 2: Estimated VOC mass discharge in grams per day based on data recorded for injection boreholes B-4, B-7, and B-9

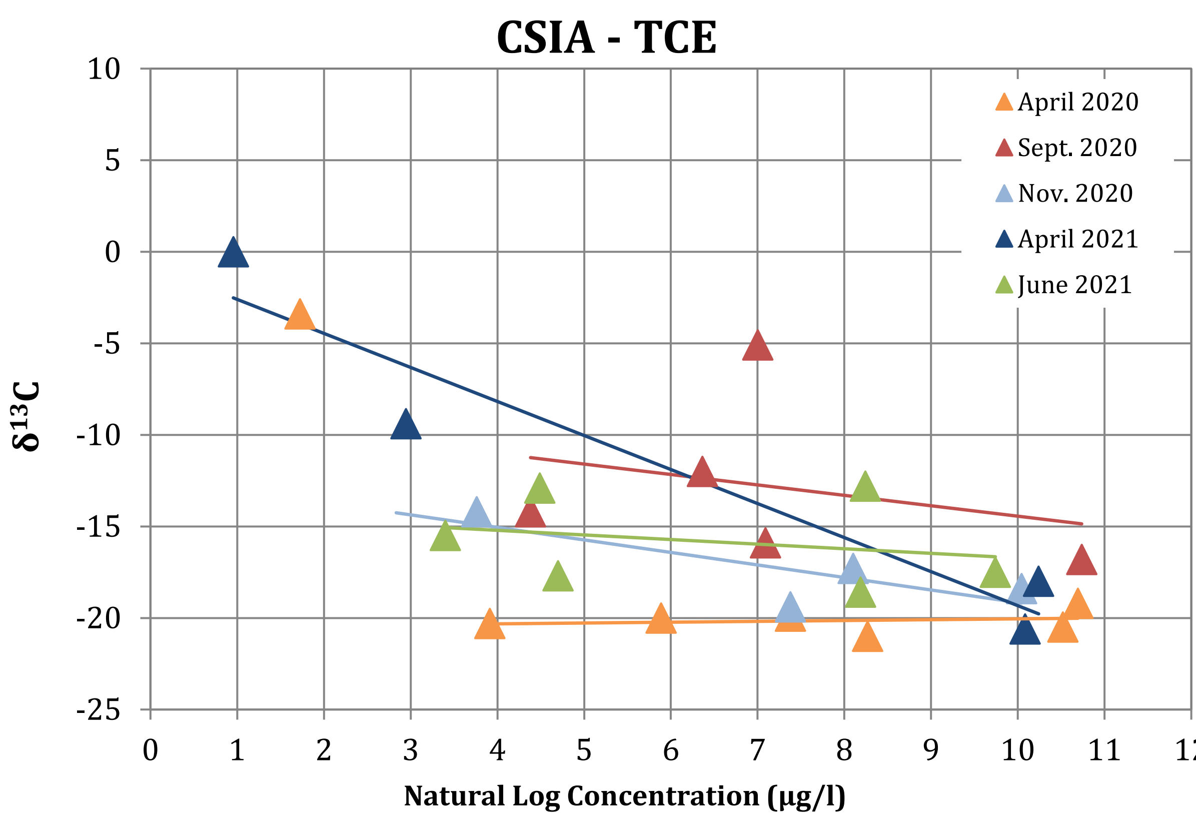


Data derived from sampling since the installation of the B-line of injection wells indicate a sustained reduction in both total VOC and TCE mass discharge. Incremental reductions to VOC mass discharge were observed following injections in August 2015 and September 2020 and, to a less degree, August 2017. As shown in the line graph above, the timeframe for a "rebound" of mass discharge is about 1 year.

We note that overall cumulative reductions from tenths of grams per day before injections began, to hundredths of grams per day currently continue to be realized. These estimates continue to support the presence of an active zone of biodegradation perpendicular to groundwater flow at the B-line, which has reduced downgradient transport of VOC mass from the primary source rock by at least one order of magnitude.

Like VOC concentrations, an example of temporary improvements following the September 2020 injection is observed in the CSIA data. A chart of $\delta^{13}C$ values for TCE is presented in Exhibit 3 below. Additional data interpretation is provided in Appendix B. Orange and red trendlines indicate pre-September 2020 injection values, while green to blue trendlines are post injection. A change in the plotted data to a steeper slope and less negative $\delta^{13}C$ values indicate an increase in biodegradation.

Exhibit 3: CSIA TCE Results April 2020 to June 2021



The nearly flat line for April and September 2020, before the injection, indicates relatively less degradation, or that mechanisms other than biodegradation are resulting in lower concentrations. Conversely the steeper slope and less negative values recorded in April

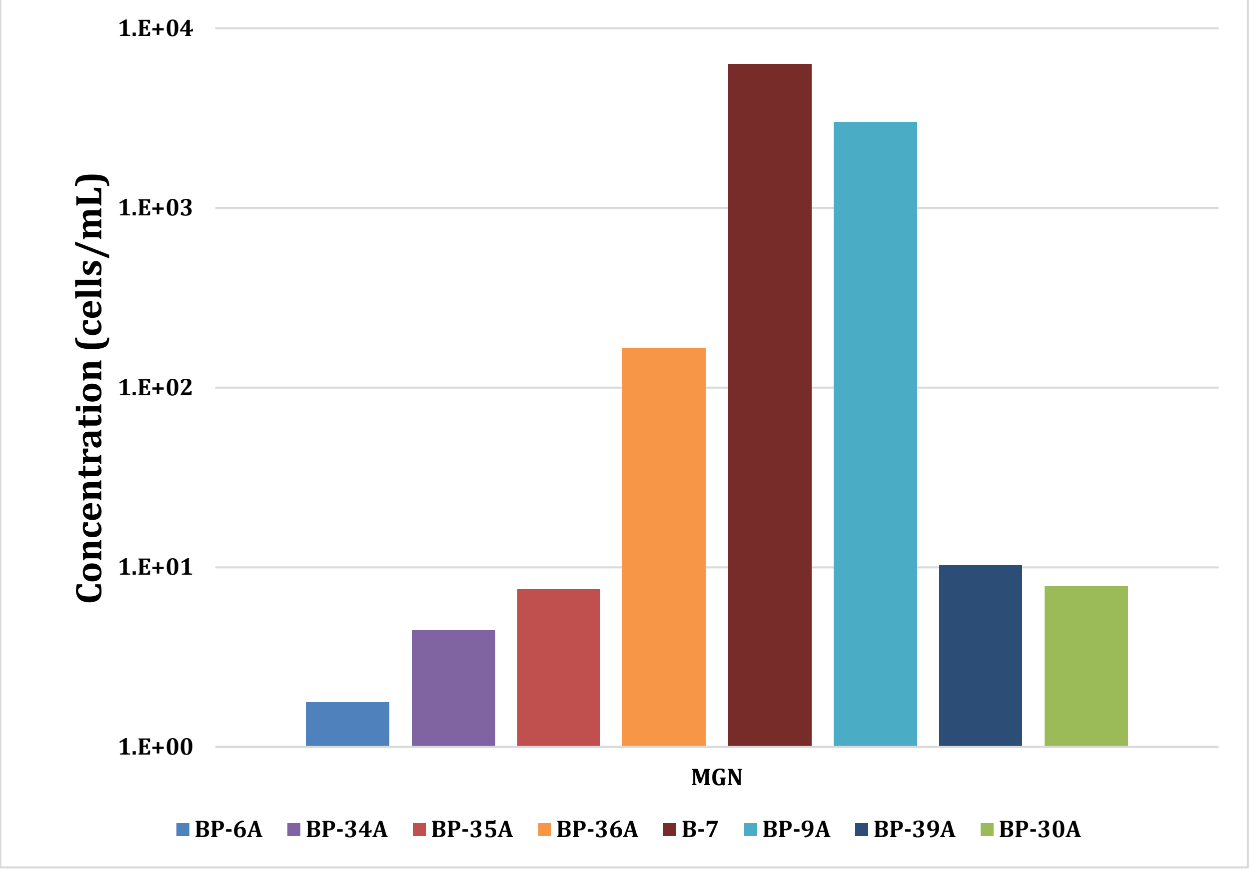
2021, approximately 7 months after the injection, suggest increased degradation. June 2021 results are flattened and more negative again, which may indicate that the beneficial effects of the injection may be shorter than the frequency of the injection events. Similar patterns are observed in quantitative polymerase chain reaction (qPCR) results, in which concentrations of *dehalococcoides* (DHC) and their associated functional genes that can be responsible for reductive dehalogenation increased after the injection, but that the beneficial effects of the injection may be shorter than the frequency of the injection events.

2.2.3 Status of Biogeochemical Conditions

In general, biogeochemical conditions remain favorable to reductive dechlorination. However, the presence of microbial competition (methanogens, MGN) and trends towards less favorable geochemical parameters (pH) in some areas suggests that additional improvement to subsurface conditions may be possible.

A chart of average MGN concentrations in each sampled well along the main core of the plume is presented in Exhibit 4 below. Individual methanogen concentration data for each round is available in Appendix B.

Exhibit 4: Average Methanogen Concentration



In aggregate, methanogens are present in higher levels primarily mid-plume, centered on BP-36A, B-7, and BP-9A. These locations also exhibit other lines of evidence of sustained biodegradation such as favorable geochemical conditions and increased production of terminal breakdown products. The presence of relatively elevated methanogens may indicate a downward pressure on DHC populations, but they are also present in many of the locations that have the highest DHC populations and the most conducive geochemical conditions.

For pH, regularly monitored wells were generally within the 6.3 to 7.5 s.u. pH range that is ideal for degradation before the most recent injection, with a small number of monitoring locations intermittently below the most conducive range. In September 2020, before the injection, the pH for wells apart from BP-13A was within or above the 6.3 to 7.5 s.u. pH range. Since the September 2020 injection, pH values have decreased such that several wells are below the most conducive range. In June 2021 monitoring, wells BP-13A, BP-2A, BP-30A, BP-35A, BP-38A, BP-39A were below the optimum range at levels that are historically low and detrimental to dechlorinating microorganisms.

3.0 REMEDY IMPROVEMENT RECOMMENDATIONS

The findings of the remedy assessment outlined in the section above and detailed in Appendix B were used to establish optimization recommendations presented in this section. We emphasize that overall, the combined effect of the low permeability cap, phytoremediation, and in-situ EBD has been successful in meeting most objectives established in the SMP. The additional improvements summarized below are expected to provide incremental benefit to the already successful remedy.

3.1 Low Permeability Cap & Phytoremediation

The combined action of capping and trees is successfully limiting infiltration of oxygen-rich rainwater and preventing the emergence of seeps along the slope near the B-line of injection boreholes. Combined with other lines of evidence, including continued reductions in TCE concentrations in monitoring wells within the main plume area and reduction of TCE concentrations in seeps that do remain further downgradient on the golf course, the low permeability cap and phytoremediation components of the remedy are meeting performance goals.

For this reason, no changes to these components of the remedy are recommended. The presence/absence of seeps will continue to be assessed during routine monitoring events and the annual Site-wide inspection. Long-term trends of redox conditions will be assessed on an on-going basis by tracking geochemical parameters at wells within the capped area, but outside the direct zone of influence of the injection boreholes (BP-1A, BP-5A, BP-37A).

With tree mortality compared to initial planting leveling off at about 35% over the last several years, and the prolific growth of surviving trees, we recommend discontinuing the assessment of tree mortality and replacing the metric of success with the following: continued observations of the occurrence of seeps to verify that the combined effect of the low permeability cap and uptake of water via phytoremediation is reducing exposure potential at the ground surface via seeps, while also limiting infiltration of rainwater to the subsurface. These metrics for success will be discussed in the annual Site-wide inspection report. The condition of the trees in aggregate will be documented during the annual inspection as part of the overall cap inspection; topsoil testing and fertilization for tree health will continue as part of routine O&M.

3.2 Enhanced Biochemical Degradation

The EBD evaluation showed that the EBD process is working to degrade VOCs; however, there is evidence that more effective delivery of amendment and more frequent injection events could incrementally improve performance. The following section provides a stepwise, incrementally conservative approach for recommendations to increase the EBD performance. The following topics will be addressed separately, and only implemented if necessary, based on the effect on EBD process efficiency: delivery, dosing, and geochemical parameters.

3.2.1 Delivery

Some well locations in the main area of the plume (BP-13A and BP-34A, among others) show minimal degradation of VOCs, decreased concentrations of TOC, and increased redox conditions, suggesting that amendment is not being delivered efficiently to the area, while other downgradient offsite wells, especially BP-39A, show evidence of increasing VOC concentration or geochemical parameters that suggest degradation could be improved in certain areas. Therefore, we recommend installation of new injection boreholes along two lines offset from the existing boreholes. The proposed locations are shown in Figure 5 and are summarized in the Exhibit below.

Exhibit 5: Proposed Supplemental Injection Boreholes

Proposed Injection Borehole	Inferred Aquitard Elevation (ft AMSL)	Inferred Ground Surface Elevation (ft AMSL)	Target Drilling Depth (ft below ground)
C-1	1373.8	1386.0	12.5
C-2	1373.0	1387.8	15
C-3	1372.2	1389.0	17
C-4	1372.0	1390.2	18
C-5	1372.2	1389.8	17.5
C-6	1372.8	1390.0	17
C-7	1373.0	1392.0	19
C-8	1373.4	1394.0	20.5
C-9	1374.0	1396.0	22
C-10	1374.8	1397.0	22
D-1	1365.0	1375.6	10.5
D-2	1365.0	1376.0	11
D-3	1365.6	1376.2	11
D-4	1366.0	1376.2	10
D-5	1366.0	1376.2	10
D-6	1366.0	1376.6	10.5
D-7	1366.0	1377.0	11
D-8	1366.0	1377.6	11.5

In general, the injection boreholes will be drilled to the top of the first unfractured aquitard interval as determined during previous investigations, approximately 10 to 20 feet below ground surface. Proposed depths in Exhibit 5 are inferred from the expected elevation of the top of the aquitard and the ground surface as documented in the record drawings included in the SMP. Final termination depth of each borehole will be based on actual conditions observed in the field. Injection wells will be constructed similar to the A- and B-line locations, with a 6" steel surface casing set below ground, with an open rock interval below the casing.

The addition of new injection boreholes will increase the pathways for EOSPro® delivery and distribution in the fractured bedrock aquifer. We expect that the capacity of each injection well to accept EOSPro® will be highly variable based on our experience with the variability in capacity with existing injection wells. As such, the process described in Section 3.2.2 will be used to make final decisions on how much EOSPro® amendment is added to each well during each injection event. Amendment volumes on a combined and well-by-well basis will be reported in IBM's routine Operations and Maintenance (O&M) memorandum summarizing the injection.

The new boreholes would be subjected to slug testing and initial baseline sampling for VOCs at all locations. Samples will also be collected for laboratory analysis of biogeochemical parameters (e.g., CSIA, qPCR, redox indicators) at a subset of the new injection wells prior to and after injection of EOS. The specific locations will be determined based on the results of slug testing. For planning purposes, we anticipate submitting 1-2 samples for biogeochemical analysis from each of the new injection rows (total of 2-4 locations).

To further evaluate the degree of mass removal accomplished following more than 7 years of injections, a re-assessment of the amount of sorbed mass present in the primary source rock will be completed. This work will include collection and analysis of rock core for analysis of VOCs using the same Discrete Fracture Network® (DFN) approach that was performed as part of the Remedial Investigation.

The results from the new injection well borehole installations, slug testing, initial groundwater sampling, and DFN rock core sampling will be provided to the Departments following completion. The results of initial sampling and testing will determine the selection of several wells in the C- and D-lines for ongoing routine monitoring of VOCs and geochemical parameters, similar to the sampling of the small subset of existing injection boreholes that currently occurs. On-going monitoring results will be communicated in IBM's routine monitoring reports.

3.2.2 Dosing

Because the geochemistry indicates that VOCs are being degraded in the subsurface using the current substrate (EOSPro®) at the calculated dosing concentration, it is not currently recommended to change the amendment, or the concentration of the EOSPro® being delivered to the subsurface. As a whole, the EBD portion of the remedy has been successful, and these recommendations are not intended to introduce major changes into the system. VOC data, geochemistry, and CSIA data indicate a varied response to the injection, ranging from no response, to producing conditions that are known to enhance degradation. Where there is evidence of improvements following injections, those improvements last about 1 year or less. We recommend increasing the frequency of injection events to annually for at least the next 3 years.

For the fall of 2021, the injection volume and total dose will remain the same, with approximately 1,080 gallons of diluted amendment targeted for select wells in the A-line, and 730 gallons for the B-line, totaling about 1,800 gallons, as shown on Figure B.2. Supplemental injection boreholes will be installed prior to the 2022 injection as described in the section above. The 2022 injection will include the typical locations and doses in the A- and B-line, and all the newly installed injection boreholes in the C- and D-line.

Similar to past assessment of injection boreholes, an initial attempt to inject 50 gallons of diluted amendment will be made for each newly installed injection borehole, which is equivalent to approximately twice the standing volume of the typical injection borehole installed to 20 feet below ground surface. The total target dose for injections after the installation of the supplemental boreholes will be 2,650 gallons of diluted amendment, equivalent to 140 gallons of undiluted amendment. The transmissivity and overall performance of the newly installed injection boreholes will be assessed, and adjustments made to individual borehole dose will be made depending on actual performance in the field once installed, which is similar to the approach used previously to establish the volumes of EOSPro® delivered to each well.

3.2.3 Contingent Adjustments to Biogeochemistry

As described above, relatively low pH conditions and the presence of competing bacteria (i.e., MGN) may be reducing the effectiveness of EBD processes. Therefore, an incremental approach to modification of biogeochemical conditions is proposed with a goal of creating more favorable conditions for helpful bacteria (e.g., DHC), and decreasing competing bacteria (i.e., MGN). The following recommendations to adjust the biogeochemistry of the system is presented in a stepwise, pilot scale testing approach, as outlined below. The proposed adjustments will be made one at a time with up to one year in between to monitor for changes. If conditions are observed to improve, as measured by VOC concentrations or biogeochemical parameters, all proposed adjustments may not be completed. Similarly, if adverse effects are observed, at the pilot scale testing phase or site-wide implementation, the adjustments will be discontinued.

pH adjustment

Historically low pH outside the optimal range (i.e., less than 6.3 s.u.) was observed in some of the wells (BP-13A, BP-2A, BP-30A, BP-35A, BP-38A, BP-39A) in June 2021. Low pH values are less conducive to biochemical degradation and tend to enhance competing bacteria (MGN). Therefore, we propose to correct and maintain pH levels in the circumneutral range to maintain beneficial conditions.

We recommend the introduction of CoBupHMg®, produced by the EOS Remediation, LLC. to increase pH levels. CoBupHMg® is a colloidal suspension of alkaline solids providing long-term, slow-release adjustment of pH in acidic aquifers to optimum levels and can be used to regulate long-term pH of the bioremediation zone, with little risk in over-increasing pH. A product specification sheet is provided in Appendix C.

CoBupHMg® is designed to be mixed with the EOSPro® amendment and injected as part of a routine injection mobilization or added directly to the affected well. We propose the following conservative stepwise approach:

- During the proposed fall 2021 injection mobilization, an appropriate amount of colloidal buffer will be added to a select number of the existing injection boreholes as a pilot-scale test of pH adjustment;
- pH will continue to be regularly monitored as part of routine performance testing at the site; and
- pH response to the pH adjustment pilot test will be assessed by evaluating pH and other field screening parameters collected during routine sampling, VOC concentrations, biogeochemical testing (e.g., qPCR and CSIA), and other redox parameters. These parameters will be tracked with the goal of evaluating whether to proceed with full site-scale application as part of the 2022 injection.

IBM will report the results and any associated recommendations and next steps from the above-described pH adjustment testing in its routine monitoring reports.

Bio-augmentation

Another approach to enhancing biochemical degradation is to augment the injections with desirable organisms (e.g., DHC), which can result in increased reductive dichlorination rates. Contingent upon the results of increasing the injection frequency and installation of additional injection boreholes and adjusting aquifer pH, we will perform a pilot study for bio-augmentation with a purchased microbial product such as BAC cultures, which is commercially available from EOS Remediation, LLC. Commercial cultures such as BAC include organisms (e.g., *Dehalococcoides mccartyi*) and enzymes in a water-based medium with a cell concentration of approximately 10^{11} Cells/L designed for enhancing biochemical degradation of VOCs. A product specification sheet is provided in Appendix C.

Microbial cultures are designed to be mixed with the EOSPro® amendment and injected as part of a routine injection mobilization or added directly to the affected well. We propose the following stepwise approach:

- Proceeding with bio-augmentation is dependent on the results of other recommended optimization steps above, and may not be performed;
- The timing of the bio-augmentation pilot is dependent on whether pH adjustment is selected to go to site-scale, and other factors, but could potentially occur during the 2023 injection mobilization.
- During the proposed fall 2023 injection, we will introduce an appropriate amount of microbial culture into a select number of wells with the lowest DHC concentration as

determined by sampling and qPCR analysis conducted just before the time of bio-augmentation;

- DHC and other microbes and functional genes will continue to be monitored with qPCR analysis at those locations; and

- Microbial response to bio-augmentation will be analyzed and tracked to evaluate the viability of site-scale bio-augmentation to potentially be completed in the 2024 injection.

4.0 CONCLUSION

This section provides a summary of findings and recommendations based on the remedy optimization assessment for the Gun Club Site. IBM elected to voluntarily conduct an optimization assessment of the remedy. The routine site inspections, routine groundwater monitoring, and supplemental forensic monitoring (e.g., qPCR and CSIA) performed over the last 1.5 years indicate the following observations and implications regarding the effectiveness of the remedy components:

- **Low Permeability Cap and Phytoremediation:** The combined action of the low permeability cap and phytoremediation are meeting performance goals established in the SMP. No substantive changes to current conditions are warranted, and data collected from the time of capping until now suggests that some alteration of the monitoring provisions of this component of the remedy are warranted.

- **Effectiveness of Delivery:** At a Site-wide scale, the EBD approach continues to be generally effective at meeting performance goals established in the SMP, but the effectiveness of delivery of the existing injection well network has decreased compared to the initial injection events in 2014. As a result, reduced delivery of carbon is observed in some areas, namely between the rows of injection wells. This is a common and expected observation at in-situ EBD sites. Therefore, installation of new injection wells is recommended to complement the existing injection well network.

- **Frequency of Injections:** There is strong evidence that the aquifer responds favorably to injection events and that sustained biochemical degradation is occurring. However, the benefits of the most recent 2020 injection were most pronounced for a period of approximately 1-year with reduced effectiveness after this timeframe. Therefore, more frequent injection events, combined with injecting at more locations, is recommended.

- **Status of Biogeochemical Conditions**: In general, biogeochemical conditions remain favorable to reductive dichlorination. However, the presence of microbial competition (methanogens) and trends toward less favorable geochemical parameters (pH) in some areas suggests that additional improvement to subsurface conditions may be possible. A phased approach to certain measures (e.g., more frequent injections), with further evaluation of options (e.g., pH adjustment and/or bioaugmentation) is recommended.

Exhibit 6 summarizes the recommendations in response to the above observations:

Exhibit 6: Summary of Recommendations and Next Steps

System Component	Recommendation	Next Steps
Low Permeability Cap and Phytoremediation	Discontinue tree counting and continue monitoring for seeps/springs and beneficial redox conditions	Update SMP and annual inspection documentation to reflect new metrics
EBD - Delivery	Installation of supplemental injection boreholes	Field work planned for 2022
EBD - Frequency	Increase injection frequency to annually	Injection scheduled for November 2021 and annually for the next three years
EBD – Adjustment of biogeochemical parameters	Addition of pH buffer to increase pH levels	Pilot-scale testing of pH adjustments during November 2021 injection; potential full scale pH adjustment in 2022
EBD – Adjustment of biogeochemical parameters	Bioaugmentation with supplemental beneficial microbes	If necessary, pilot-scale testing to be performed during 2023 injection with potential full-scale implementation in 2024

In summary, we recommend increasing the frequency of injection to annually for a period of at least 3 years, adding injection boreholes, and adjusting certain biogeochemical parameters to increase degradation, if necessary. We recommend proceeding in a stepwise manner followed by an appropriate monitoring interval to assess changes. As such, the next injection would be scheduled for fall 2021, with installation of supplemental boreholes in the spring/summer 2022, and injection into a combination of original and newly installed injection boreholes in early fall 2022. A pilot of pH adjustment will be performed during the fall 2021 injection event and if warranted, full scale pH adjustment would be completed as part of the fall 2022 injection event. If warranted, pending the results of the pH adjustments, a pilot bio-augmentation would be performed as part of the fall 2023 injection with the potential to perform full scale implementation of bio-augmentation as part of the 2024 injection event.

As summarized on Table 1, and in accordance with the SMP, IBM will continue with groundwater monitoring three times per year through 2024, with main plume monitoring performed three times per year, and a more comprehensive round conducted annually in the summer. This approach will allow for consistent monitoring as we adjust and optimize the remedy. After installation of 18 new injection boreholes, a comprehensive round of pre-injection groundwater samples for routine analysis (VOCs and geochemical parameters) will be collected. A selection of injection boreholes arrayed across the proposed C- and D-lines will be sampled for qPCR and CSIA analyses. These data in conjunction with slug test analysis and groundwater flow information will be used to select a subset of the newly installed injection wells for ongoing routine monitoring. For planning purposes, we have assumed 2 locations per new line of injection boreholes will be added to the routine sampling program.

In addition to the analyses required by the SMP, IBM will continue to perform supplemental microbial and isotope analysis (qPCR and CSIA) as shown in Table 1. As assessment of potential scope reduction of groundwater monitoring will be provided as part of the 10-year remedy review, which will be completed in 2025.

No alteration of the low permeability cap or phytoremediation approach is proposed. IBM intends to discontinue annual tree mortality assessment and replace this evaluation with on-going monitoring of redox conditions beneath the capped area, and evaluation of the presence/absence of seeps. Pending the Departments' concurrence with this recommendation, the SMP will be revised to include these metrics. Changes to injection frequency and new injection boreholes were anticipated in the SMP as possible future system maintenance; therefore, IBM does not believe an update to the SMP is necessary for these changes.

IBM intends to proceed based on the general schedule provided in Exhibit 6 and will keep the Departments informed of its progress as part of routine reports, which are submitted based on the requirements of the SMP. IBM would be pleased to meet with the Departments to discuss the recommendations in this report, and to provide routine updates on the progress.

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TABLE

Table 1

Summary of Routine and Supplemental Monitoring Program

IBM Gun Club - Former Burn Pit Area

Union, New York

Monitoring Type	Monitoring Location	Monitoring Location Type	Analytical Laboratory							Field Screening
			VOCs	Light Gasses	TOC	VFAs	Geochem (Iron, Ferrous Iron, Nitrate, Sulfate, Sulfide)	qPCR	CSIA	Water Quality Parameters
Annual Summer Comprehensive Round (In addition to locations listed below)	BP-7A	Monitoring Well	x							x
	BP-8A	Monitoring Well	x							x
	BP-10A	Monitoring Well	x							x
	BP-11A	Monitoring Well	x							x
	BP-12A	Monitoring Well	x							x
	BP-14A	Monitoring Well	x							x
	BP-16A	Monitoring Well	x							x
	BP-17A	Monitoring Well	x							x
	BP-18A	Monitoring Well	x							x
	BP-19A	Monitoring Well	x							x
	BP-20A	Monitoring Well	x							x
	BP-21A	Monitoring Well	x							x
	BP-22A	Monitoring Well	x							x
	BP-23A	Monitoring Well	x							x
	BP-24A	Monitoring Well	x							x
	BP-25A	Monitoring Well	x							x
	BP-26A	Monitoring Well	x							x
	BP-27A	Monitoring Well	x							x
	BP-30A	Monitoring Well	x							x
	BP-32A	Monitoring Well	x							x
	GC-2A	Monitoring Well	x							x
	GC-1, P-1	Multi-Depth	x							x
	GC-1, P-8	Multi-Depth	x							x
	BP-12D, P1	Multi-Depth	x							x
	BP-12D, P7	Multi-Depth	x							x
	BP-13D, P1	Multi-Depth	x							x
	BP-13D, P5	Multi-Depth	x							x
	BP-15D, P1	Multi-Depth	x							x
	BP-15D, P5	Multi-Depth	x							x
Routine Spring, Summer and Fall monitoring	IB-7	Injection Borehole	x	x	x	x				
	A-13	Injection Borehole	x	x	x	x				
	B-4	Injection Borehole	x	x	x	x				
	B-7	Injection Borehole	x	x	x	x	x	x	x	x
	B-9	Injection Borehole	x	x	x	x				
	C-#	Injection Borehole	x	x	x	x	x	x	x	x
	C-#	Injection Borehole	x	x	x	x				
	D-#	Injection Borehole	x	x	x	x	x	x	x	x
	D-#	Injection Borehole	x	x	x	x				
	BP-1A	Monitoring Well	x	x	x	x	x	x	x	x
	BP-2A	Monitoring Well	x	x	x	x	x			x
	BP-4A	Monitoring Well	x	x	x	x	x			x
	BP-5A	Monitoring Well	x	x	x	x	x	x	x	x
	BP-6A	Monitoring Well	x	x	x	x	x	x	x	x
	BP-9A	Monitoring Well	x	x	x	x	x	x	x	x
	BP-13A	Monitoring Well	x	x	x	x	x			x
	BP-31A	Monitoring Well	x	x	x	x	x			x
	BP-34A	Monitoring Well	x	x	x	x	x	x	x	x
	BP-35A	Monitoring Well	x	x	x	x	x	x	x	x
	BP-36A	Monitoring Well	x	x	x	x	x	x	x	x
	BP-37A	Monitoring Well	x	x	x	x	x			x
	BP-38A	Monitoring Well	x	x	x	x	x			x
	BP-39A	Monitoring Well	x	x	x	x	x	x	x	x
	111	Seep/spring	x							x
	112	Seep/spring	x							x
	113	Seep/spring	x							x
	118	Seep/spring	x							x
	119	Seep/spring	x							x

Notes:

1. This table is intended to summarize the programs of routine and performance monitoring for remedy operations at the IBM Gun Club - Former Burn Pit Area. Additional monitoring points may be sampled based on field observations. Shaded cells indicate placeholders for the addition of up to two injection wells installed in the C- and D-lines to be added to the routine sampling program.

2. Analytical laboratory samples:
"VOCs" indicates volatile organic compounds.
"Light gasses" includes methane, ethene and ethane.
"TOC" indicates total organic carbon.
"VFAs" indicates volatile fatty acids.
"qPCR" indicates quantitative polymerase chain reaction analysis (DNA-based analysis to quantify specific microorganisms and functional genes responsible for biodegradation)
"CSIA" indicates compound-specific isotope analysis (ratio of stable carbon isotopes in TCE, cDCE, and VC)

3. " Water quality parameters" indicates screening during well purging and water quality sampling by multi-parameter probes, e.g. by YSI® 556 multi-Probe meter or similar and HACH® turbidity meter or similar (low flow, multi-level system, bailer, and surface water sampling) or by water quality parameter sounding (PDB sampling). The water quality parameters may include temperature, specific conductance, oxidation-reduction potential, dissolved oxygen, pH, and turbidity. In addition surface water samples will include water clarity descriptors (transparency, translucence, or opaqueness, and color).

FIGURES

Figure 1

Monitoring Location and Site Vicinity Plan

IBM Gun Club - Former Burn Pit Area

Union, New York

Drawn By: H. LaPointe
Designed By: E. Bosse
Reviewed By: B. Green
Project No: 3526.05
Date: September 2021

Figure Narrative

This figure summarizes the locations of monitoring wells, multi-level monitoring systems, and surface water sampling points where depth to water is measured and water quality samples may be collected for field and analytical laboratory testing as part of routine and performance monitoring programs.

The locations of site features, including monitoring wells, seeps and springs, and culverts are based on field survey by Butler Land Surveying, LLC. of Little Meadows Pennsylvania in the period 2006 through 2012.

Refer to report text for further discussion.

Legend

- Parcel B Site Boundary
- Injection Borehole
- Observed Drainage Features (arrows indicate flow direction)
- Monitoring Well
- Multi-Level Monitoring Installation
- Surface Water Sampling Point
- Culvert

Feet
100 50 0 100 200

SANBORN HEAD

Last Edited By: hpothier

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Figure 2

Summary of Site Conditions

Remedy Optimization Report

IBM Gun Club - Former Burn Pit Area

Union, New York

Drawn By: H. LaPointe
Designed By: E. Bosse
Reviewed By: D. Shea
Project No: 3526.05
Date: September 2021

Figure Narrative

This figure shows the exploration locations and historical extent of primary and secondary source rock, as defined during the Remedial Investigation. It also categorizes monitoring locations frequently discussed in the report by location - Injection Displacement Zone, Downgradient On-Site, and Downgradient Off-Site. Primary and secondary source rock isopleths are inferred from rock core sampling completed in 2009-2012, before the remedy was implemented.

Refer to the report text and Appendix B for further information.

Legend

- Well Location
- Injection Displacement Zone
- Downgradient On-Site Wells
- Downgradient Off-Site Wells

30 15 0 30 60 Feet

SANBORN HEAD

Last Edited By: hlapointe

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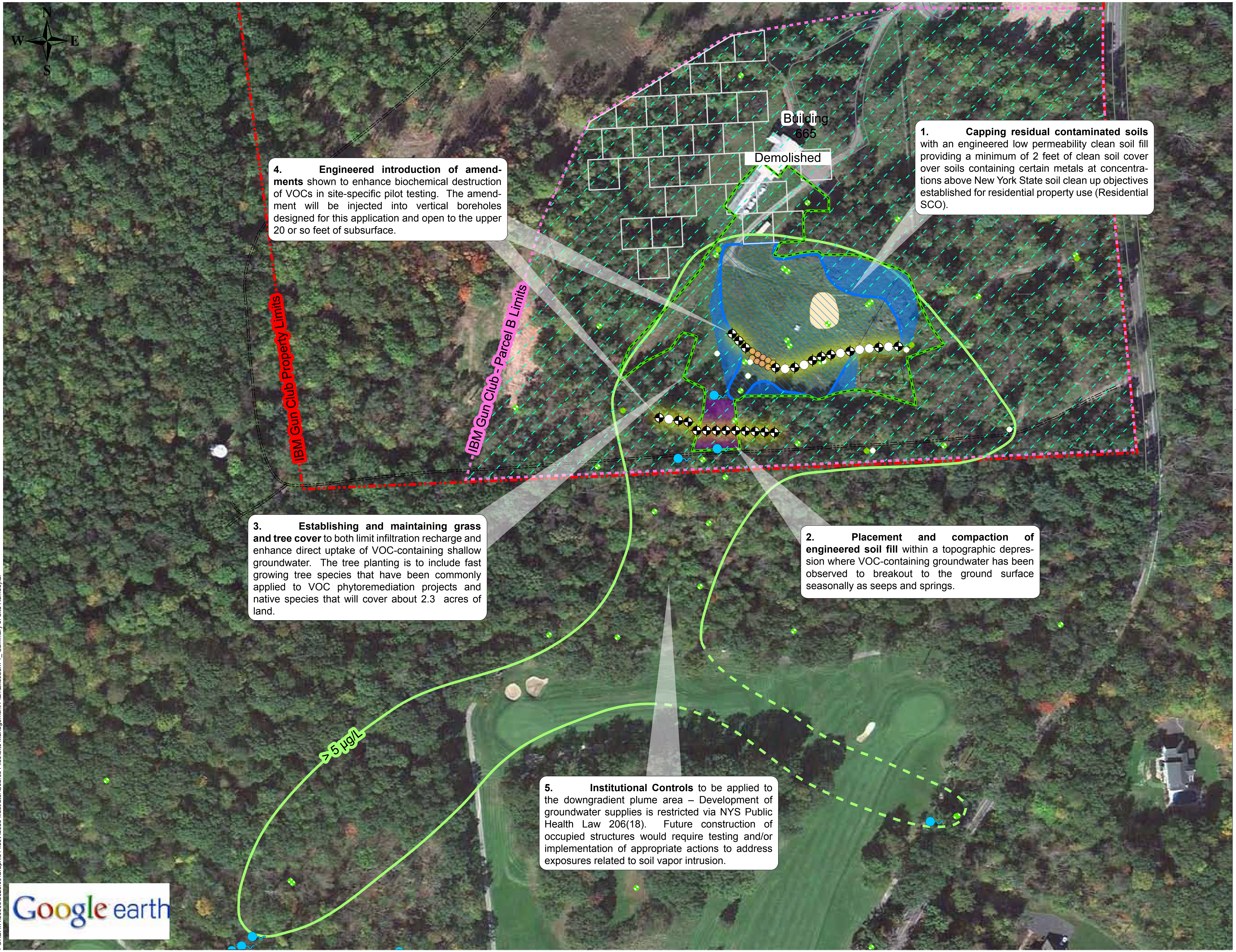

Figure 3

Summary of Site Remedy

Remedy Optimization Report

IBM Gun Club - Former Burn Pit Area

Union, New York

Drawn By: H. LaPointe
Designed By: E. Bosse
Reviewed By: B. Green
Project No: 3526.05
Date: September 2021

Figure Narrative

This figure is intended to summarize the environmental remediation of the IBM Former Burn Pit under the New York State Brownfield Cleanup Program. The remedy involves excavation and capping of surficial soils and enhancing in situ biochemical processes already active at the site and the planting and maintenance of trees to enhance uptake of VOC-containing groundwater.

Please refer to the Site Management Plan and report text for further discussion.

Legend

- Proposed Injection Boring Location
- Former Burn Pit Disposal Area
- Surveyed boundaries of Burn Pit Property (Parcel B). Entire parcel to be subject to deed restrictions associated with groundwater development/use, and construction of human occupied structures.
- Area of property to meet Track 2 residential SCOs
- Inferred limits of groundwater TCE concentrations exceeding 5 µg/L (pre-remedy)
- Limits of Tree Planting
- Track 4 Surficial Soil Remedy Area - 1.28 Acre area requiring two feet of Soil Fill Cap meeting soils standards for residential use (Residential Soil Cleanup Objectives or SCO). The area subject to the deed restriction is larger and more regular (see Record Drawings in the SMP)
- Approximate Limit of Soil Cap Extension - resulting from proposed final grading of imported soils.
- Approximate limit of additional fill required for filling topographic depression
- Surveyed limits of soil removal conducted under Interim Remedial Measure (IRM) in May 2012 to meet residential SCO

75 37.5 0 75 150 Feet

SANBORN HEAD

Last Edited By: swarner

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PORDATA\3000s\3025.00\Graphic Files\Adobe Illustrator\Source Files\Site Management Plan\ExecSum-1_ Summary of Site Remedy.ai

Figure 4

Distribution of TCE in Groundwater - October 2014 and June 2021

Remedy Optimization Report

IBM Gun Club - Former Burn Pit Area

Union, New York

Drawn By:	H. LaPointe
Designed By:	E. Bosse
Reviewed By:	B. Green
Project No:	3526.05
Date:	September 2021

Figure Narrative

This figure shows distribution of TCE in groundwater based on samples collected in October 2013 and June 2021.

Notes

1. Aerial Image Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

Legend

TCE Concentrations (μg/L)

- Not Detected
- ND - <10
- 10 - <100
- 100 - <1,000
- 1,000 - <10,000
- >10,000

62.5 31.25 0 62.5 125 Feet

SANBORN HEAD

Last Edited By: hlapointe

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Figure 5

Proposed Injection Borehole Location Plan

Remedy Optimization Report

IBM Gun Club - Former Burn Pit Area

Union, New York

Drawn By:	H. LaPointe
Designed By:	E. Bosse
Reviewed By:	D. Shea
Project No:	3526.05
Date:	September 2021

Figure Narrative

This figure depicts the proposed locations for two new rows of injection boreholes as part of the Site remedy optimization.

Primary and secondary source rock isopleths are inferred from rock core sampling completed in 2009-2012, before the remedy was implemented.

Legend

- Well Location
- Injection Boring Location
- Proposed Injection Boring Location

30 15 0 30 60 Feet

SANBORN HEAD

Last Edited By: hlapointe

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APPENDIX A

LIMITATIONS

APPENDIX A
LIMITATIONS

1. The conclusions and recommendations described in this report are based in part on the data obtained from a limited number of soil samples from widely spaced subsurface explorations. The nature and extent of variations between these explorations may not become evident until further investigation is initiated. If variations or other latent conditions then appear evident, it will be necessary to re-evaluate the recommendations of this report.

2. The generalized soil profile described in the text is intended to convey trends in subsurface conditions. The boundaries between strata are approximate and idealized and have been developed by interpretations of widely spaced explorations and samples; actual soil transitions are probably more gradual. For specific information, refer to the exploration logs.

3. Water level measurements have been made in the observation wells at times and under conditions stated within the text of the report and indicated on the exploration logs and in the report. Note that fluctuations in the level of the groundwater may occur due to variations in rainfall and other factors not evident at the time measurements were made.

4. Quantitative laboratory analyses were performed as part of the investigation as noted within the report. The analyses were performed for specific parameters that were selected during the course of this study. It must be noted that additional compounds not searched for during the current study may be present in soil and groundwater at the site. Sanborn Head has relied upon the data provided by the analytical laboratory, and has not conducted an independent evaluation of the reliability of these data. Moreover, it should be noted that variations in the types and concentrations of contaminants and variations in their distribution within the groundwater and soil may occur due to the passage of time, seasonal water table fluctuations, recharge events, and other factors.

5. The conclusions and recommendations contained in this report are based in part upon various types of chemical data. While Sanborn Head has reviewed that data and information as stated in this report, any of Sanborn Head's interpretations, conclusions, and recommendations that have relied on that information will be contingent on its validity. Should additional chemical data, historical information, or hydrogeologic information become available in the future, such information should be reviewed by Sanborn Head and the interpretations, conclusions and recommendations presented herein should be modified accordingly.

6. This report has been prepared for the exclusive use of International Business Machines (IBM) in accordance with generally accepted hydrogeologic practices. No other warranty, express or implied, is made.

7. The analyses and recommendations contained in this report are based on the data obtained from the referenced subsurface explorations. The explorations indicate subsurface conditions only at the specific locations and times, and only to the depths penetrated. They do not necessarily reflect strata variations that may exist between such locations. The validity of the recommendations is based in part on assumptions Sanborn Head has made about conditions at the site. Such assumptions may be confirmed only during remediation. If subsurface conditions different from those described become evident, the recommendations in this report must be re-evaluated.

8. In the event that any changes in the nature, design, or location of the facility or remedy are planned, the conclusions and recommendations contained in this report should not be considered valid unless the changes are reviewed, and conclusions of this report modified or verified in writing by Sanborn Head. Sanborn Head is not responsible for any claims, damages, or liability associated with interpretation of subsurface data or re-use of the subsurface data or engineering analyses without the express written authorization of Sanborn Head.

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APPENDIX B

BACKGROUND INFORMATION AND TIME SERIES PLOTS

TABLE OF CONTENTS

TABLES

FIGURES

ATTACHMENT

The Site remedy components include capping, phytoremediation, and enhanced biochemical degradation (EBD). The status and performance of each of the remedy components are discussed in the sections below.

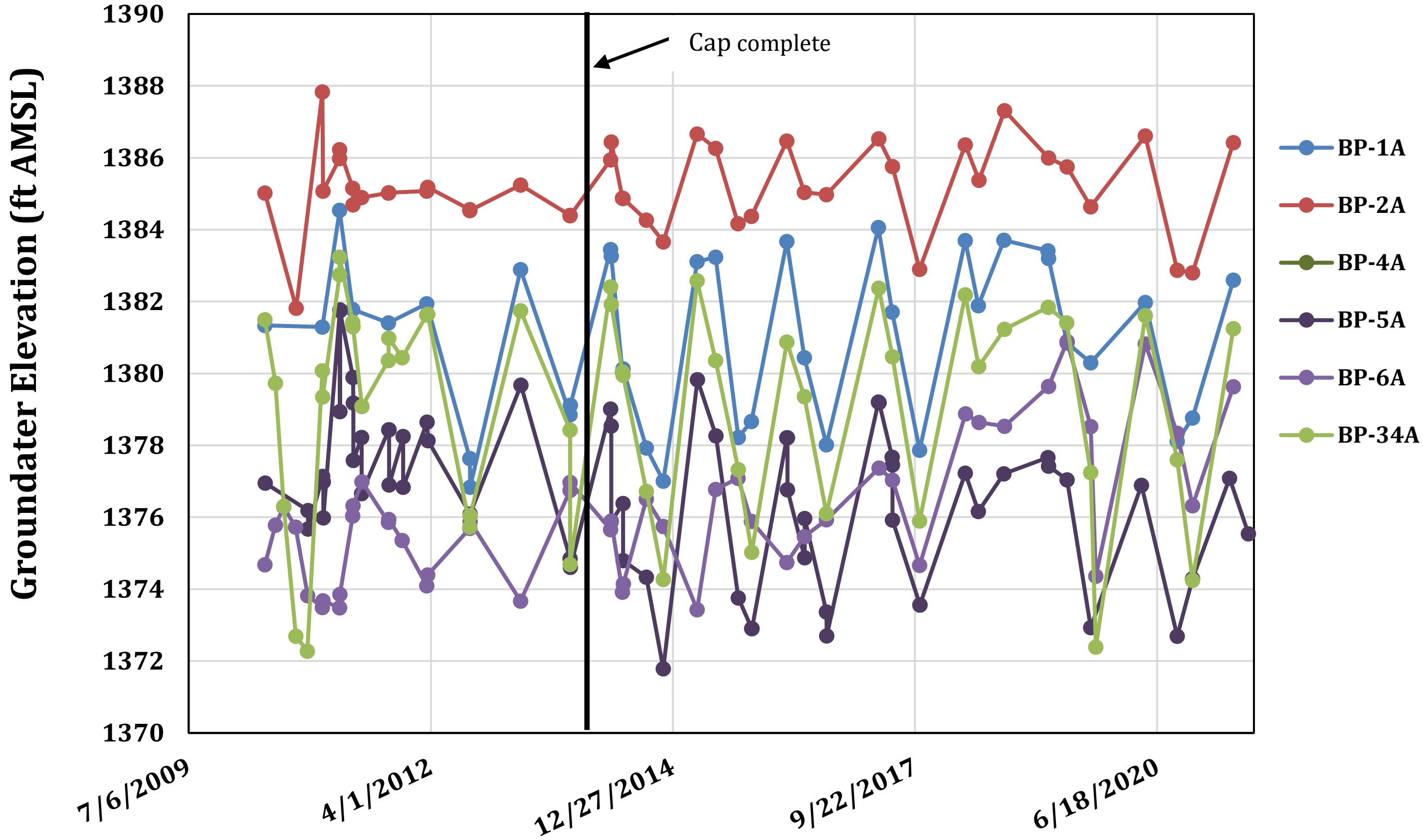
B.1 Low Permeability Cap & Phytoremediation

The combined goals of the low permeability capping and phytoremediation components of the remedy are to limit infiltration of precipitation through underlying volatile organic compound (VOC)-containing rock, eliminate downgradient seeps, improve redox conditions in groundwater, and provide supplemental uptake of groundwater and VOCs via phytoremediation. Metrics of success include reduction of VOC flux across the property boundary and the observation of the presence or absence of new or re-emerging seeps and springs along the hillslope and gravel access road north of the Country Club property boundary. An assessment of long-term trends in groundwater elevation and reduction-oxidation (redox) conditions pre- and post- capping and tree planting is presented in the sections below.

B.1.1 Water Levels and Redox Conditions

Construction of the low-permeability cap was substantially complete by October 2013 and tree planting was complete by June 2014. A January 1, 2014 cap completion date is used for the purpose of this discussion. Groundwater elevations are recorded regularly during routine performance monitoring, and the presence of new seeps and springs is assessed during monitoring events and the annual Site-wide inspection. A time series plot of water levels in select monitoring wells located within the area of the low permeability cap and tree planting is presented in Exhibit B.1 below.

Exhibit B.1: Groundwater elevation in monitoring wells within the capped area



As shown in the exhibit above, the completion of the cap does not appear to have had substantial effects on groundwater elevation in the long term. Water levels in monitoring wells continue to be driven by seasonal fluctuations, with the highest groundwater elevations observed in spring just after snow melt and lowest in early fall. Additionally, 2019 and 2020 were dryer than average years, which seems to have depressed water levels somewhat. Overall, groundwater elevations are similar before and after cap construction and tree planting and subsequent growth.

Seep activity is also tracked as another line of evidence of the effects of the cap and plantings. Before capping, groundwater broke out along the slope in the vicinity of the B-line injection wells at many locations. Since the cap installation in the seep area, one new seep has been observed at the base of the capped area along the southern access road (Seep #119). 119 is intermittently observed following wet weather. No additional seeps along the periphery of the capped area or breakouts within the capped area have been observed. In that regard, the capping of the slope has been successful in its goal of preventing additional seeps and potential for human exposure to VOC-containing groundwater.

As a generality, under higher water level conditions, a shift to more oxidizing geochemistry is expected due to infiltration of oxygen containing water, while more reducing geochemistry is expected under lower water conditions. With water levels essentially remaining the same since the completion of the cap and continued growth of trees, it would be expected that redox conditions may also be unchanged. To assess the effects of the cap on redox conditions, geochemical parameters were compared at select monitoring wells within the capped area. To differentiate from the redox effects of amendment injection and enhanced biodegradation, monitoring wells side gradient to the line of injection boreholes, or further away with no apparent injection influence, were selected. Time series plots of dissolved oxygen (DO) and oxidation-reduction potential (ORP) for BP-1A, BP-5A, and BP-37A are shown in Exhibits B.2 and B.3 below.

Exhibit B.2: Dissolved Oxygen in monitoring wells within the capped area

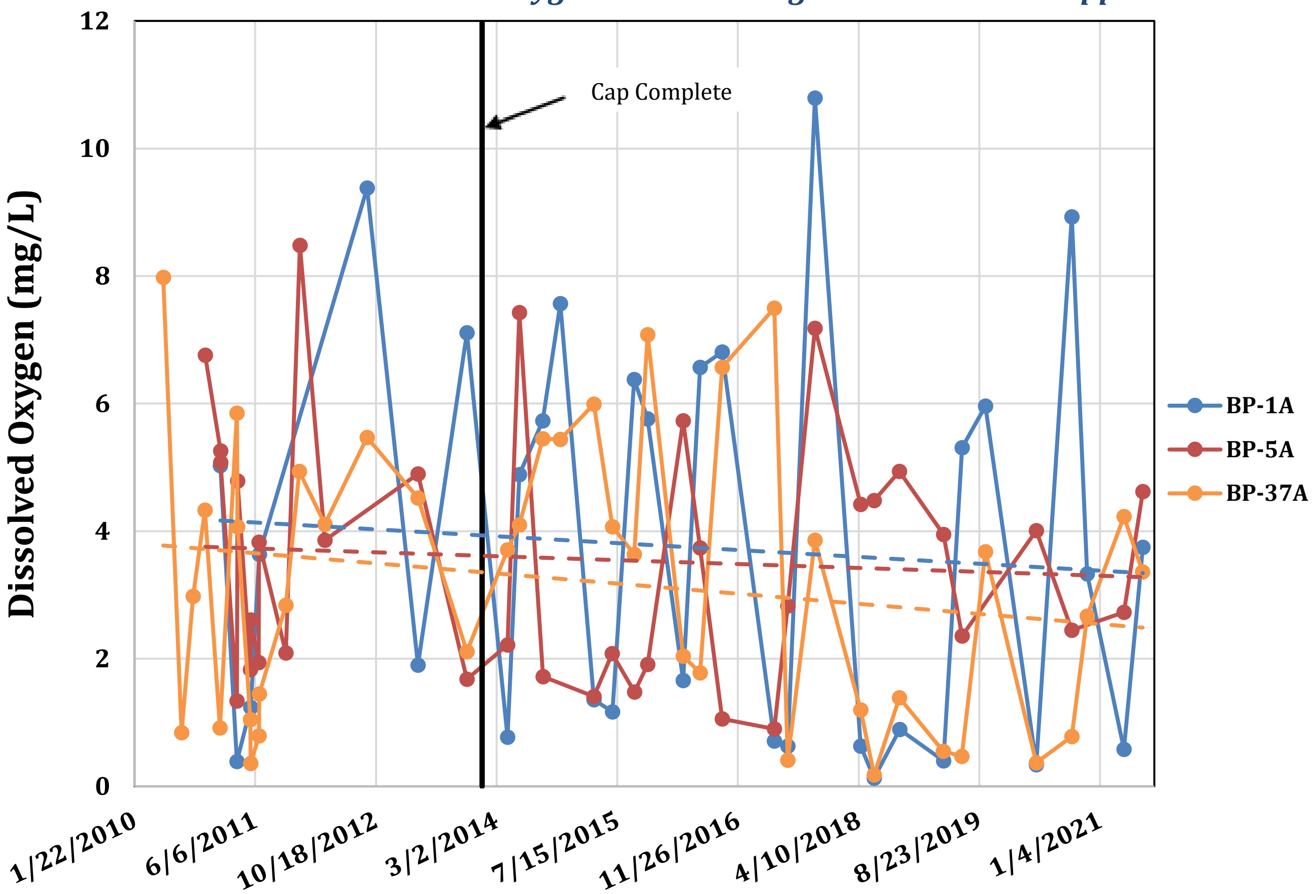
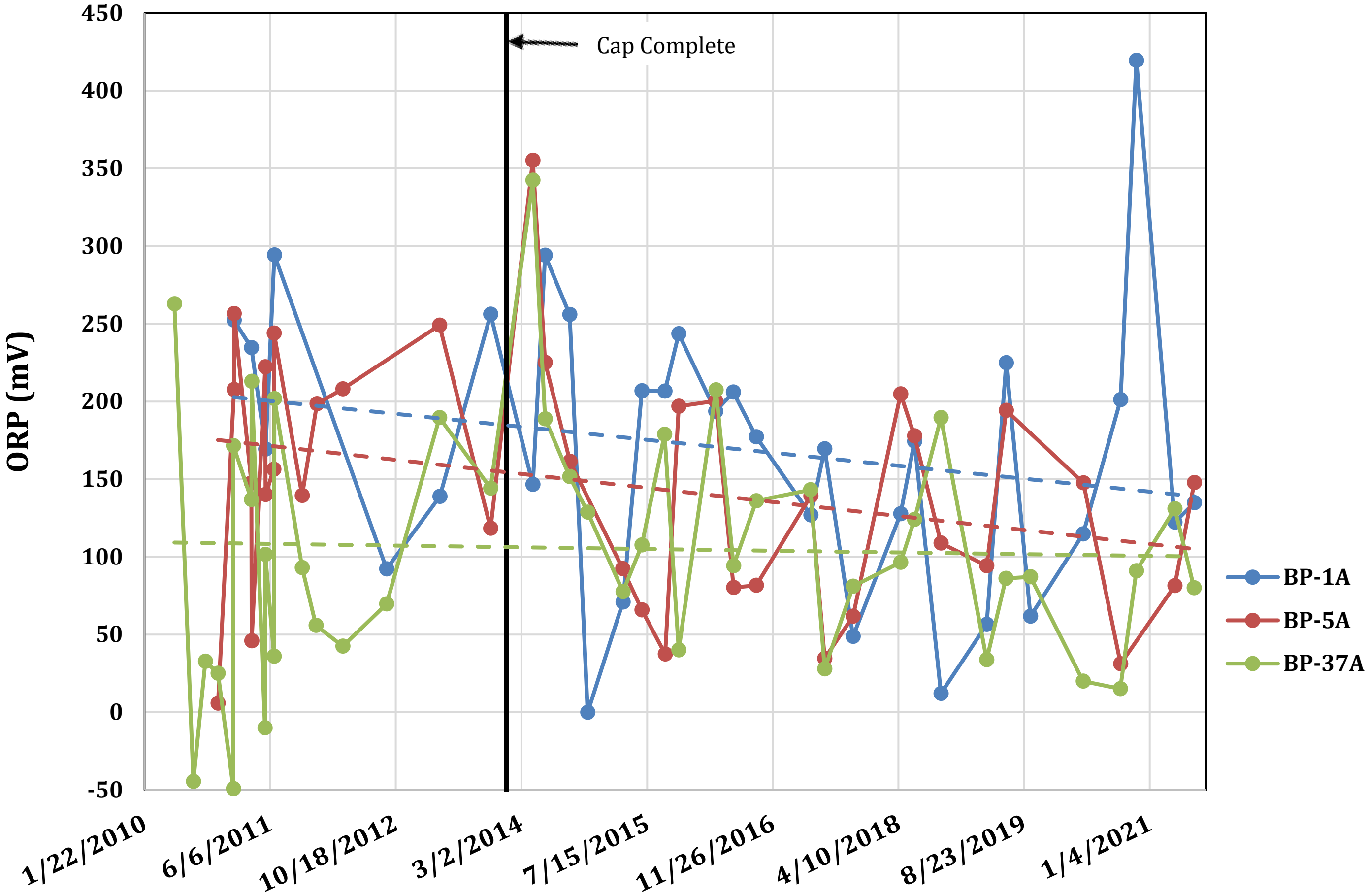


Exhibit B.3: Oxidation-Reduction Potential (ORP) in monitoring wells within the capped area



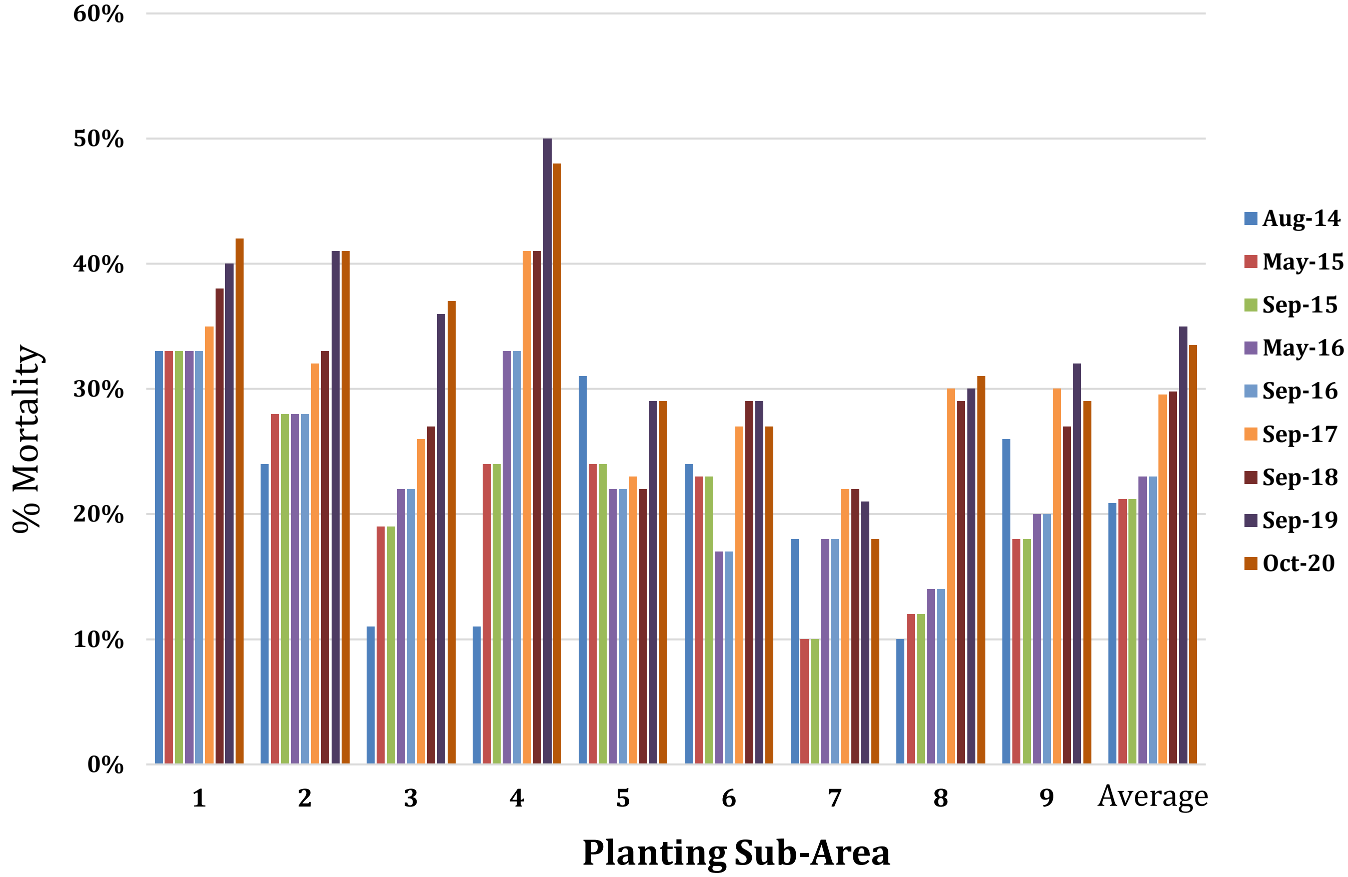
While major changes were not observed just after completion of the cap, DO and ORP levels have gradually improved (relatively lower values that are more conducive to EBD) since 2014. Taking into consideration seasonal fluctuations, DO has decreased on average for BP-1A, BP-5A, and BP-37A. ORP has become more negative in BP-1A and BP-5A but is generally unchanged for BP-37A. Overall, redox conditions are improved in monitoring wells in the capped area, but outside the area of influence of the injection boreholes, indicating the combined action of the low permeability cap and trees is reducing infiltration and reducing redox conditions as designed.

B.1.2 Phytoremediation

Planting of trees was a component of the capping portion of the remedy. A location plan showing the planting sub-area grid is included as Figure B.1. As described above, the combined effect of the capping and trees is to reduce infiltration of oxygen-rich rainwater and ultimately contribute to the reduction of mass flux across the property boundary. As outlined in the SMP, routine maintenance of the trees currently includes an assessment of tree mortality and re-planting if the tree mortality reaches 25% in any of the Remediation Areas, compared to initial conditions.

Tree mortality has been tracked at least annually since the fall of 2014 and reported regularly in annual Site-Wide Inspection reports. An average tree mortality across all the planting sub-areas is shown in the exhibit below.

Exhibit B.4: Summary of Tree Mortality



On average, tree mortality has stabilized around 30 to 35% compared to initial planting over the last several years. Individual sub-area mortality ranged from 18 to 48% in the October 2020 annual inspection, with Area 4 exhibiting the highest mortality and Area 7 the lowest. Hybrid poplars have also been observed to be spreading, with saplings emerging up to 10 feet from established trees.

Additionally, surviving poplars that were originally planted as poles outside the footprint of the low-permeability cap, and those planted as cuttings within the cap footprint, have grown to an average approximate height of 30 and 20 feet, respectively. Average circumference is 1.2 feet for poles and 0.75 feet for cuttings. Taking into consideration an average mortality of 35% and current tree size, the volume of trees available for transpiration and water uptake has increased by over four orders of magnitude.

Besides mortality, other measures of success that have been realized include: 1) the continuing growth progress of live trees; 2) the apparent stabilization of overall average mortality around or below 30% in Areas 5, 6, 7, and 8, as shown in the above histogram, with some improvements in recent years; and 3) a good portion of the mortality is in areas outside of the primary and secondary source rock (Areas 1 and 4). We note also that the goal of less than 25% mortality may not be achievable in areas that exhibit conditions that are not conducive to tree growth (e.g., shallow bedrock, encroachment of woody brush, poor infiltration in the capped area), and re-planting may lead to the same result. For example, the highest tree mortality is observed in Area 4, which has the highest proportion of other native woody bushes and trees and is often shaded. Tree mortality was a useful metric at the beginning of the remedy at a time when it was important to understand the success of the tree planning work. However, it is no longer useful for monitoring performance of the remedy. Rather, the most important metrics for demonstrating the effectiveness of the phytoremediation remedy is continued reducing conditions in the aquifer, and the absence of seeps in downgradient areas. Taken together, these metrics provide an assessment tool that demonstrate the combined effectiveness of the phytoremediation and cap.

B.2 Enhanced Biodegradation Assessment

Major aspects of the EBD portion of the remedy, including the injection design, dosing, and frequency are discussed in the section below. In addition to the design of the injections, an assessment of the Site geochemistry is also reviewed.

B.2.1 Injection Design

The design of the EBD remedy for the Site includes introduction of an edible soybean oil amendment to enhance biochemical destruction of VOCs via injections using two rows of vertical boreholes open to the upper 20 or so feet of subsurface. Design components include choice of the amendment, dosing parameters, timing, and the delivery process.

The amendment chosen for the EBD design was the edible soybean oil amendment EOSPro®, produced by EOS Remediation, LLC (EOSPro®) as the carbon source for biological degradation. EOSPro ® was chosen because it is longer lasting than other typical carbon sources such as lactate or acetate that are more mobile. Preparation of the amendment includes mixing/diluting with treated groundwater/Site water that is stripped of oxygen by sparging with nitrogen gas. The sparging of nitrogen gas is important for maintaining low dissolved oxygen concentrations in the groundwater for reductive dechlorination and anaerobic degradation to proceed.

The EBD dosing was designed for an approximate 30-year design loading, which is the equivalent of 6,000 gallons of undiluted edible oil substrate (EOSPro®) for the 1.6-acre primary sourcing area, with the understanding that the actual demand will be greater or less in site scale application. To date, approximately 490 gallons of undiluted amendment has been injected. During the initial injections into the A-line (December 2013) and B-line (June 2014) the dose was 200 gallons of amendment, which was diluted 10 times, resulting in 2,000 gallons of diluted amendment, which was roughly equivalent to about 25% of the fracture pore volume in the primary source rock. With 2,000 gallons of diluted EOS in total, 1,300 gallons were injected into the A-line and 700 gallons were injected in the B-line. These volumes amount to approximately 50 gallons per borehole (twice the borehole volume, assuming 15 ft per borehole).

After the first injection into each borehole of each line in 2013-2014, a selection of the more transmissive locations was chosen for ongoing Site-scale injections, which were then completed in August 2015, August 2017, and September 2020. The scope of injection has been the same since 2015, with approximately 1,800 gallons of diluted amendment injected into the system, with approximately 1,100 gallons via the A-line injection boreholes and 730 gallons via the B-line injection boreholes. The amendment substrate is mixed with 19:1 water. The water was obtained from the Garfield Avenue treatment facility in Endicott, New York, which is used for its oxygen deficiency and lack of chlorine (as found in potable municipal water). Nitrogen gas was bubbled through the water to maintain a low oxygen headspace. In addition, 115 milliliters (ml) of a vitamin B supplement are added per 14 gallons of substrate mix to enhance biological activity. While the total design does of the injection has been realized in the 3 Site-wide injections, performance of individual injection boreholes has varied.

In 2019, injection boreholes were mechanically re-developed to increase the likelihood that amendment could be accepted. Visual observations suggested that non-mobile, viscous, and solidified standing amendment was removed from the boreholes. Hydraulic observations suggested the flow into the boreholes was less than that observed in 2013 before any amendment was introduced. Some boreholes (e.g., B-10, A-9) were noted to have accepted more amendment in 2020 than in 2017, which may be attributed to the mechanical re-development, but overall transmissivity of the injection boreholes is less than that observed in 2013.

Figure B.2 compares the difference in gallons of amendment introduced during the injection in 2015 versus 2020. While the same overall dose to the subsurface was achieved, several locations did not accept as much amendment, most notably B-9 in the center of the B-line, a cluster (IB-6, A-4, A-5) in the center of the A-line, and several on the eastern edge of the A-line (A-12, A-13, A-15). Additionally, the current target dose of diluted amendment for each injection borehole is indicated on Figure B.2, which shows the spatial variability in injection dose.

B.2.2 Biogeochemistry

Enhanced biochemical degradation of VOCs in groundwater is being monitored by: 1) tracking changes in concentration of the parent contaminant compound, trichloroethene (TCE), 2) tracking the presence of breakdown products of TCE, including the terminal breakdown products ethene and ethane, 3) tracking the presence of geochemical conditions favorable to biochemical conditions by reductive dehalogenation, and 4) supplemental analysis (compound specific isotope analysis [CSIA]/quantitative polymerase chain reaction [qPCR]) to inform the mechanisms and rates for contaminant degradation.

To aid in discussion, regularly sampled monitoring wells are grouped according to location, as summarized in the exhibit below and shown on Figure 2 in the main body of the report. Wells in the injection displacement zone (IDZ) are within the area of influence of injection boreholes.

Exhibit B.5: Summary of Monitoring Well Location

Location	Monitoring Well Location
BP-2A BP-4A BP-13A BP-36A	Injection Displacement Zone
BP-1A BP-5A BP-6A BP-9A BP-34A BP-35A BP-37A	Downgradient – On-Site
BP-31A BP-38A BP-39A	Downgradient – Off-Site

VOCs in Groundwater

Time series plots of VOC data for the wells in the table above are included in Appendix B.2. VOC data is presented on a standard concentration basis, molar concentration, and as a molar percentage. Groundwater conditions in June 2021 are shown on Figure B.3, which depicts groundwater monitoring results on a molar percentage basis. TCE is no longer the most prevalent chlorinated ethene found in groundwater locations within the primary source rock, with TCE molar fractions generally less than 50%, and the remaining mass consisting of cis-1,2-dichloroethene (cDCE) and terminal breakdown products (vinyl chloride [VC], ethene, and ethane). As previously reported, prior to the initiation of the remedy, TCE made up most of the chlorinated ethene mass, representing 85% to over 90% of the mass within the plume, with small amounts of cDCE and only traces of the terminal breakdown products.

As reflected in selected time-series line plots, concentrations of the principal parent compound, TCE, continue to decline consistent with the objectives of the long-term remedy. Data summaries for a selection of monitoring wells of interest are as follows:

- BP-2A is a location in the IDZ immediately adjacent to the A-line injection wells. The most recent data for BP-2A indicate that TCE concentrations represent less than 1% of the VOC mass at this location. The non-toxic terminal breakdown products ethene and ethane represented about 25% of the molar mass at the highest but has declined to 10% or less since April 2020 monitoring, which was before the most recent injection event in September 2020. The overall VOC concentration has decreased from an historical high in June 2018, which was primarily driven by an increased prevalence of breakdown products, not TCE. Biodegradation appears to be progressing through completion, with about even proportions of both vinyl chloride and the terminal breakdown products.

- BP-9A is located about 60 feet downgradient of the B-line injection boreholes near the property boundary. Recent TCE concentrations are 1 to 1.5 orders of magnitude below the historical high. Following the first B-line injection, cDCE has been the most prevalent breakdown product until April 2021 monitoring, when terminal breakdown products ethene and ethane became most predominant, which occurred approximately 7 months following the most recent injection event in September 2020. Terminal breakdown products comprised approximately 78% and 58% of the molar mass in April and June 2021 monitoring, respectively. Concentrations of VC have been progressively increasing since the first Site-wide injection but are generally at levels similar to or below terminal breakdown products.

- BP-39A is located about 80 feet south of the property boundary, or 150 feet downgradient of the B-series injection boreholes. cDCE became more prevalent than TCE on a molar basis in June 2016, for the first time since Site-wide injections began. The recent increase in total VOC concentrations is driven by increasing breakdown products, including terminal breakdown products. Sulfate-reducing conditions conducive to biodegradation are intermittently observed in the vicinity of BP-39A. BP-39A is on the periphery of the primary source rock defined during the RI and increasing concentrations may reflect increased back diffusion and enhanced dissolution of the VOC mass due to the enhanced biochemical activity and/or downgradient transport of VOCs.

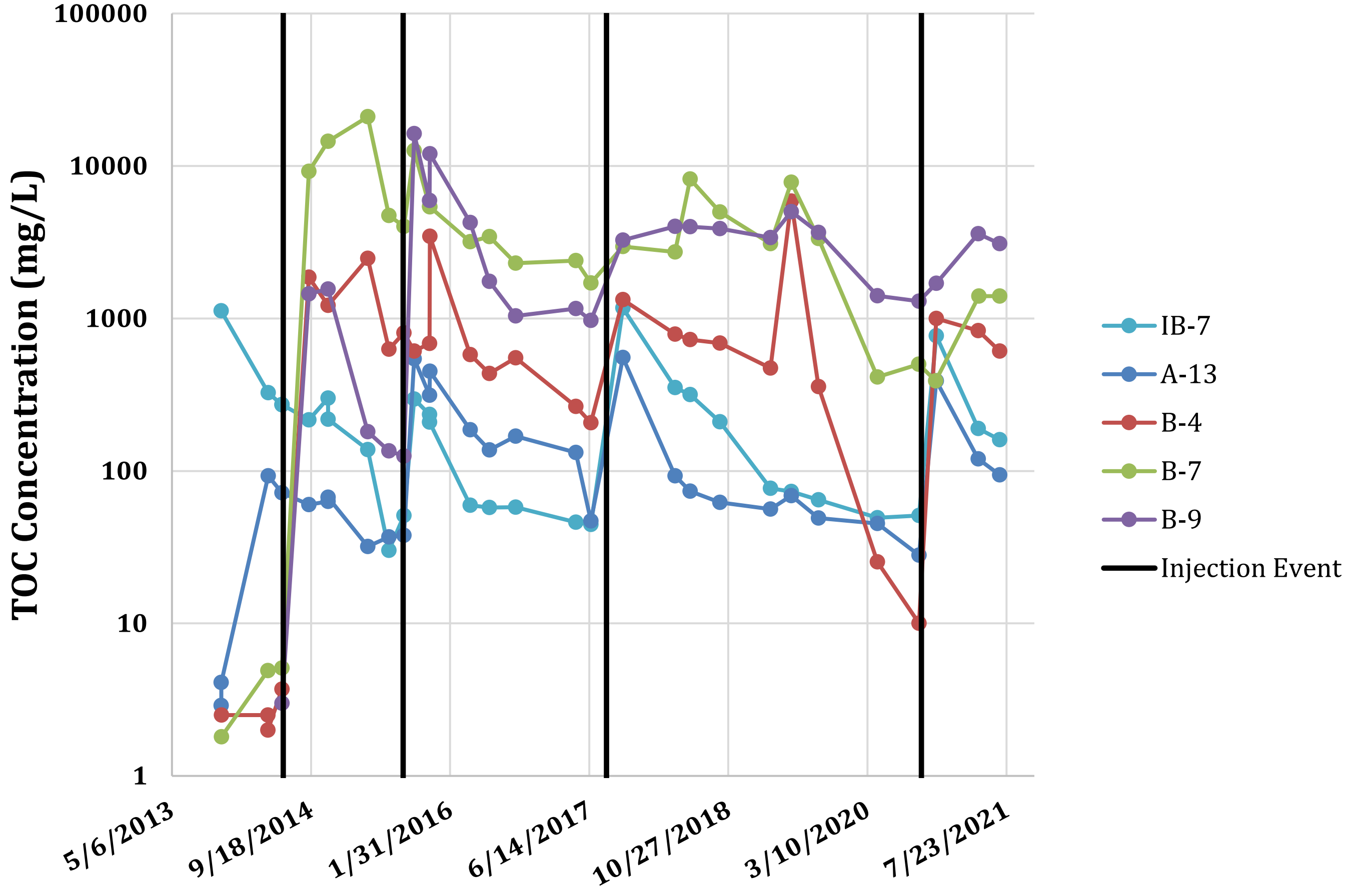
It has been noted in past sampling reports that there is indication of an increasing trend of VC at BP-39A. VC was infrequently detected at low levels through April 2018. It was detected at 7.2 μg/L in the June 2018 sample, which exceeds the New York State Department of Environmental Conservation Class GA Groundwater quality standard of 2 μg/L. Since June 2018, VC has been detected in samples collected from BP-39A from each sampling round, at concentrations ranging from 0.2 to 20 μg/L. However, during this time, terminal breakdown products ethene and ethane, which had not typically been detected above the reporting limit at this well, have been detected consistently, suggesting biodegradation has not stalled at vinyl chloride, but that vinyl chloride may be travelling farther downgradient than previously, before being degraded. Wells further downgradient on the golf course have not exhibited this trend suggesting downgradient transport of VC is not occurring, which is likely because VC is being degraded to its terminal breakdown products (ethene and ethane).

In aggregate, the VOC data suggest remediation progress is being made across the primary source rock at differing rates. Differences in transmissivity, groundwater flow conditions, and geochemical conditions likely account for the variability, but the net effect is that the proportion of TCE has decreased from 80-90% down to 50% -1% of molar mass in groundwater samples collected across the Site. This reduction in TCE molar mass concentrations along with long-term sustained improvement of overall geochemical conditions verifies the on-going effectiveness of this remedial approach. As with any in-situ remedial project, there are areas where optimization may be helpful to further improve geochemical conditions, as further discussed in Section 3 of the main report.

Total Organic Carbon

Concentrations of total organic carbon (TOC) greater than 100 milligrams per liter (mg/L) are thought to be sufficient to sustain biochemical degradation. TOC presence in monitoring wells within the displacement zone and further downgradient is an indicator of the effects of amendment (a carbon source) travel distance and delivery. TOC time series for sampled injection boreholes are shown in Exhibit B.6 below.

Exhibit B.6: Time Series of TOC in Injection Boreholes



TOC response to injection events in injection boreholes are apparent during the sampling event immediately following, and then decrease consistent with consumption of carbon and dissipation of amendment downgradient. Falling below the threshold of 100 mg/l is one indication that it is time to inject again. A-13 and IB-7 exhibit the steepest TOC decline and are approaching 100 mg/l.

TOC concentrations in wells within the injection displacement zone and further downgradient are shown in the time series in Exhibits B.7 and B.8 below.

Exhibit B.7: Time Series of TOC in Injection Displacement Zone Wells

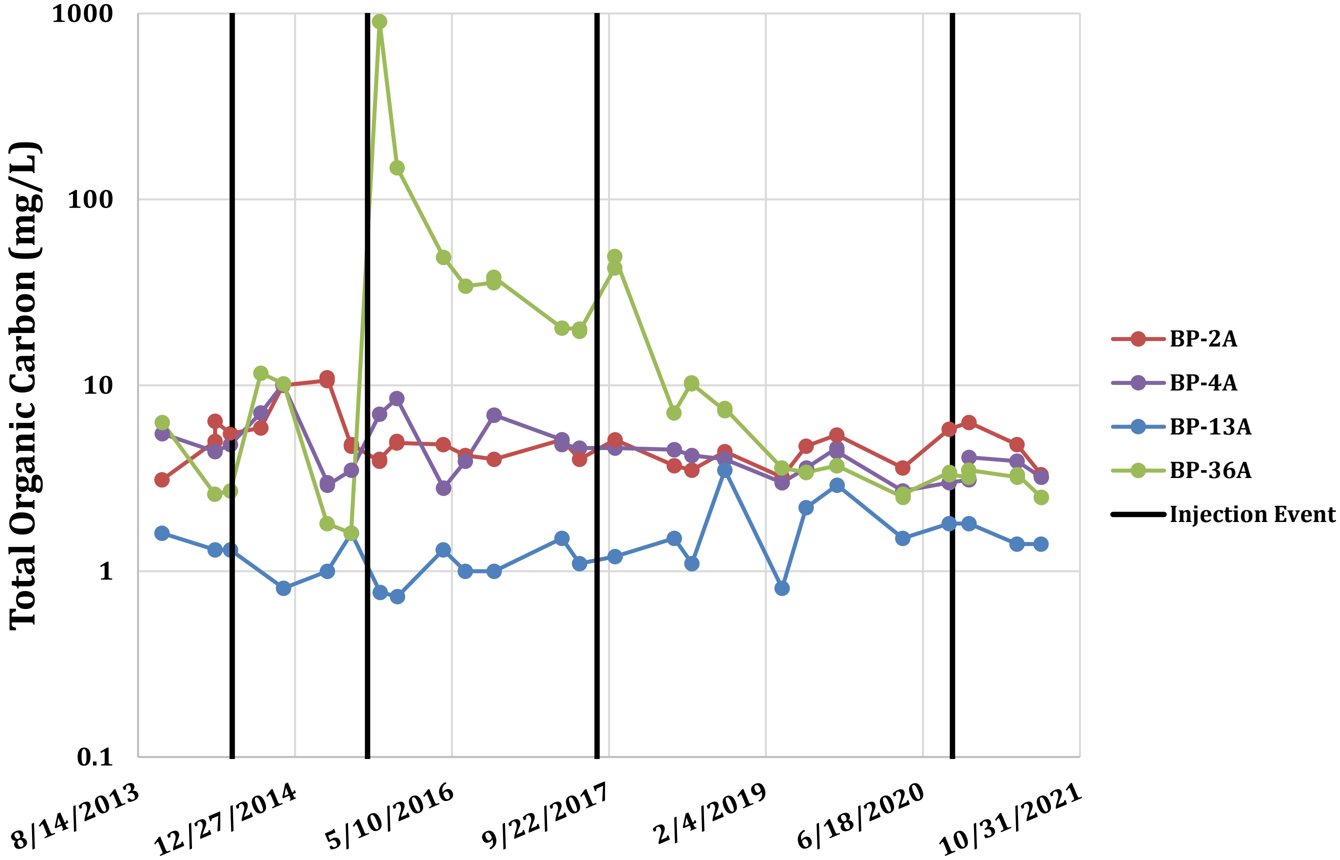
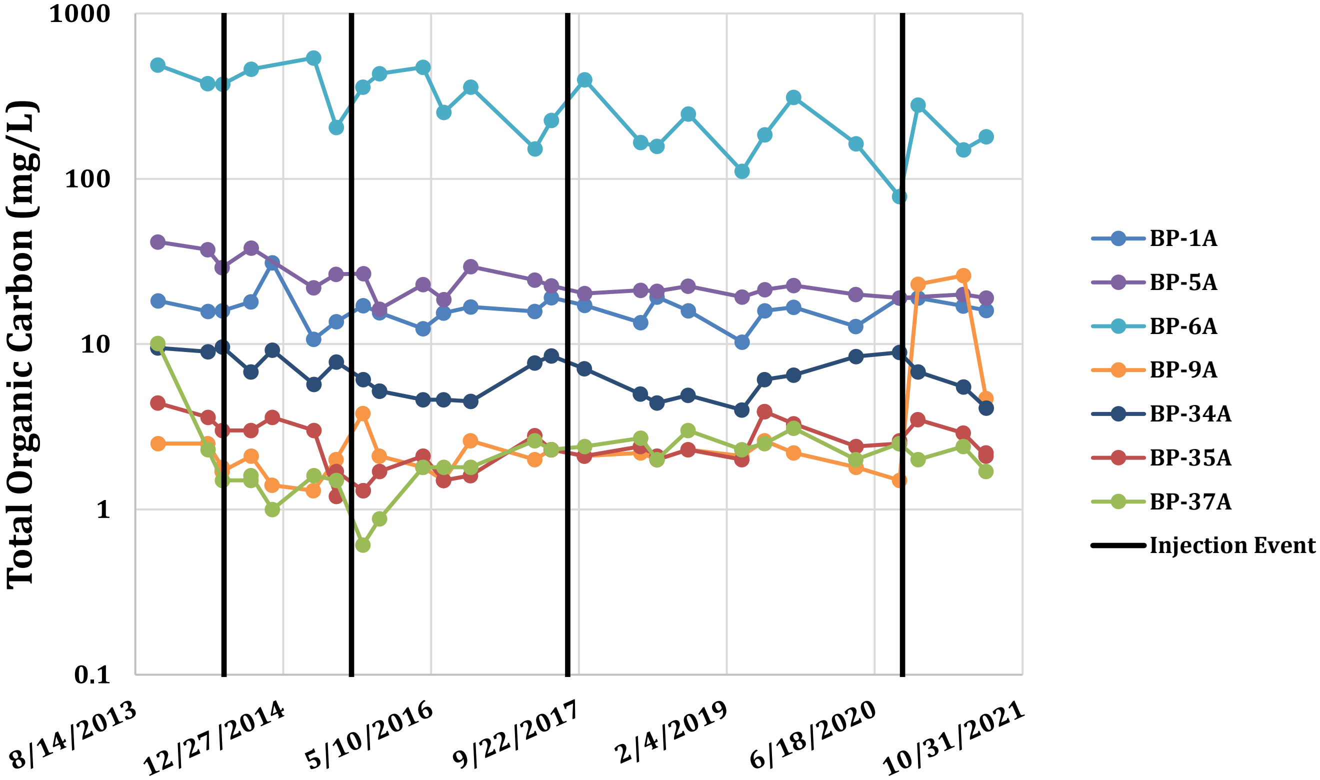


Exhibit B.8: Time Series of TOC in Downgradient Wells



Some wells, namely BP-4A and BP-36A, exhibited TOC increases in response to earlier injections, but not for the most recent September 2020 injection, suggesting a changed condition for amendment delivery to the IDZ. Further downgradient, TOC concentrations do not exhibit a direct response to injection, apart from BP-9A, where TOC was observed to increase by 1 Oom for the first time following the 2020 injection. The elevated TOC in BP-9A lasted approximately 7 months after the injection and has decreased in the most recent sampling of June 2021. Off-Site, no immediate effects of injections are observed, and long-term TOC trends are neutral, suggesting that carbon delivery may not be reaching off-Site areas.

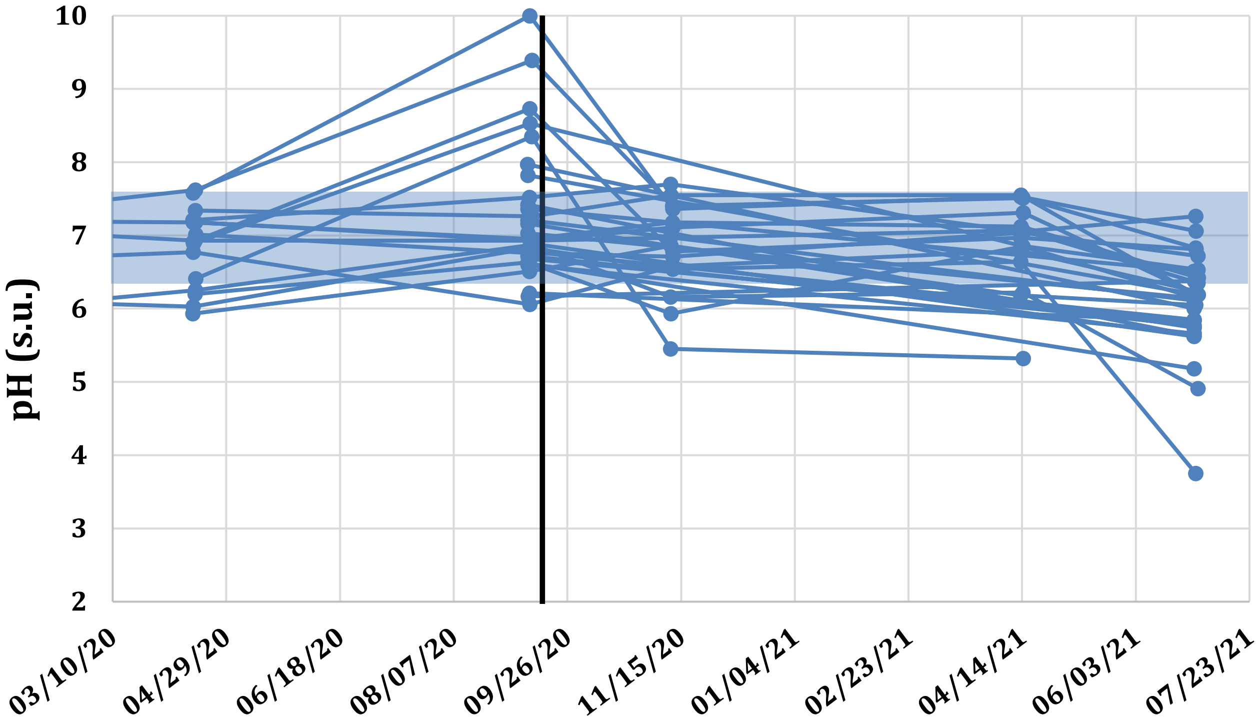
pH

Subsurface pH conditions influence the microbial cultures responsible for PCE and TCE dechlorination at circumneutral pH (6.3 to 7.5 standard units [s.u.]).[1] However, under acidic conditions, dechlorination rates can decline substantially or cease all together. Inside the bioremediation zone, the dechlorination rate of TCE depends on the availability of hydrogen (H_2), which is used as the electron donor for dechlorinating bacteria. However, in different oxidation-reduction processes, the H_2 in anaerobic systems could be also competitively consumed by different microbial species, and this would result in decreased TCE

[1]Borden, Robert C., Stephen D. Richardson, and Adria A. Bodour. "Enhanced reductive dechlorination of trichloroethene in an acidic DNAPL impacted aquifer." Journal of environmental management 237 (2019): 617-628.

dechlorination rate due to the lack of availability of H_2 to dechlorinating bacteria.[2] As stated above, pH in the range of 6.3 to 7.5 s.u. is most conducive to degradation, with pH levels below the range particularly detrimental to dechlorination rates. Time series of pH as an aggregate for all sampled wells before and after the most recent injection in September 2021 is shown in Exhibit B.9 below. The blue shaded area represents the ideal pH range of 6.3 to 7.5 s.u.

Exhibit B.9: Time Series of pH in Monitoring Wells before and after the September 2020 Injection



pH values, along with other geochemical parameters, before and after the September 2020 injection, are shown spatially on interactive figures included in Appendix C. Prior to the most recent injection, regularly monitored wells were generally within the circumneutral range, with some monitoring locations intermittently exceeding the most conducive range. In September 2020, before the injection, the pH for the bulk of the wells was within or above the pH range that is ideal for dechlorination. In aggregate, results from sampling rounds conducted after the injection have exhibited progressively lower pH values. For the most recent sampling in June 2021, wells BP-13A, BP-2A, BP-30A, BP-35A, BP-38A, BP-39A were below the circumneutral range. Overall, the pH values from June 2021 monitoring were historically low and are at levels that are detrimental to dechlorinating microorganisms.

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[2] Paul, Laiby, et al. "Reductive dechlorination of trichloroethylene (TCE) in competition with Fe and Mn oxides—observed dynamics in H2-dependent terminal electron accepting processes." Geomicrobiology Journal 33.5 (2016): 357-366.

Reducing-Oxidizing Conditions

The oxidation-reduction potential (ORP) time series are presented in the Exhibits below. The blue shaded area represents ORP values less than 0 millivolts, which is considered the most conducive to reductive dechlorination.

Exhibit B.10: Time Series of ORP in Injection Displacement Zone Wells

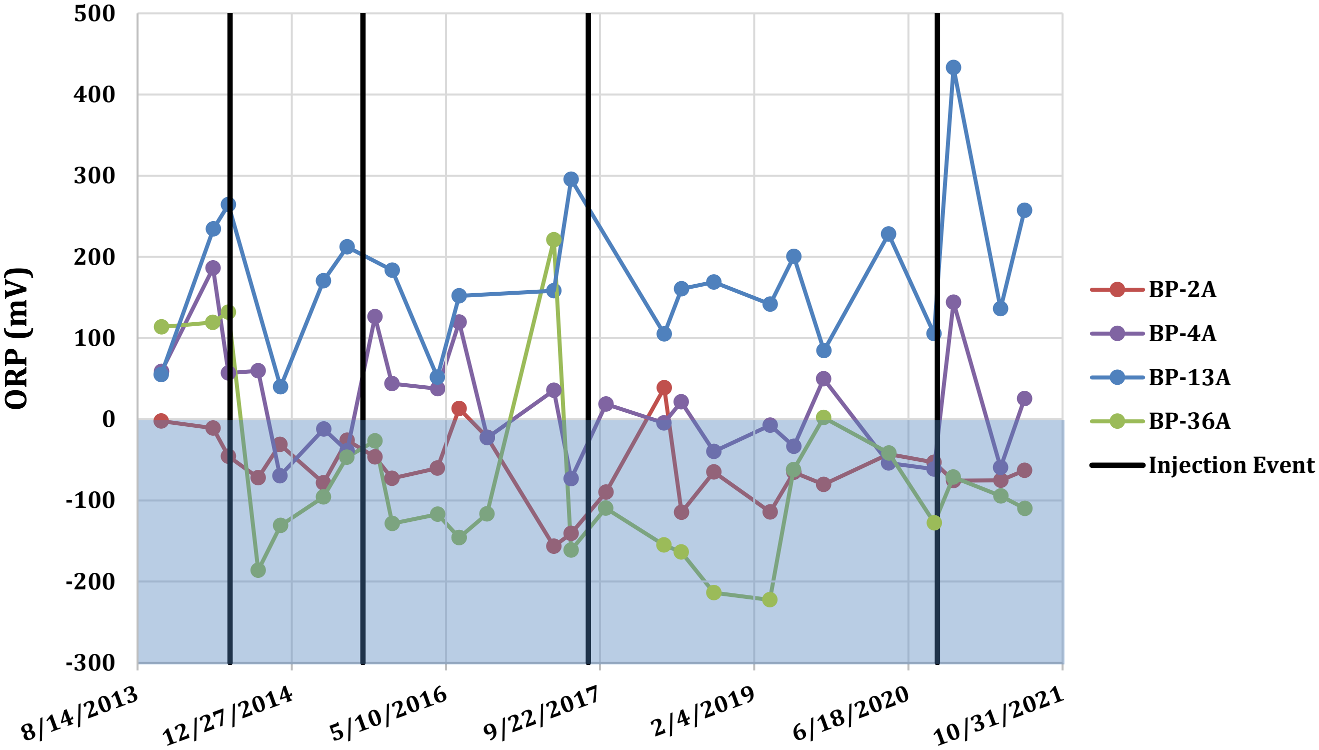


Exhibit B.11: Time Series of ORP in Downgradient Wells

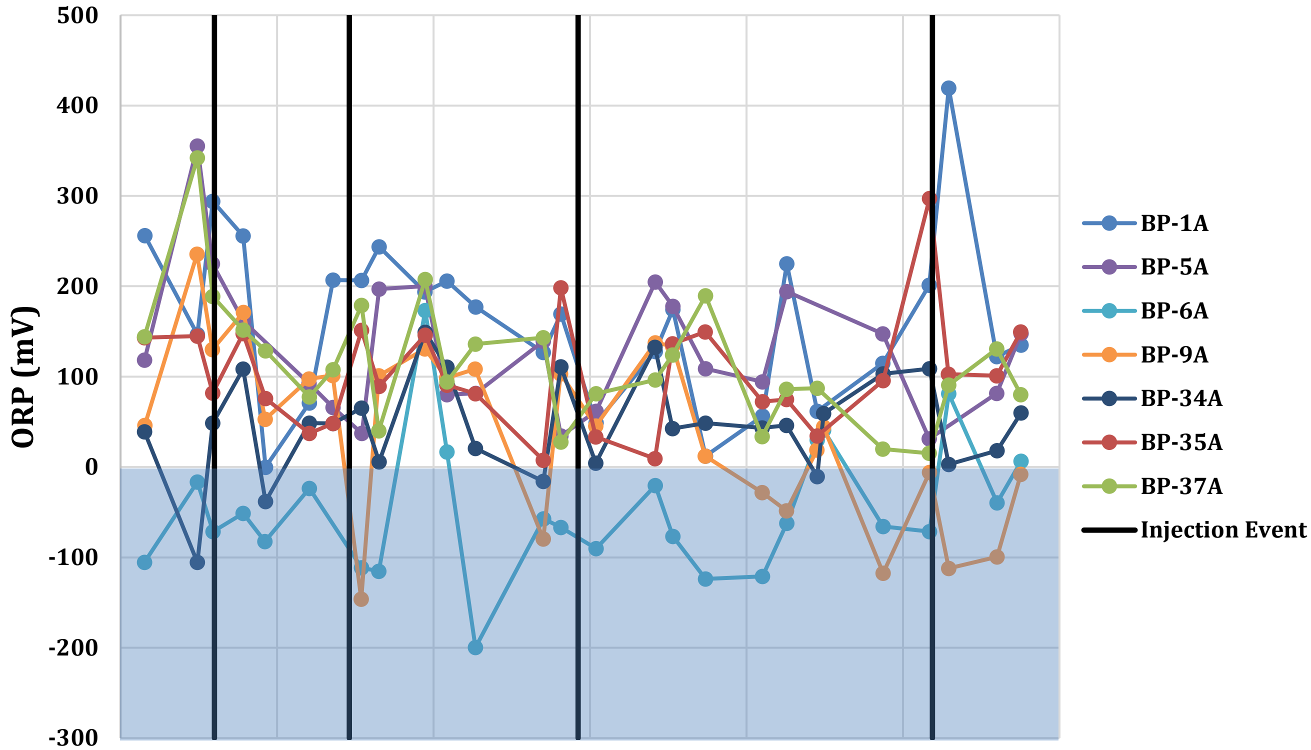
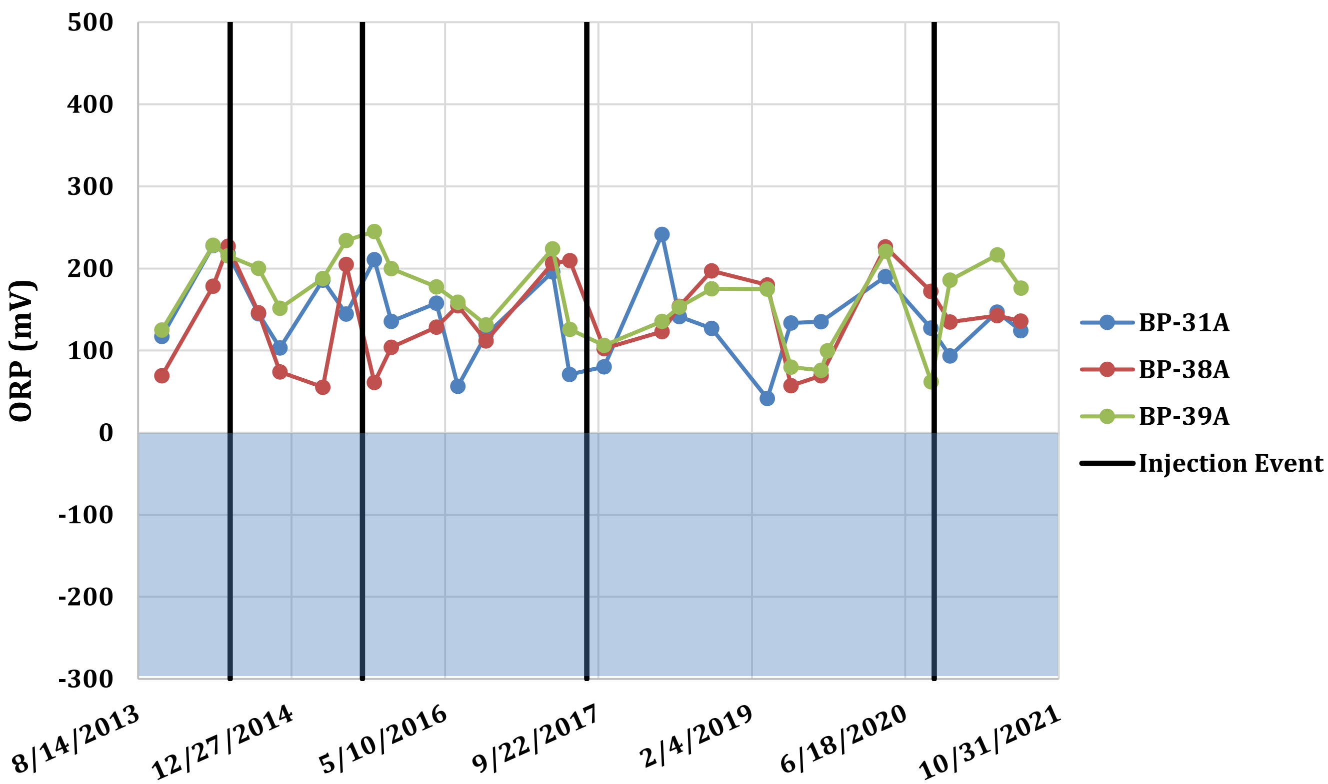


Exhibit B.12: Time Series of ORP in Off-Site Wells



For wells within the IDZ, ORP is variable, but trending down (more favorable) and generally below zero for BP-2A, BP-4A, and BP-36A. The trend for BP-13A is slightly increasing and levels are generally above 100 millivolts (mV). For locations immediately downgradient there is some evidence of influence from injection of ORP levels in BP-6A and BP-9A, which are both trending slightly downward since injections began. For wells further downgradient, both on and off-Site, no apparent trend or acute reaction to injections are observed. This is particularly true for locations BP-34A and BP-35A in between the two rows of injection boreholes and for BP-31A, BP-38A, and BP-39A located south of the property boundary, where ORP values are typically above 100 mV. The data from these wells suggest that the geochemical benefits of amendment injection are not being fully realized in these areas.

Geochemical conditions including ORP and dissolved oxygen are used to infer sulfate-reducing areas, which are somewhat conducive to reductive dechlorination, and methanogenic conditions which are most conducive. Inferred extent of sulfate reducing and methanogenic conditions from September 2020, before the most recent injection compared to June 2021, approximately 9 months after the injection, are shown on Figure B.4.

Sulfate reducing and methanogenic conditions are inferred to be somewhat variable both to the north, with the sulfate-reducing area seasonally encompassing as far north as BP-5A, and as far downgradient to the south as BP-39A. Except for intermittent variations at the boundaries, the overall extent of methanogenic conditions has generally remained unchanged since it was inferred to dissipate in between the A- and B-lines of injection boreholes first observed in April 2017 monitoring. The August 2017 and September 2020 injections did not appear to re-establish methanogenic conditions between the two lines of injection boreholes.

November 2014 redox condition boundaries collected several months after the first injection are also shown on Figure B.4. Compared to 2014 monitoring, methanogenic conditions are consistently observed at downgradient location BP-9A, and both methanogenic and sulfate-reducing conditions have expanded to the north. Overall redox conditions continue to support the maintenance of both sulfate-reducing and methanogenic areas over much of the primary source rock and proximal to the injection borehole lines, respectively. `

qPCR Results

qPCR analysis was conducted during 4 rounds of sampling from April 2020 to April 2021 to supplement typical VOC and geochemical analysis by looking at populations of microbes and the presence of functional genes known to degrade VOCs. A summary of qPCR results is included in Table B.1. The qPCR includes the population of *dehalococcoides* (DHC), and their associated functional genes that can be responsible for reductive dehalogenation of TCE (tceA), DCE+VC (vcrA), VC (bvcaA). A competitor organism (methanogen, MGN) that can adversely influence reductive dehalogenation, was also quantified.

A "heat map" of qPCR results is included in Exhibit B.13 below. A color gradation was applied to indicate relative concentrations in each row, with the highest concentrations at each location indicated by green, intermediate concentrations by orange, and the lowest concentration represented by red. Additionally, populations above the 10^4 cells per milliliter (cells/mL) threshold thought to be most conducive to reductive dechlorination are emboldened. The most recent injection occurred between the September 2020 and November 2020 sampling events and is indicated by a vertical dashed black line. Additionally, the monitoring locations are listed in "plume order" or arranged north to south through the plume core as shown on Figures 1 and 2 in the main body of the text.

Exhibit B.13: Population variation of beneficial microorganism DHC

Concentration DHC (cells/mL)				
Well	**4/15/2020**	**9/10/2020**	**11/11/2020**	**4/14/2021**
BP-6A	6,420	**37,800**	**191,000**	**31,800**
BP-34A	1,380	239	3,000	11.2
BP-35A	61.2	0.7	3.7	ND
BP-36A	9,030	**30,300**	**39,800**	ND
B-7	4,420	431	282	218
BP-9A	239	358	647	**33,600**
BP-39A	2.2	2.4	6.6	0.3
BP-30A	2.5	0.6	0.7	1.5

DHC concentrations above 10^4 cells/mL are intermittently observed within the IDZ (BP-36A) and downgradient to the north and south (BP-6A, BP-9A). There were marginal increases at those locations following the injection. Notably, DHC populations in the injection well B-7 never reached a concentration higher than 10^3, which occurred before the September 2020 injection. Concentrations of DHC in BP-9A, downgradient by the property boundary, increased by 2 Oom in April 2021, approximately 7 months after the injection. Conversely, concentrations at BP-6A and BP-36A decreased by at least 1 Oom in samples collected in April 2021, after moderate increases associated with the 2020 amendment injection, which suggests that the injection events have a positive influence on DHC populations, but that the effects of the injection may be shorter than the frequency of the injection events.

Exhibit B.14: Abundance of beneficial functional genes

Concentration tceA reductase (cells/mL)				
Well	**4/15/2020**	**9/10/2020**	**11/11/2020**	**4/14/2021**
BP-6A	1.1	0.3	0.5	0.6
BP-34A	0.5	0.6	0.5	0.1
BP-35A	0.5	0.5	0.4	ND
BP-36A	0.5	0.2	0.5	ND
B-7	2.5	1.8	1.0	6.3
BP-9A	0.4	0.5	1.1	0.5
BP-39A	0.5	0.5	1.4	0.5
BP-30A	0.5	0.5	0.5	0.5

Concentration bvcA (cells/mL)				
Well	**4/15/2020**	**9/10/2020**	**11/11/2020**	**4/14/2021**
BP-6A	1.1	1.0	0.5	0.6
BP-34A	0.5	1.0	0.5	0.5
BP-35A	0.5	0.5	0.5	ND
BP-36A	0.5	0.5	0.5	ND
B-7	2.5	1.8	4.3	6.3
BP-9A	0.5	0.5	1.1	0.5
BP-39A	0.5	0.5	0.1	0.5
BP-30A	0.5	0.5	0.5	0.5

Concentration vcrA (cells/mL)				
Well	**4/15/2020**	**9/10/2020**	**11/11/2020**	**4/14/2021**
BP-6A	1550	13,600	47,000	8,300
BP-34A	1,150	181	1,180	78
BP-35A	5.4	0.1	0.7	ND
BP-36A	1,770	11,600	7,040	ND
B-7	1,110	287	69.9	61.1
BP-9A	34.7	127	53.6	5,370
BP-39A	0.2	1.9	1.6	0.1
BP-30A	0.2	0.5	0.5	0.2

As previously discussed in routine sampling reports, the presence of functional genes tceA and bvcaA are low and often not detected. In general, the detection of individual genes is indicative of degradation of those compounds and higher concentrations are indicative of more favorable conditions. However, the absence of individual genes does not necessarily demonstrate that reductive dechlorination is not occurring.

These genes indicate microorganisms capable of degrading TCE and vinyl chloride, respectively. On a relative basis, the functional gene that degrades cDCE and VC (vcrA) is present in marginal concentrations, especially at BP-6A and BP-36A. In general, the presence of functional genes confirms reductive dechlorination of each compound is occurring. However, the absence of functional genes does not necessarily mean that reductive dechlorination is not occurring; rather, it means that it was not measurable based on this line of evidence. For example, we note that the lack of tceA is not consistent with the results of the CSIA analysis discussed below and the documented presence of ethene/ethane, which indicates degradation is occurring.

Additionally, populations of other microbes (*Dehalobacter* [DHBt], *Desulfitobacterium* [DSB], and *Desulfuromonas* [DSM]) capable of reductive dechlorination, a functional gene that supports aerobic co-metabolic pathways (soluble methane monooxygenase [SMMO], were also quantified at a selection of locations[3] in April, September, and November 2020.

DHBt and DSB were typically found at relatively high concentrations at BP-6A. Most were detected in sampled wells, however, at low levels not expected to contribute materially to degradation. In general, concentrations of these bacteria increased from April to November. SMMO was generally not detected in the sampled wells, suggesting that the aerobic degradation pathway is not materially contributing to degradation.

Methanogens are competitor microbes to DHC, and their presence may inhibit reductive dechlorination. As such, the color scale presented in Exhibit B.15 below is reversed

[3] BP-6A, BP-30A, BP-39A, B-7

compared to the charts above. The highest MGN levels are indicated by red-shaded data entries. Methanogens are present in higher levels primarily mid-plume, centered on BP-36A, B-7, and BP-9A. These locations also exhibit other lines of evidence of sustained biodegradation such as favorable geochemical conditions and increased production of terminal breakdown products. The presence of relatively elevated methanogens may indicate a downward pressure of DHC populations, but they are also present in many of the location that have the highest DHC populations and the most conducive geochemical conditions.

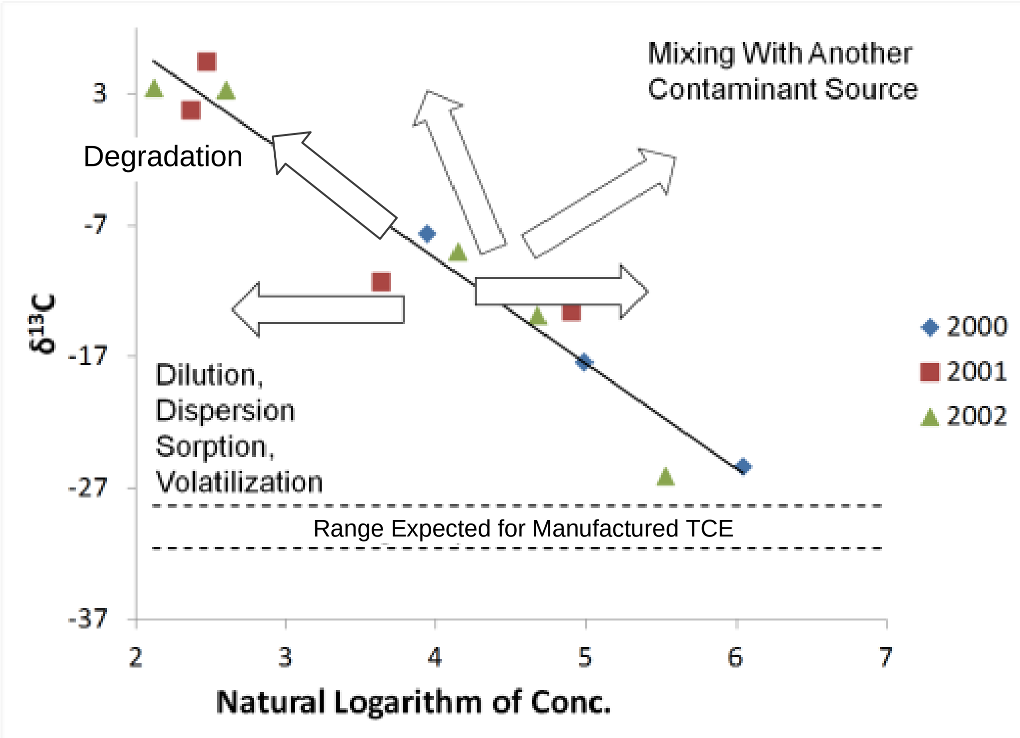
Exhibit B.15: Population variation of detrimental microorganism MGN

Concentration MGN (cells/mL)				
Well	**4/15/2020**	**9/10/2020**	**11/11/2020**	**4/14/2021**
BP-6A	0.4	4.9	0.9	0.9
BP-34A	4.9	2.8	5.4	4.8
BP-35A	4.0	0.3	18.3	ND
BP-36A	16.4	321	163	ND
B-7	1,170	2,640	10,400	11,100
BP-9A	0.2	26	333	11,700
BP-39A	3.5	8.0	4.1	18.7
BP-30A	0.1	5.0	2.1	24.1

Compound Specific Isotope Analysis (CSIA)

Exhibit B.16 provides a summary of a method for interpreting the mechanisms for contaminant reductions using CSIA results. For chlorinated solvent sites like the Gun Club Site, we are most interested in whether reductive dechlorination is occurring. As shown on Exhibit B.16, a trend of more positive numbers on the y-axis (moving up from negative towards 0) while moving from high concentration areas to low concentration areas (i.e., moving right to left on the x-axis) suggests evidence of reductive dechlorination. A negative slope is indicative of reductive dechlorination, while a limited to no slope suggests other attenuation mechanisms (e.g., dilution, dispersion, sorption, volatilization) are responsible for the reduction in concentrations, as shown in the diagram below.

Exhibit B.16: CSIA data interpretation diagram



Linear regression for 5 rounds of CSIA analysis from April 2020 to June 2021 for TCE, cDCE, and VC are shown on Figures B.5A through B.5C and the data are summarized on Table B.1.

CSIA results suggest that reductive dechlorination is generally the mechanism for concentration reductions in the downgradient direction. A review of the linear regression plots presented in Figures B.5A through B.5C indicates the following:

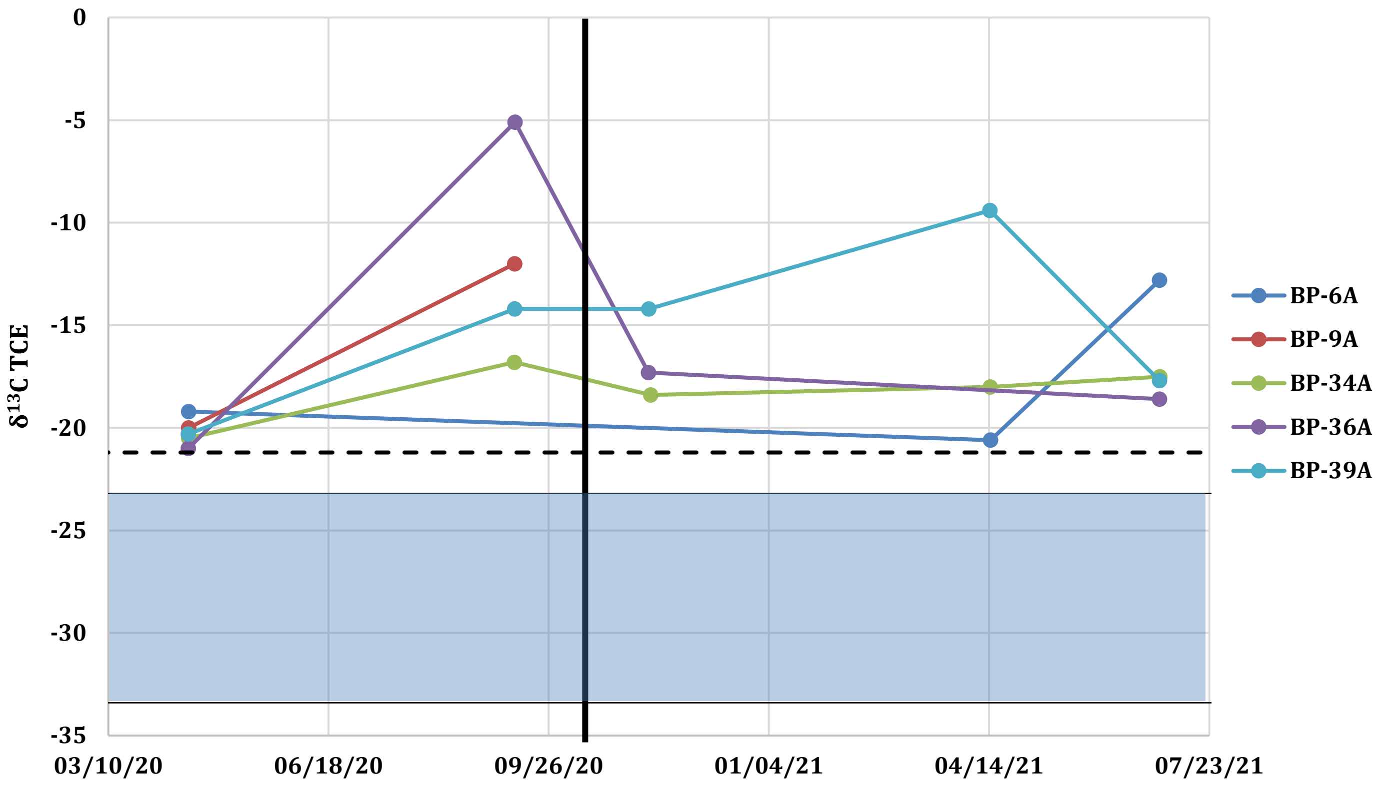
- The slope of linear regression for TCE in April 2020 was generally flat but is noticeably more negative for subsequent sampling events after the September 2020 injection event. The slope was most sharply negative in April 2021, approximately 7 months after the injection and is slightly reduced for June 2021, suggesting that the effects of the injection events have a positive influence on reductive dichlorination, but that the effects of the injection may be shorter than the frequency of the injection events.

- Linear regression results for cDCE produce a steep negative slope for each of the 5 sampling rounds. Patterns for September and November 2020 are similar and most negative, indicating the most active degradation. Unlike for TCE, there does not seem to be a clear response to the September 2020 injection. The linear regression for April 2021 values is generally the same slope as the remainder of the sampling rounds and is more negative than September and November. The linear regression for June 2021 is very similar to April 2020, which suggests the injection did not appreciably influence cDCE degradation; and

- Linear regression results for VC are variable, but generally fit a negative slope for the 5 sampling rounds. Individual values were most positive for the April 2021 sampling round, which may be evidence of the injection increasing degradation of VC. However, the results for the most recent sampling event in June 2021 returned to more negative values and similar pre-injection slope. This may indicate that any positive influence the injection had on VC degradation lasted about 7 months.

Another way to look at the CSIA data is presented in Exhibits B.17, B.18, and B.19 which display $\delta^{13}C$ values on a time series basis before and after the September 2020 injection. We note that groundwater travel times are not equivalent for all locations shown and it may be expected that an injection response is not observed at downgradient areas. Positive shift of 2‰ compared to $\delta^{13}C$ values typical of undegraded manufactured product is indicative that degradation is occurring. Simply put, any data that plots above the 2‰ shift dashed black line represents evidence that reductive dichlorination is occurring at meaningful rates, with less negative values representing higher rates of reductive dechlorination. The blue-shaded area on the exhibits below shows the range of published $\delta^{13}C$ values for TCE, which as the parent product, is used to compare cDCE and VC as well[4]. The 2‰ shift compared to the undegraded product is indicated by a horizontal dashed black line.

Exhibit B.17: Time series of $\delta^{13}C$ for TCE

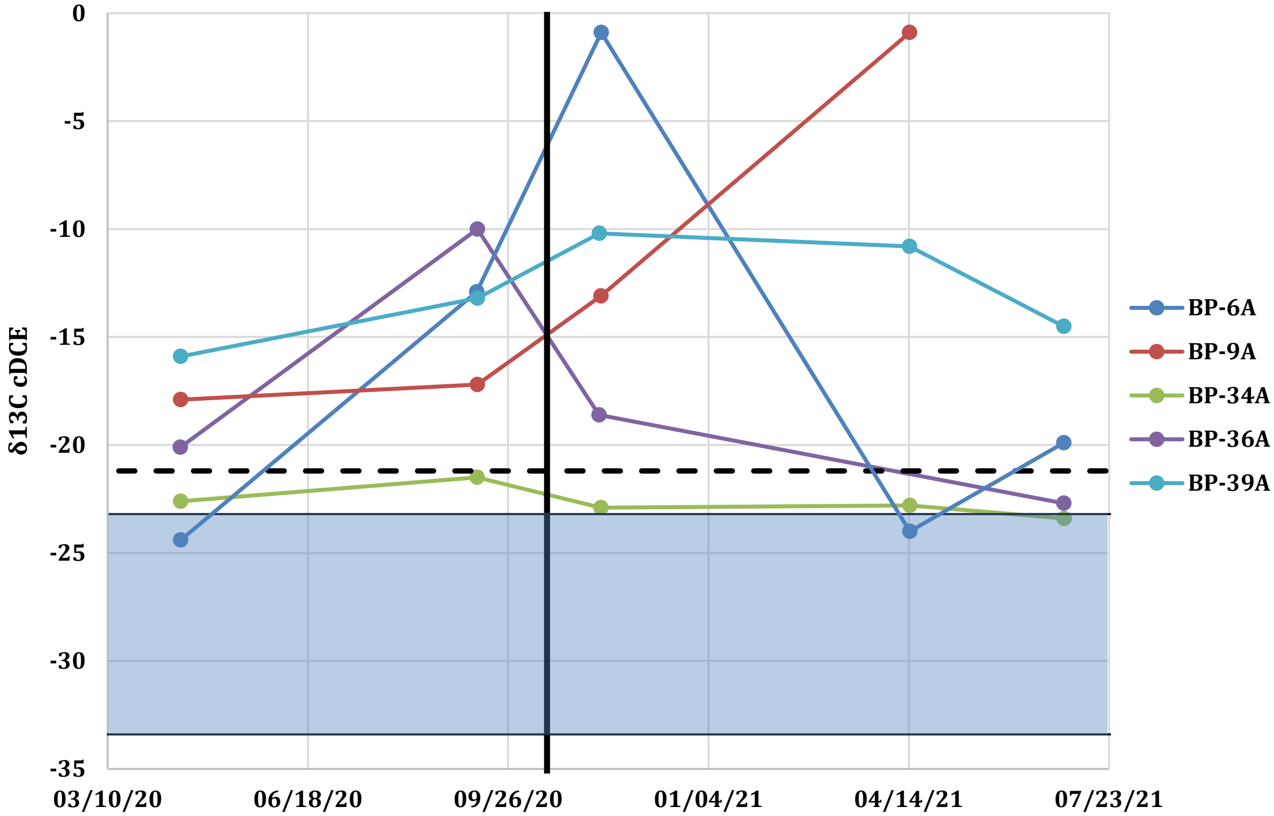


$\delta^{13}C$ values for TCE are variable, but a positive shift of 2‰ compared to the estimated manufactured product $\delta^{13}C$ range are realized for all sampling events. These data would suggest that more reductive dechlorination is occurring in September 2020 sampling, just before the injection, and April 2021. An apparent trend or response to the injection are not

[4] Microbial Insights, "Compound Specific Isotope Analysis". https://microbe.com/compound-specific-isotope-analysis-csia (Accessed August 27, 2021).

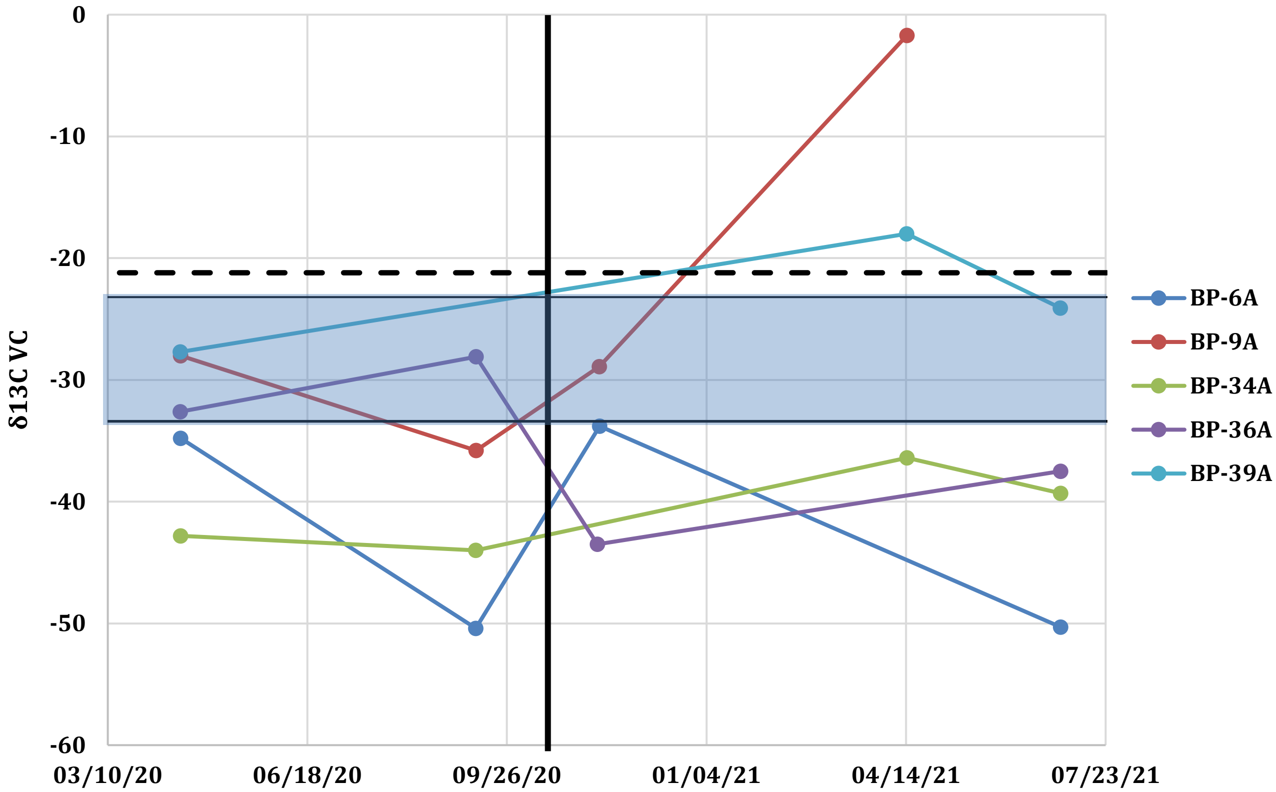
observed at BP-36A, which is in the IDZ where response to injections should be relatively immediate. The more positive shift at BP-6A, which is located further downgradient, observed in June 2021 sampling may indicate a positive response to the September 2020 injection.

Exhibit B.18: Time series of δ13C for cDCE



$\delta^{13}C$ values for cDCE are variable, and a positive 2‰ shift is observed for most sampling results. BP-34A results for all sampling rounds are within the 2‰ buffer, which may indicate biochemical degradation of cDCE is not as robust at this location. There is a possible response to the injection observed BP-9A, located downgradient on the property boundary. $\delta^{13}C$ values have become less negative since the injection, but the location was not sampled for CSIA analysis in June 2021, so trends will continued to be monitored to determine if the changes are within typical variations or if it was a result of the injection. Regardless, the data suggest that reductive dichlorination of cDCE is occurring much of the time.

Exhibit B.19: Time series of $\delta^{13}C$ for VC



$\delta^{13}C$ values for VC are typically not greater than the 2‰ positive shift expected when biochemical degradation is occurring. Most $\delta^{13}C$ values for VC are below (more negative) the reference range which suggests that CSIA data do not support that VC degradation is occurring at these locations, especially BP-6A, BP-34A, and BP-36A. We note that this finding is not consistent with the results from other lines of evidence, including qPCR results, redox conditions, and the documented presence of ethene/ethane, which is produced when VC is degraded. Additionally, we note that the range of $\delta^{13}C$ values shown are from published values for undegraded product. The exact product or mix of product and its state of enrichment originally disposed of at the Gun Club is unknown.

Similar to $\delta^{13}C$ values for cDCE, a possible response to the injection is observed at BP-9A, where $\delta^{13}C$ values for VC have become sharply less negative since the September 2020 injection.

APPENDIX B

TABLE

TABLE B.1
SUMMARY OF qPCR & CSIA ANALYSIS
Remedy Optimization Report
IBM Gun Club - Former Burn Pit Area
Union, New York

Analytical Method	Analyte	Units	BP-6A					BP-9A				BP-30A			
			04/15/20	09/10/20	11/11/20	04/14/21	06/30/21	04/15/20	09/10/20	11/11/20	04/14/21	04/15/20	09/10/20	11/10/20	04/14/21
qPCR	**Dechlorinating Bacteria**														
	Dehalococcoides (DHC)	cells/mL	6.42E+03	3.78E+04	1.91E+05	3.18E+04	-	2.39E+02	3.58E+02	6.47E+02	3.36E+04	2.50E+00	6.00E-01	7.00E-01	1.50E+00
	Dehalobacter spp.	cells/mL	4.64E+04	3.14E+05	6.06E+05	-	-	-	-	-	-	1.09E+01	<5.00E+00	7.56E+01	-
	Desulfitobacterium spp.	cells/mL	1.46E+04	6.28E+04	6.09E+05	-	-	-	-	-	-	1.08E+01	1.30E+00 J	1.11E+02	-
	Desulfuromonas spp.	cells/mL	6.58E+03	6.04E+02	3.18E+02	-	-	-	-	-	-	1.00E-01 J	6.00E-01 J	2.70E+00 J	-
	Functional Genes														
	BAV1 Vinyl Chloride Reductase (bvcA)	cells/mL	<1.10E+00	1.00E+00	<5.00E-01	<6.00E-01	-	<5.00E-01	<5.00E-01	<1.10E+00	<5.00E-01	<5.00E-01	<5.00E-01	<5.00E-01	<5.00E-01
	tceA Reductase (tceA)	cells/mL	<1.10E+00	3.00E-01 J	<5.00E-01	<6.00E-01	-	4.00E-01 J	<5.00E-01	<1.10E+00	<5.00E-01	<5.00E-01	<5.00E-01	<5.00E-01	<5.00E-01
	Vinyl Chloride Reductase (vcrA)	cells/mL	1.55E+03	1.36E+04	4.70E+04	8.30E+03	-	3.47E+01	1.27E+02	5.36E+01	5.37E+03	2.00E-01 J	<5.00E-01	<5.00E-01	2.00E-01 J
	Soluble Methane Monooxygenase	cells/mL	<1.06E+01	7.80E+01	<5.00E+00	-	-	-	-	-	-	<4.6E+00	<5.00E+00	<4.70E+00	-
	Methanogens	cells/mL	4.00E-01 J	<4.90E+00	9.00E-01 J	9.00E-01 J	-	2.00E-01 J	2.60E+01	3.33E+02	1.17E+04	1.00E-01 J	<5.00E+00	2.10E+00 J	2.41E+01
CSIA	$^{13}C/^{12}C$ TCE	‰	-19.2	NA	NA	-20.6	-12.8 J	-20	-12.0	NA	NA	-3.4	ND	8.1 J	ND
	$^{13}C/^{12}C$ cis-DCE	‰	-24.4	-12.9	-0.9	-24.0	-19.9	-17.9	-17.2	-13.1	-0.9	-10.3	ND	5.2	-6.0 J
	$^{13}C/^{12}C$ Vinyl Chloride	‰	-34.8 J	-50.4	-33.8	NA	-50.3 J	-28	-35.8	-28.9	-1.7	NA	NA	NA	NA

TABLE B.1
SUMMARY OF qPCR & CSIA ANALYSIS
Remedy Optimization Report
IBM Gun Club - Former Burn Pit Area
Union, New York

Analytical Method	Analyte	Units	BP-34A					BP-35A			BP-36A			
			04/15/20	09/10/20	11/11/20	04/14/21	06/30/21	04/15/20	09/10/20	11/10/20	04/15/20	09/10/20	11/10/20	06/30/21
qPCR	**Dechlorinating Bacteria**													
	Dehalococcoides (DHC)	cells/mL	1.38E+03	2.39E+02	3.00E+03	1.12E+01	-	6.12E+01	7.00E-01	3.70E+00	9.03E+03	3.03E+04	3.98E+04	-
	Dehalobacter spp.	cells/mL	-	-	-	-	-	-	-	-	-	-	-	-
	Desulfitobacterium spp.	cells/mL	-	-	-	-	-	-	-	-	-	-	-	-
	Desulfuromonas spp.	cells/mL	-	-	-	-	-	-	-	-	-	-	-	-
	Functional Genes													
	BAV1 Vinyl Chloride Reductase (bvcA)	cells/mL	<5.00E-01	<1.00E+00	<5.00E-01	<5.00E-01	-	<5.00E-01	<5.00E-01	<5.00E-01	<5.00E-01	<5.00E-01	<5.00E-01	-
	tceA Reductase (tceA)	cells/mL	<5.00E-01	6.00E-01 J	<5.00E-01	1.00E-01 J	-	<5.00E-01	<5.00E-01	4.00E-01 J	<5.00E-01	2.00E-01 J	<5.00E-01	-
	Vinyl Chloride Reductase (vcrA)	cells/mL	1.15E+03	1.81E+02	1.18E+03	7.80E+01	-	5.40E+00	1.00E-01 J	7.00E-01	1.77E+03	1.16E+04	7.04E+03	-
	Soluble Methane Monooxygenase	cells/mL	-	-	-	-	-	-	-	-	-	-	-	-
	Methanogens	cells/mL	<4.90E+00	2.80E+00 J	<4.80E+00	<5.40E+00	-	4.00E+00 J	3.00E-01 J	1.83E+01	1.64E+01	3.21E+02	1.63E+02	-
CSIA	$^{13}C/^{12}C$ TCE	‰	-20.5	-16.8	-18.4	-18.0	-17.5	-19.9	-15.9	-19.4	-21	-5.1 J	-17.3	-18.6
	$^{13}C/^{12}C$ cis-DCE	‰	-22.6	-21.5	-22.9	-22.8	-23.4	-20.6	-19.0	-22.1	-20.1	-10.0	-18.6	-22.7
	$^{13}C/^{12}C$ Vinyl Chloride	‰	-42.8 J	-44.0 J	NA	-36.4	-39.3 J	NA	NA	NA	-32.6	-28.1	-43.5	-37.5

TABLE B.1
SUMMARY OF qPCR & CSIA ANALYSIS
Remedy Optimization Report
IBM Gun Club - Former Burn Pit Area
Union, New York

Analytical Method	Analyte	Units	BP-39A					B-7			
			04/15/20	09/10/20	11/10/20	04/14/21	06/30/21	04/15/20	09/10/20	11/10/20	04/14/21
qPCR	**Dechlorinating Bacteria**										
	Dehalococcoides (DHC)	cells/mL	2.20E+00	2.40E+00	6.60E+00	3.00E-01 J	-	4.42E+03	4.31E+02	2.82E+02	2.18E+02
	Dehalobacter spp.	cells/mL	4.7E+00 J	<4.80E+00	2.00E+02	-	-	<2.50E+01	<1.75E+01	<4.35E+01	-
	Desulfitobacterium spp.	cells/mL	3.20E+00 J	<4.80E+00	1.49E+01	-	-	<2.50E+01	<1.75E+01	<4.35E+01	-
	Desulfuromonas spp.	cells/mL	3.00E-01 J	5.10E+00	5.40E+00	-	-	<2.50E+01	<1.75E+01	<4.35E+01	-
	Functional Genes										
	BAV1 Vinyl Chloride Reductase (bvcA)	cells/mL	<5.00E-01	<5.00E-01	1.00E-01 J	<5.00E-01	-	<2.50E+00	<1.80E+00	<4.30E+00	<6.30E-01
	tceA Reductase (tceA)	cells/mL	<5.00E-01	<5.00E-01	1.40E+00	<5.00E-01	-	<2.50E+00	<1.80E+00	1.00E+00 J	<6.30E-01
	Vinyl Chloride Reductase (vcrA)	cells/mL	2.00E-01 J	1.90E+00	1.60E+00	1.00E-01 J	-	1.11E+03	2.87E+02	6.99E+01	6.11E+01
	Soluble Methane Monooxygenase	cells/mL	4.30E+01	<4.80E+00	<4.80E+00	-	-	<2.50E+01	<1.75E+01	<4.35E+01	-
	Methanogens	cells/mL	3.50E+00 J	8.00E+00	4.10E+00 J	1.87E+01	-	1.17E+03	2.64E+03	1.04E+04	1.11E+04
CSIA	$^{13}C/^{12}C$ TCE	‰	-20.3	-14.2	-14.2	-9.4	-17.7	NA	NA	-18.5	NA
	$^{13}C/^{12}C$ cis-DCE	‰	-15.9	-13.2	-10.2	-10.8	-14.5	-17.1	-10.2	-18.9	ND
	$^{13}C/^{12}C$ Vinyl Chloride	‰	-27.7	NA	NA	-18.0 J	-24.1	NA	NA	NA	NA

Notes:

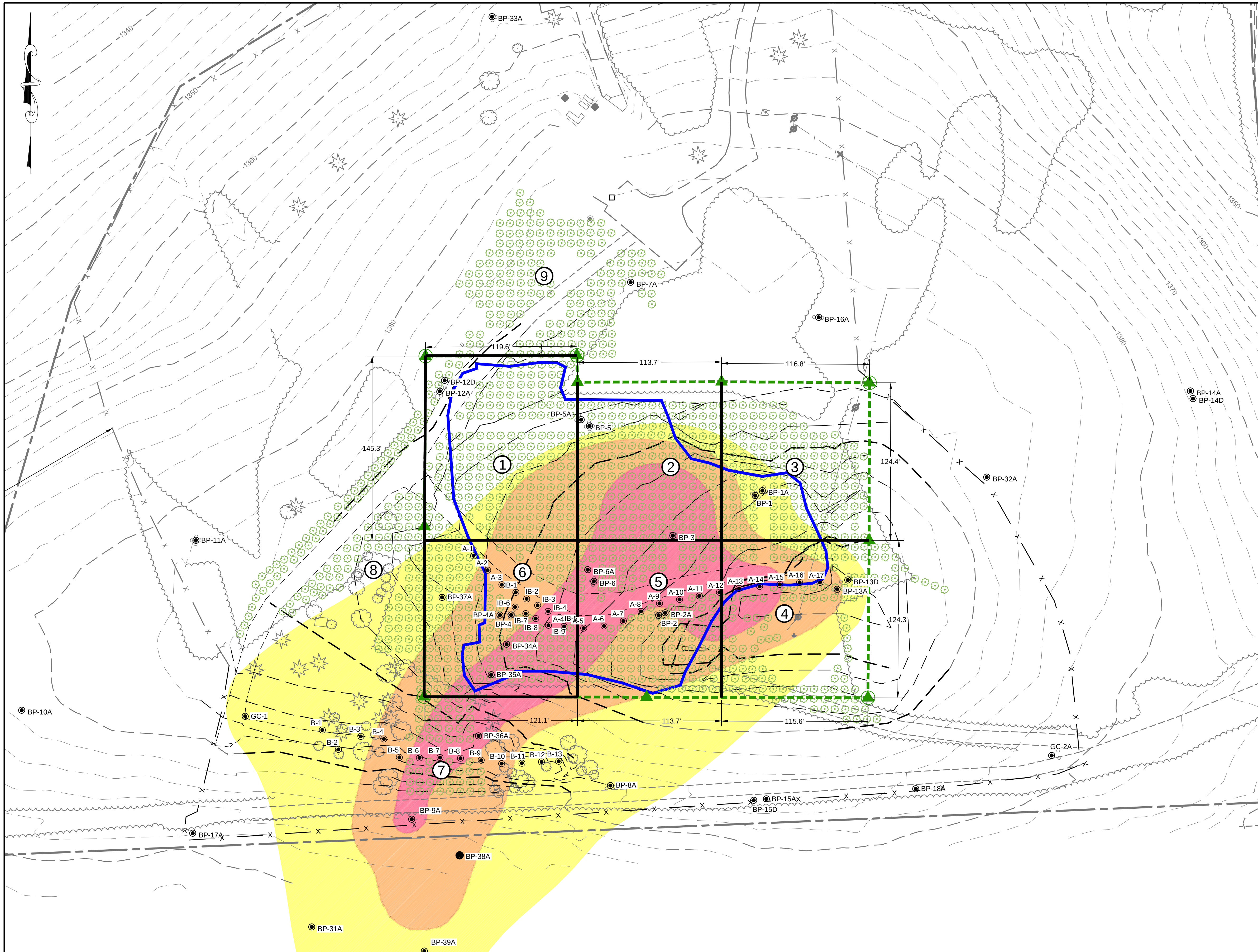
1. The table summarizes samples collected on the dates indicated as part of supplemental forensic sampling at the IBM Gun Club former Burn Pit Area. Samples were analyzed by Microbial Insights of Knoxville, Tennesee (MI). Results are recorded in units indicated on the table.

2. Definitions:
"qPCR" indicates quantitative polymerase chain reaction analysis, which is a DNA-based analysis used to quantify specific microorganisms and specific functional genes responsible for biodegradation.
"CSIA" indicates compound-specific isotope analysis, which identifies the ratio of carbon-13 to carbon-12 isotopes in the compounds of interest for this site (TCE, cDCE, and vinyl chloride)
"J" indicates that the laboratory data was below the lowest quantifiable limit and therefore estimated.
"NA" indicates that the compound was not detected in the VOC sample collected concurrently with the CSIA sample, so CSIA results are not applicable. NA results for compounds detected in the VOC sample were due to targets below the limit of detection after required dilutions and were therefore not analyzed.
"ND" indicates not detected.

3. Refer to the report text for further discussion.

APPENDIX B

FIGURES



NOTES:

1. THIS FIGURE IDENTIFIES THE AREAS WHERE TREES WERE PLANTED AS PART OF THE PHYTOREMEDIATION COMPONENT OF THE REMEDY . THE BOUNDARY OF TREE PLANTINGS WAS SURVEYED AS PART OF THE AS-BUILT DRAWINGS INCLUDED IN THE FINAL ENGINEERING REPORT. INDIVIDUAL TREE LOCATIONS WERE NOT SURVEYED. TREE PLANTING SUB-AREAS WERE ESTABLISHED TO AID IN THE ASSESSMENT OF TREE MORTALITY CONDUCTED AT LEAST ANNUALLY SINCE PLANTING

2. REFER TO THE SITE MANAGEMENT PLAN AND FINAL ENGINEERING REPORT FOR ADDITIONAL NOTES AND LEGEND INFORMATION.

LEGEND

- 1350 — EXISTING 10-FOOT CONTOUR
- EXISTING 2-FOOT CONTOUR
- 1380 — AS-BUILT 10-FOOT CONTOUR
- AS-BUILT 2-FOOT CONTOUR
- X — EXISTING CHAIN-LINK FENCE
- X — AS-BUILT CHAIN-LINK FENCE
- EXISTING TREE LINE
- EXISTING UTILITY LINE
- EXISTING EDGE OF PAVED ROAD
- EXISTING EDGE OF GRAVEL PATH
- AS-BUILT EDGE OF GRAVEL PATH
- SURVEYED EXTENT OF MARKER LAYER
- BP-6 — EXISTING MONITORING WELL LOCATION AND DESIGNATION
- IB-4 — EXISTING INJECTION WELL LOCATION AND DESIGNATION
- A-1 — AS-BUILT INJECTION WELL LOCATION AND DESIGNATION
- DEED RESTRICTION BOUNDARY
- MONUMENT TO DOCUMENT DEED RESTRICTED AREA
- MONUMENT TO DOCUMENT DEED RESTRICTED AREA WITH SIGNAGE INSTALLED
- SURVEYED TREE PLANTING LIMITS
- 3 — PHYTOREMEDIATION AREA BOUNDARY AND DESIGNATION
- PRIMARY SOURCE ROCK
- SECONDARY SOURCE ROCK

SANBORN HEAD ENGINEERING

GRAPHICAL SCALE
60' 30' 0 60' 120'

NO.	DATE	DESCRIPTION	BY

DRAWN BY: E. WRIGHT
DESIGNED BY: E. BOSSE
REVIEWED BY: B. GREEN
PROJECT MGR: E. BOSSE
PIC: B. GREEN
DATE: SEPT 2021

Remedy Optimization Report
IBM GUN CLUB - FORMER BURN PIT AREA
UNION, NEW YORK

Tree Planting Areas

PROJECT NUMBER: 3526.05

FIGURE NUMBER: B.1

Figure B.2

Summary of Injection Borehole Performance

IBM Gun Club - Former Burn Pit Area

Union, New York

Drawn By: H. Pothier
Designed By: E. Bosse
Reviewed By: B. Green
Project No: 3526.05
Date: September 2021

Figure Narrative

The color coded dots on this figure indicate the difference in gallons of amendment between 2015 and 2020 Injections. A negative change indicates less amendment was able to be injected under pressure in 2020 compared to 2015.

Posted values are the design dose in gallons of diluted amendment. Soybean oil amendment is diluted with water in a 1:19 ratio. Refer to the October 2011 EBD Pilot Test Report for further information

Notes

1. Aerial imagery provided by Google Earth Pro. (October 2017). Union, New York, USA. 42° 7'51.80"N, 76° 0'19.14"W, Eye alt 2,005 feet. [September 2021].

Legend

A-15 100 — Well Designation & Design dose (gal)

Amendment volume difference between 2015 and 2020 injections (gallons)

- < -100
- -100 to -20
- -20 to 0
- >0
- Location not included in current injection design

15 7.5 0 15 30 Feet

SANBORN HEAD

Last Edited By: hlapointe

Path: P:\3500s\3526.02\Graphics Files\GIS\Figures\202109 Optimization\Inj_Borehole.mxd

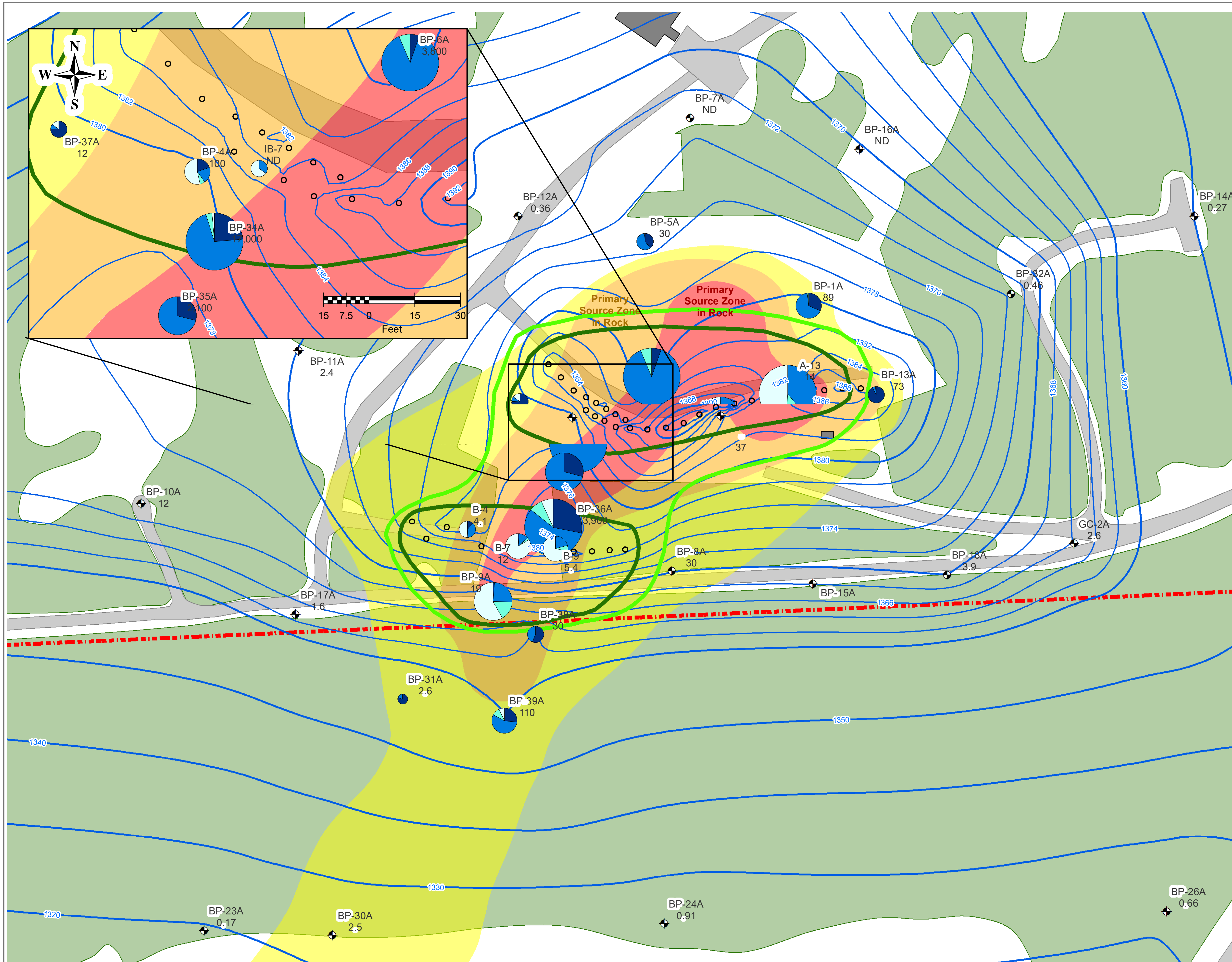


Figure B.3

Summary of June 2021 Groundwater Quality Conditions

IBM Gun Club - Former Burn Pit Area

Union, New York

Drawn By:	H. Pothier/Z. Svoboda
Designed By:	E. Bosse
Reviewed By:	B. Green
Project No:	3526.05
Date:	August 2021

Figure Narrative

This figure shows groundwater quality data and inference based on monitoring conducted June 2021.

The groundwater data for site key VOCs including TCE, cDCE, vinyl chloride, and ethane/ethene from water table monitoring wells are presented as pie diagrams. The wedges of each pie diagram represent concentrations of the four compounds expressed in micromoles per liter (umol/L). The relative diameter of each pie diagram varies based on the sum of the five VOCs and tDCE at each location.

The inferred sulfate-reducing and methanogenic conditions are based on observations of oxidation-reduction potential (ORP), methane, sulfide, ferrous and total iron, and nitrate. Methanogenic conditions are characterized by methane concentrations ≥ 20 µg/L, sulfate reducing by sulfide ≥ 50 µg/L, iron reducing by Fe(II)/Fe(tot) ≥ 0.7 mg/L, and nitrate reduction by nitrate <1 mg/L. ORP is generally expected to be <200 for iron reduction, <100 for sulfate reduction, and <0 for methanogenic conditions. See Figure 3 for geochemical data.

Not all geochemical conditions are satisfied within the areas shown for sulfate-reducing and methanogenic conditions. The inferred areas assume the presence of a transition zone between sulfate-reducing and methanogenic, and the position and size of these zones are based on judgement of the combined data. Other interpretations are possible.

Refer to the report text for further discussion.

Legend

BP-34A 23,000 — Well Name and June 2021 TCE Concentrations in Groundwater (µg/L).

Inferred Groundwater Contour June 2021

Inferred Methanogenic Conditions

Inferred Sulfate-Reducing Conditions

Parent VOC (Trichloroethene)

Primary Daughter Product (*cis*-1,2DCE)

Secondary Daughter Product (Vinyl Chloride)

Terminal Breakdown Products (Ethane, Ethene)

Total Chlorinated Ethanes & Ethenes in Groundwater (µmol/L)

< 0.1

>0.1 to 1

>1 to 10

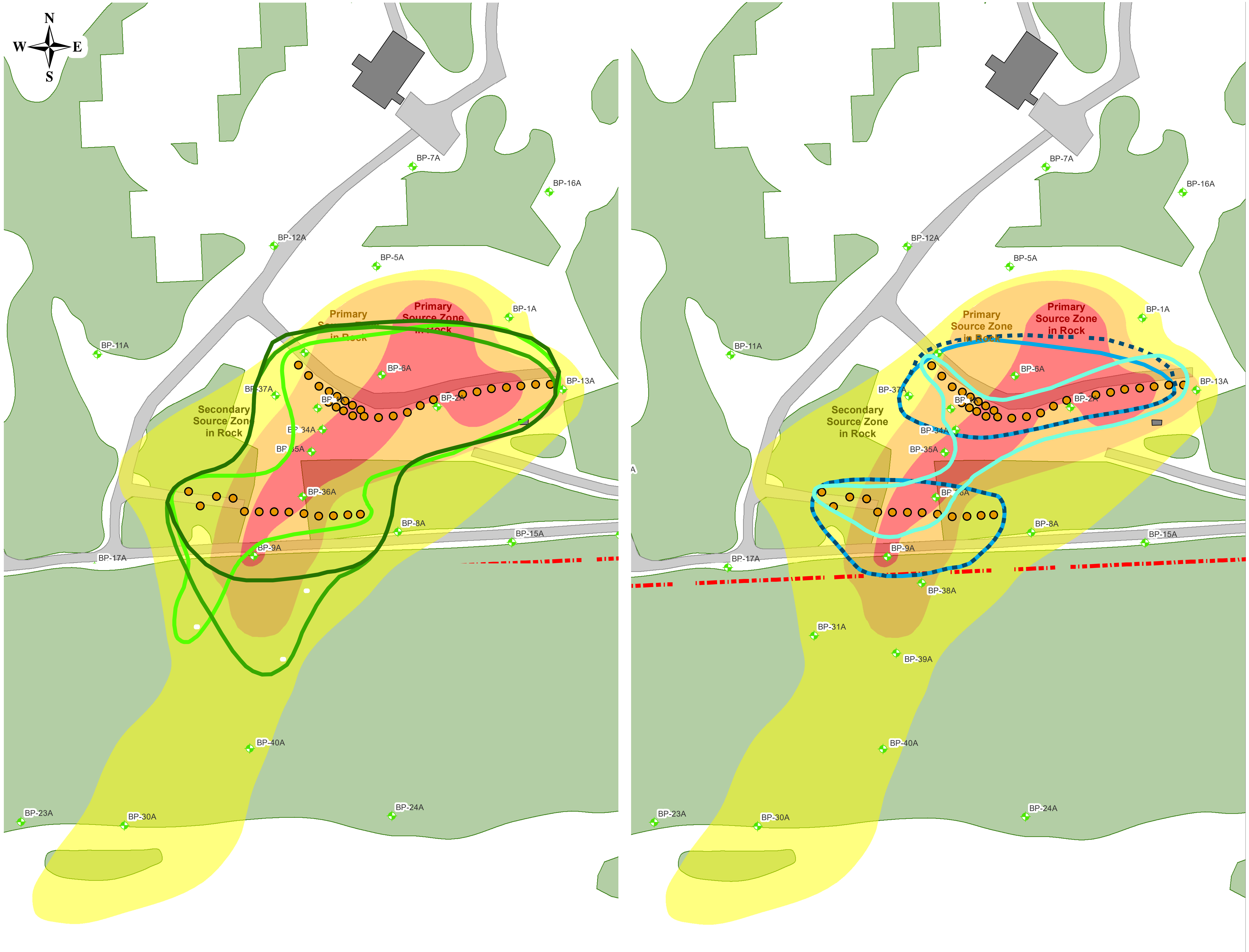
>10 to 100

>100

40 20 0 40 80

Feet

SANBORN HEAD



B.4

Summary of Geochemical Conditions

Remedy Optimization Report

IBM Gun Club - Former Burn Pit Area

Union, New York

Drawn By:	H. LaPointe
Designed By:	E. Bosse
Reviewed By:	D. Shea
Project No:	3526.05
Date:	September 2021

Figure Narrative

This figure summarized the extent of inferred geochemical conditions as a measure of remedy performance pre- and post- September 2020 injection. Maintenance of geochemical conditions is one of the engineering controls established to address migration in groundwater and VOC source mass over time.

The inferred geochemical conditions are based on observations of oxidation-reduction potential (ORP), methane, sulfide, ferrous and total iron, and nitrate. The assessment is based on data record in performance monitoring conducted in 2020 and 2021.

Primary and secondary source rock isopleths are inferred from rock core sampling completed in 2009-2012, before the remedy was implemented.

Legend

Well Location

Inferred Extent of Sulfate-Reducing Conditions

- November 2014
- September 2020
- June 2021

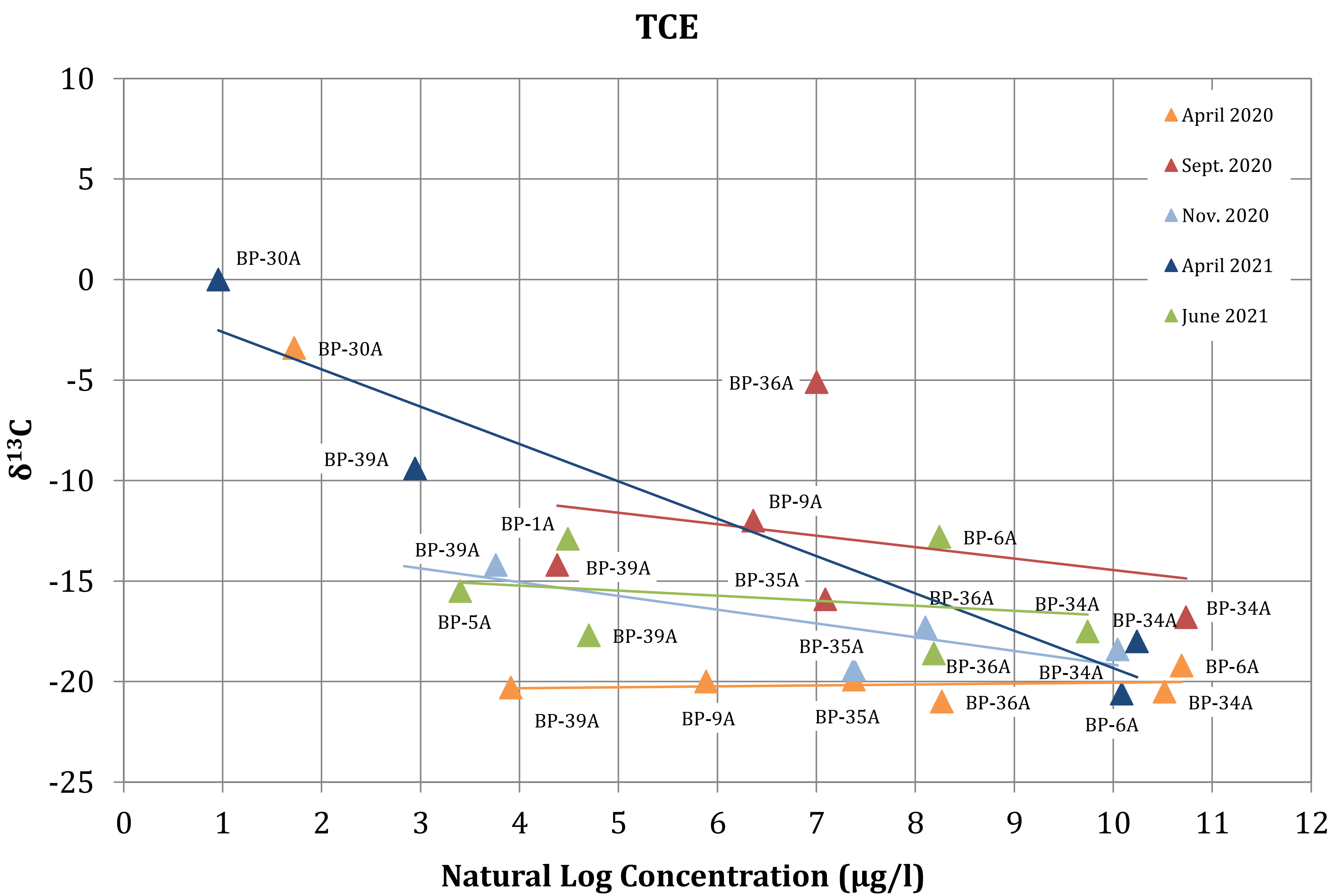
Inferred Extent of Methanogenic Conditions

- November 2014
- September 2020
- June 2021

50 25 0 50 100 Feet

SANBORN HEAD

Figure B.5A
CSIA Results - TCE
Remedy Optimization Report
IBM Gun Club - Former Burn Pit Area
Union, New York



P:\3500s\3526.02\Source Files\2021 Optimization\Appendices\Appendix B\
Fig B.5_CSIA_Charts.xlsx

Figure B.5B
CSIA Results - cis-DCE
Remedy Optimization Report
IBM Gun Club - Former Burn Pit Area
Union, New York

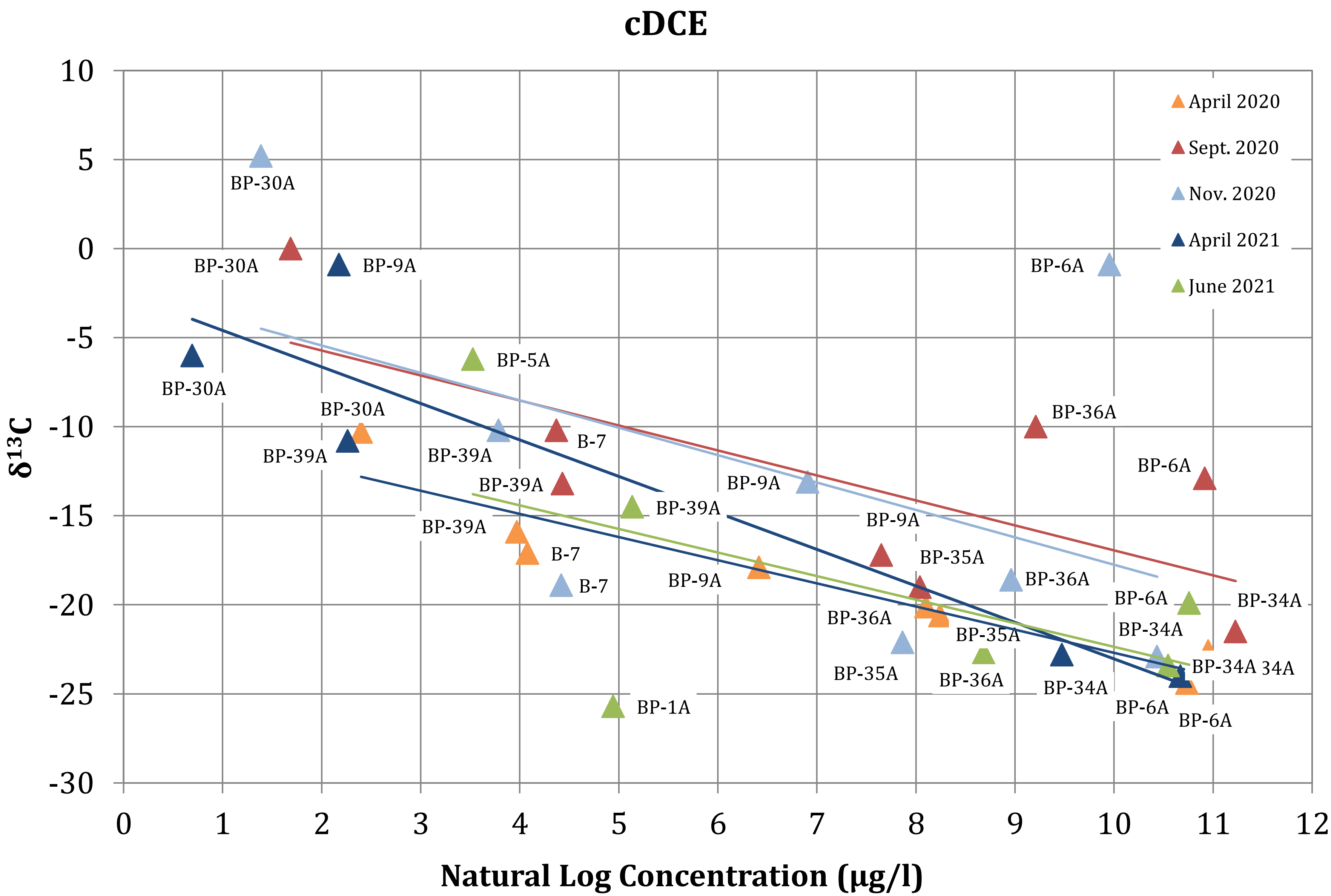
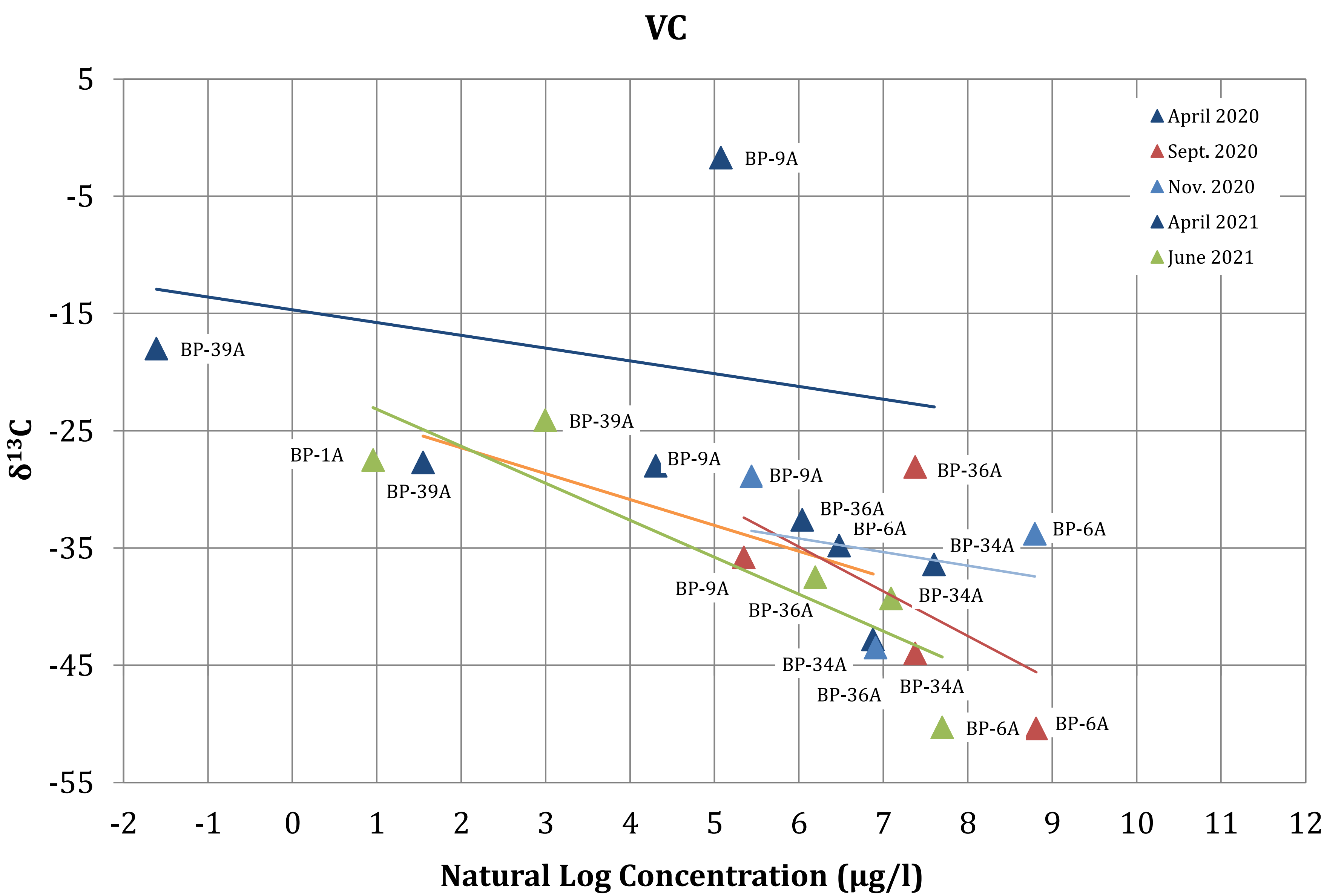


Figure B.5C
CSIA Results - VC
Remedy Optimization Report
IBM Gun Club - Former Burn Pit Area
Union, New York



APPENDIX B

TIME SERIES PLOTS

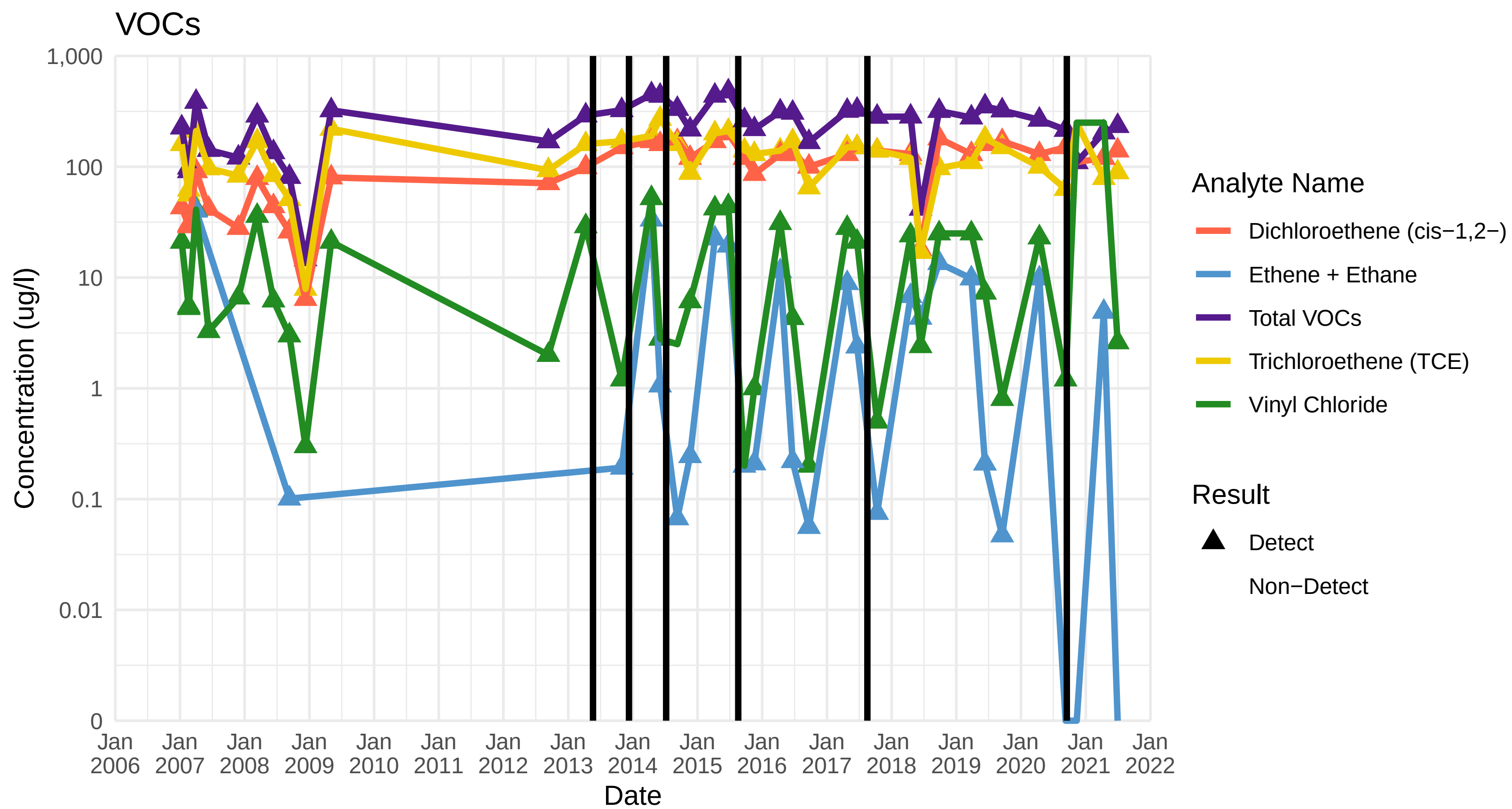
BP−1A

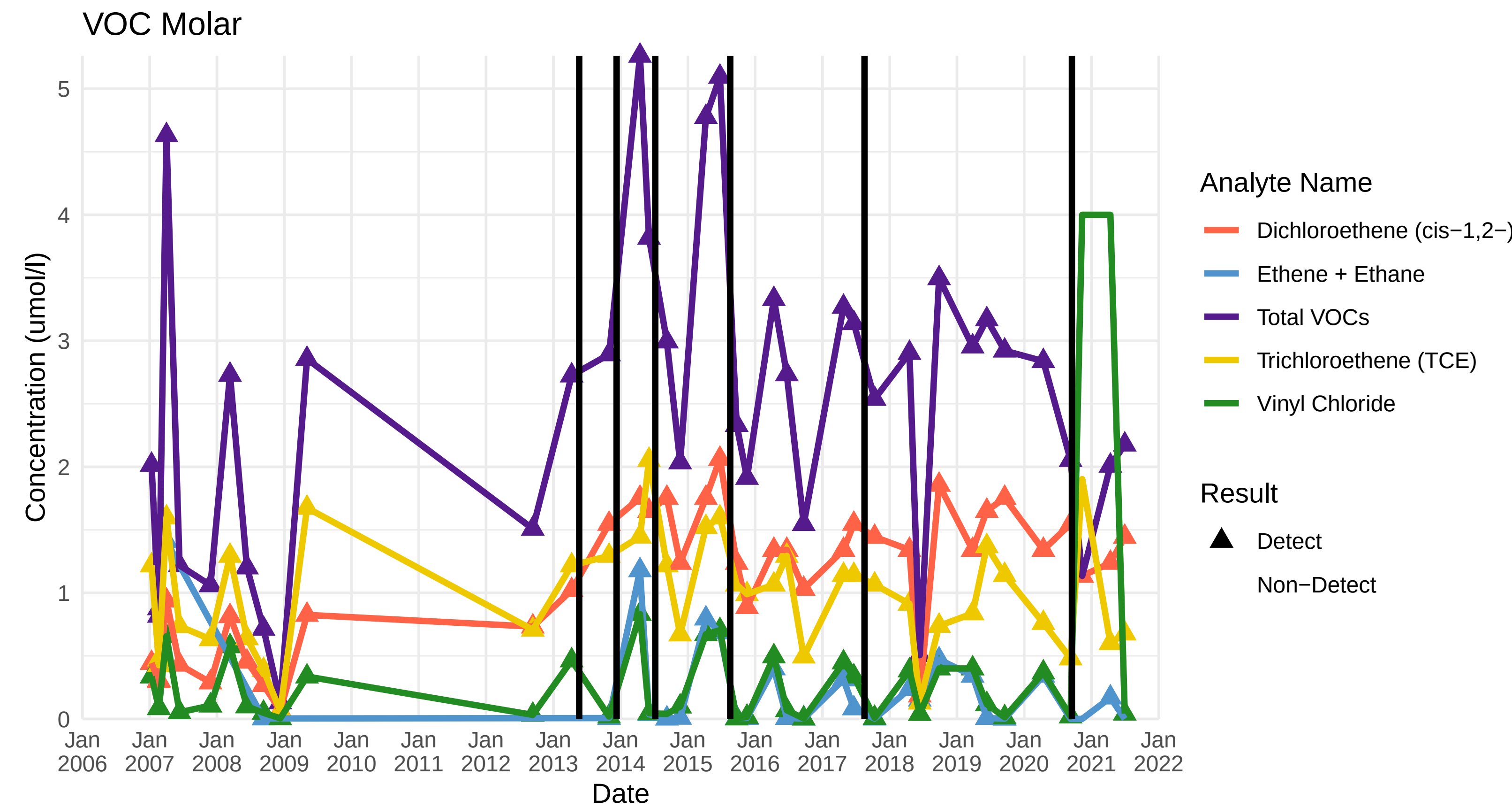
Notes:

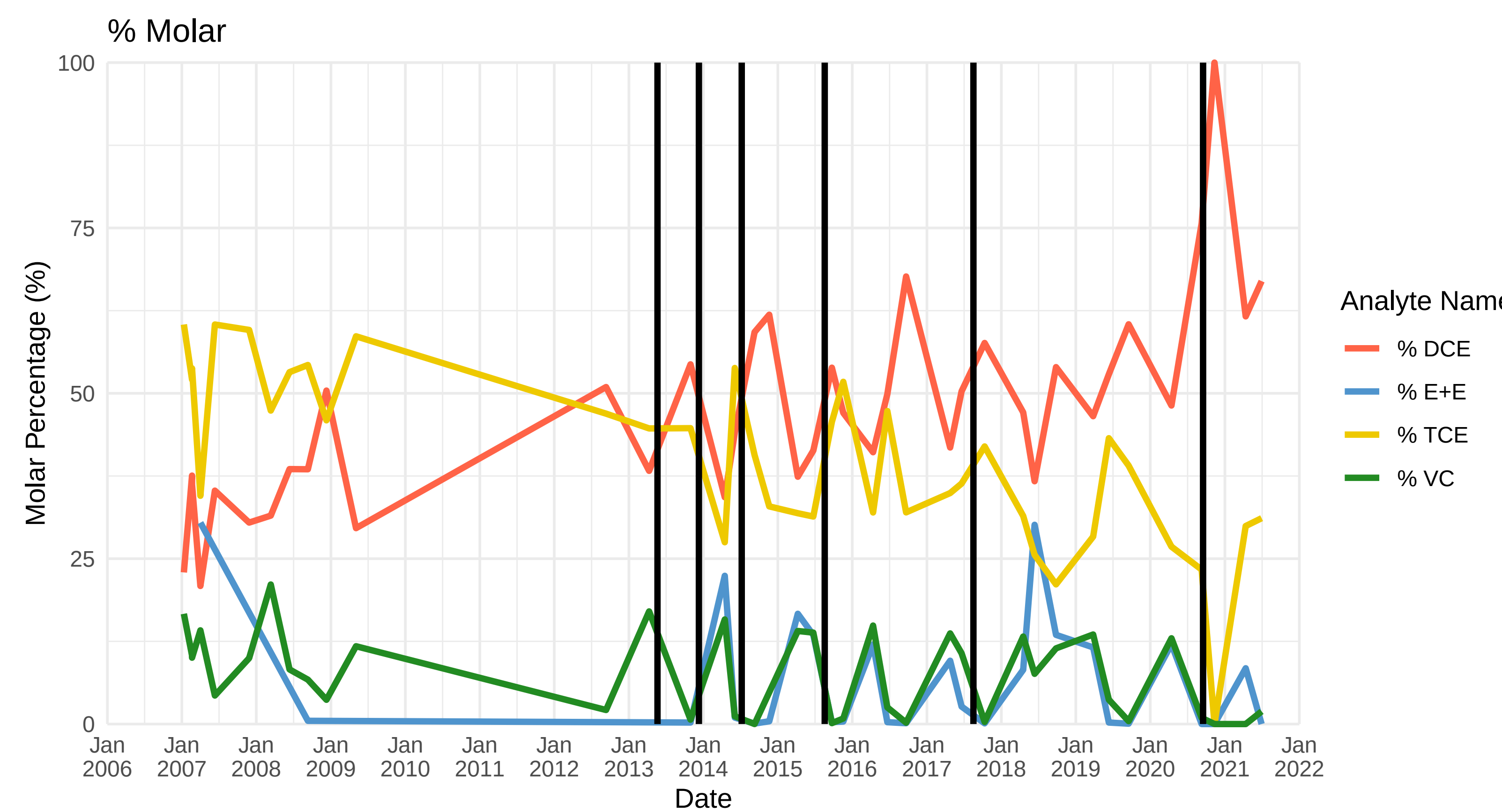
(1) Where applicable, non−detects are plotted at reporting limit and are shown with hollow symbols. Summed (total) concentrations are plotted at zero.

(2) Black vertical lines indicate amendment injection events.

(3) Reporting limits can fluctuate based on sample dilutions performed by the lab due to varying concentrations of other compounds, some of which may not be shown in these time series, matrix interference like the presence of amendment oil droplets, or other factors.







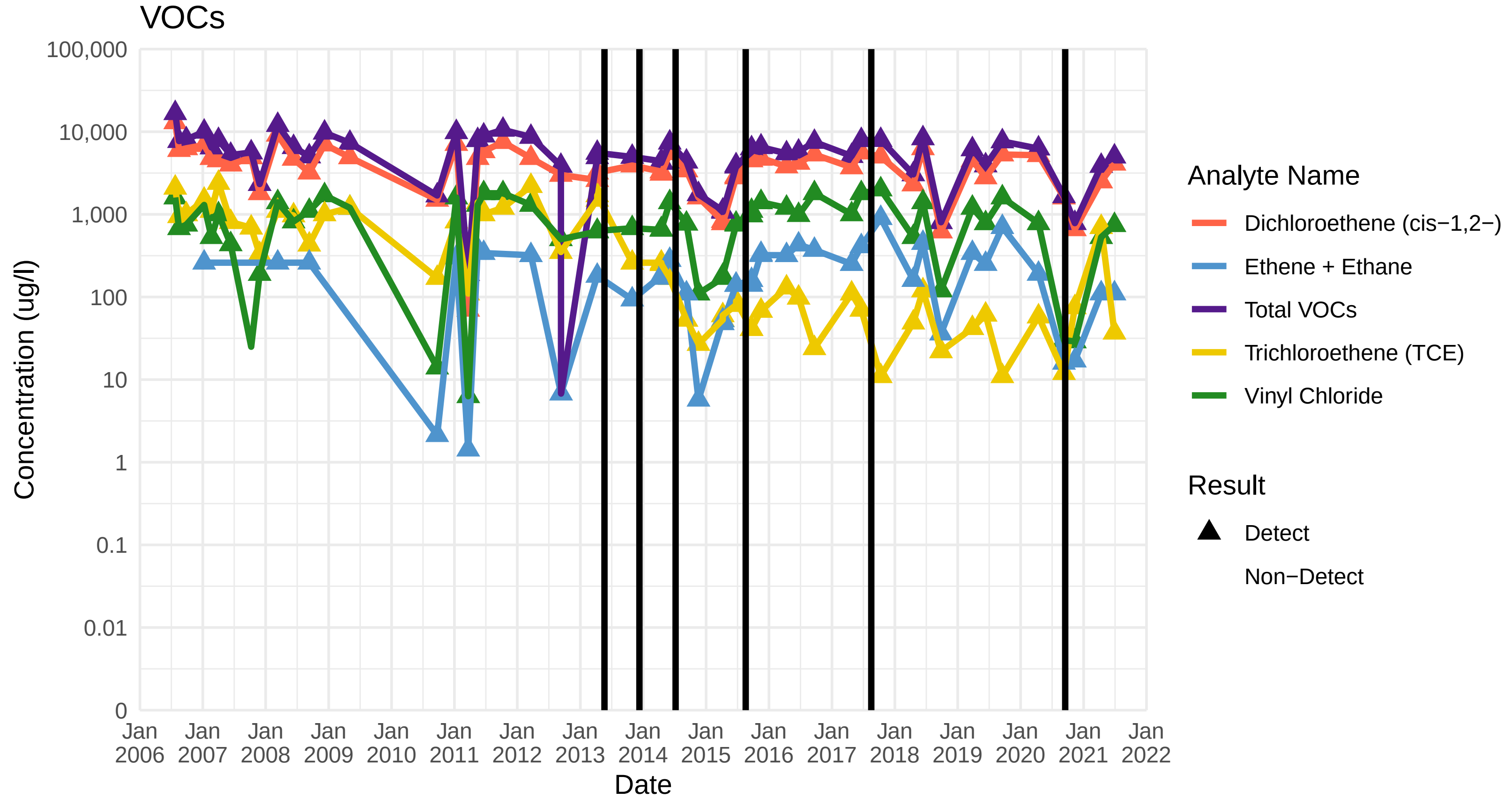
BP−2A

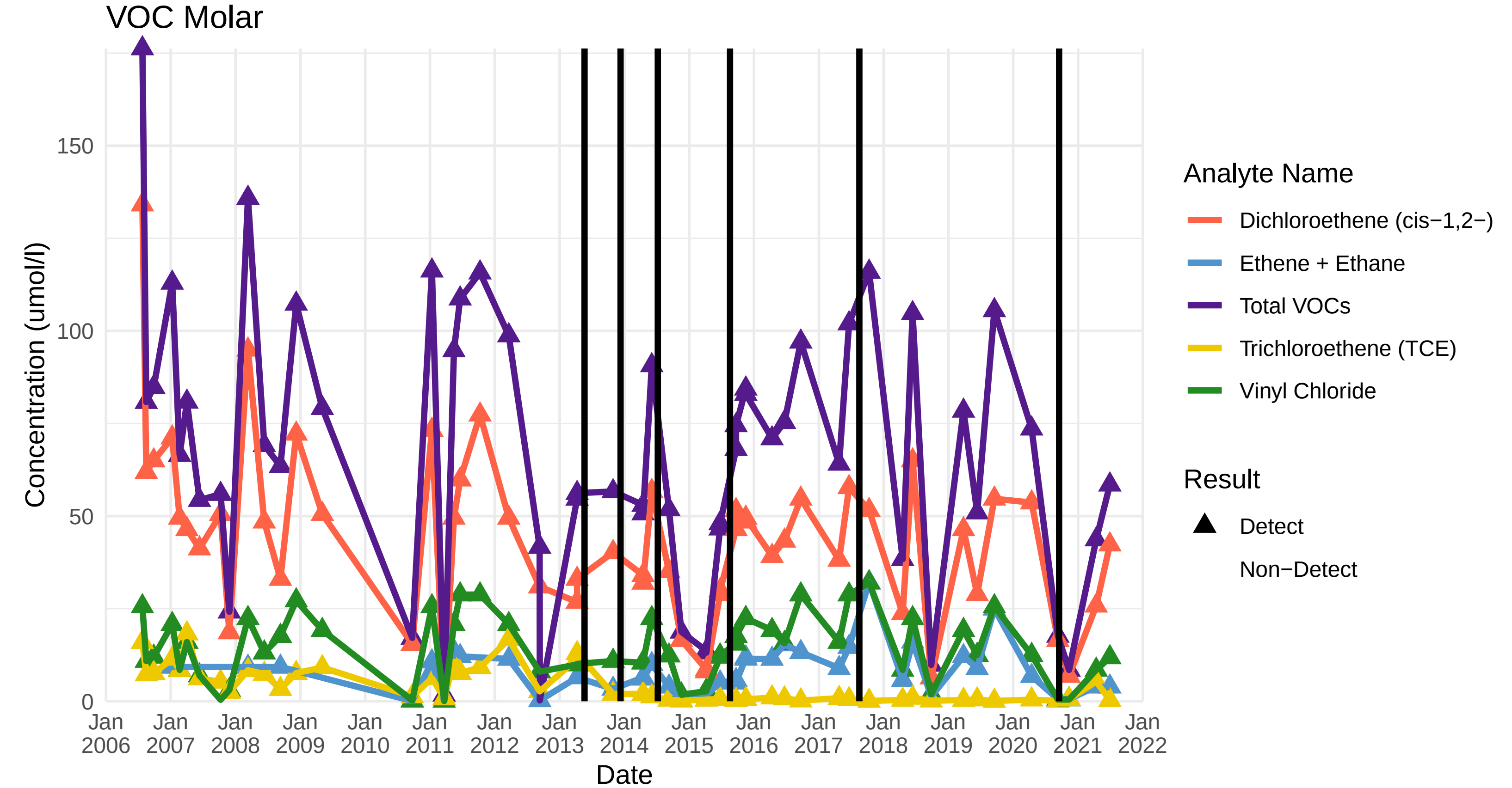
Notes:

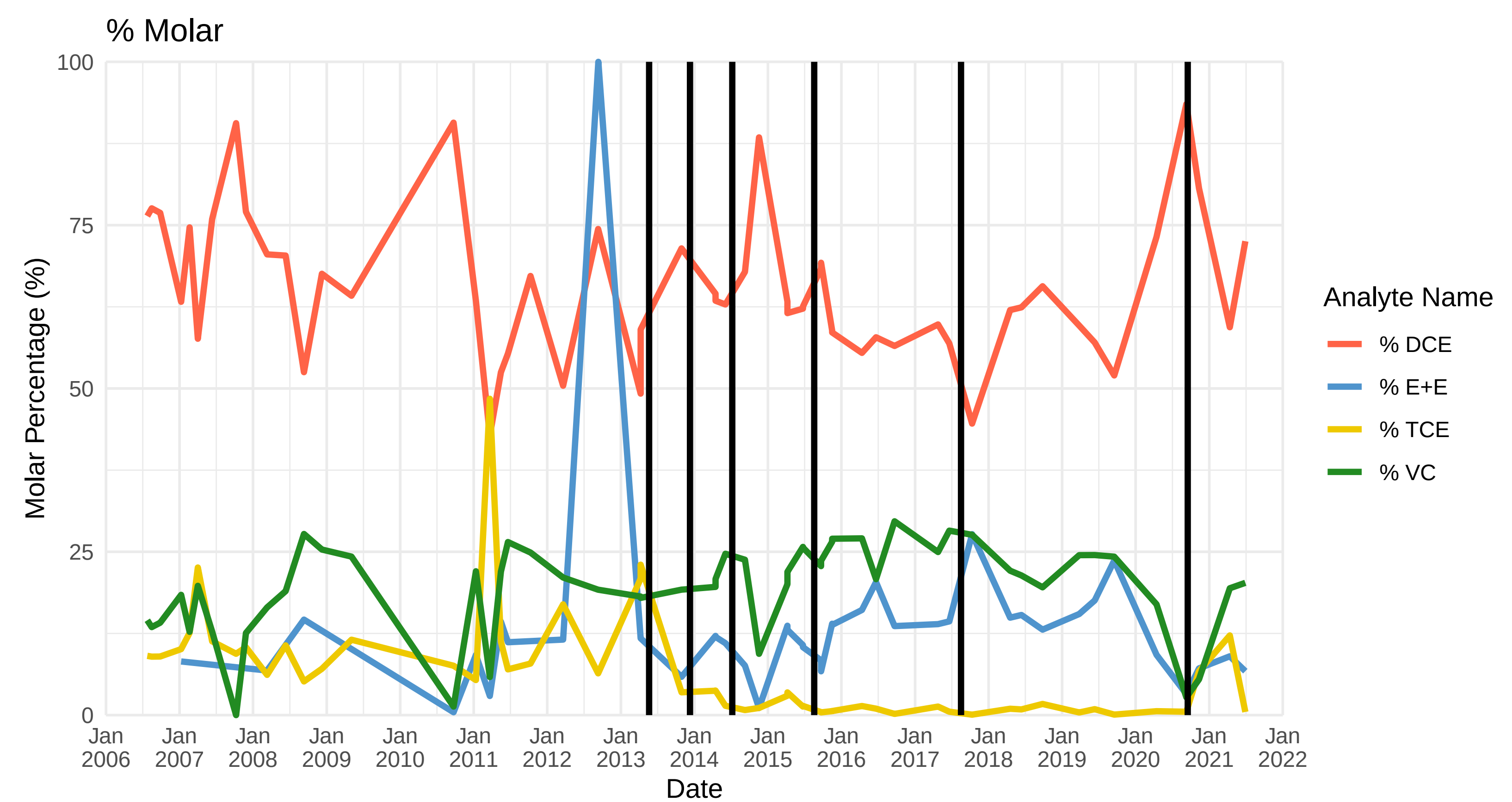
(1) Where applicable, non−detects are plotted at reporting limit and are shown with hollow symbols. Summed (total) concentrations are plotted at zero.

(2) Black vertical lines indicate amendment injection events.

(3) Reporting limits can fluctuate based on sample dilutions performed by the lab due to varying concentrations of other compounds, some of which may not be shown in these time series, matrix interference like the presence of amendment oil droplets, or other factors.







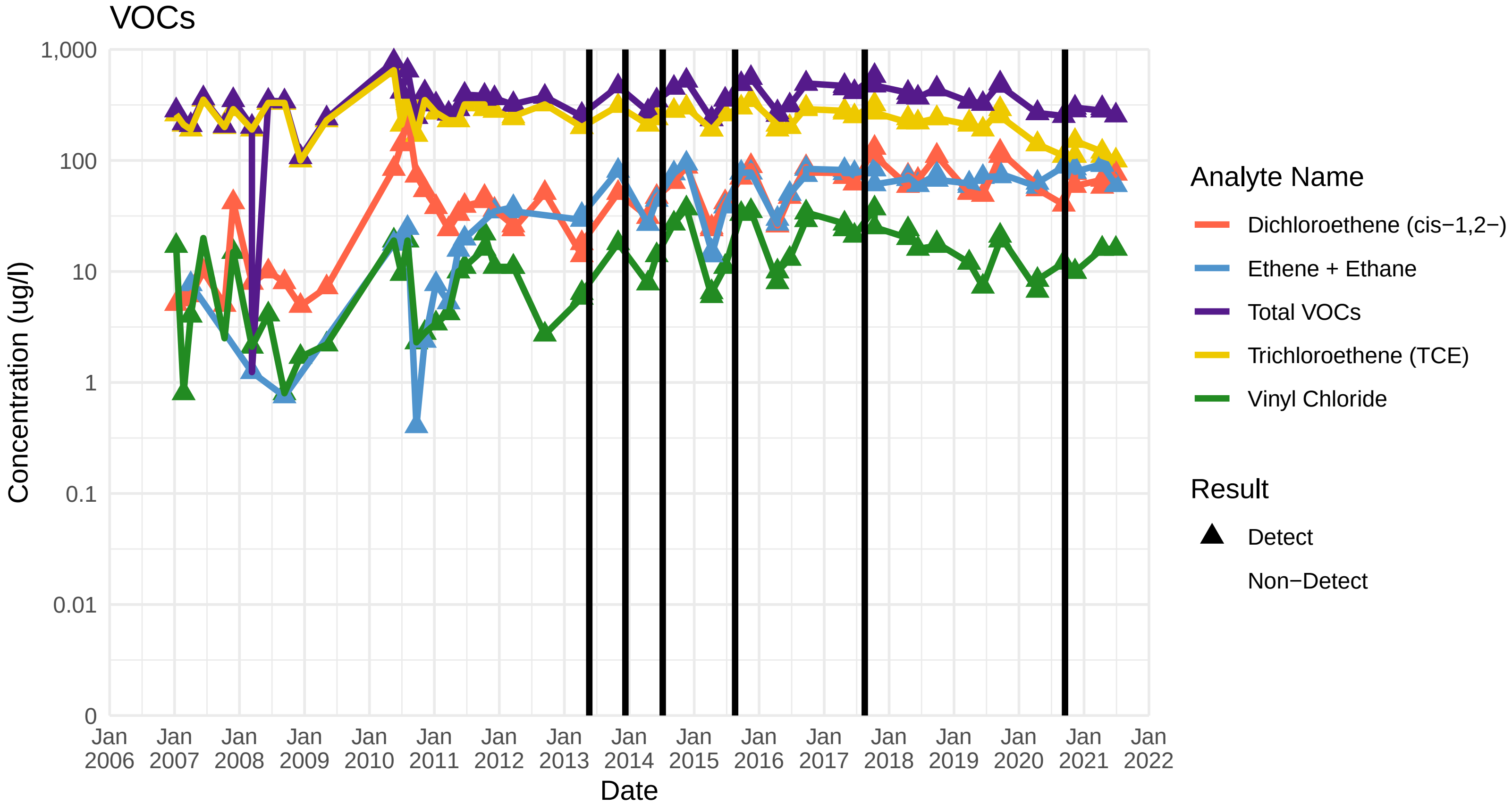
BP−4A

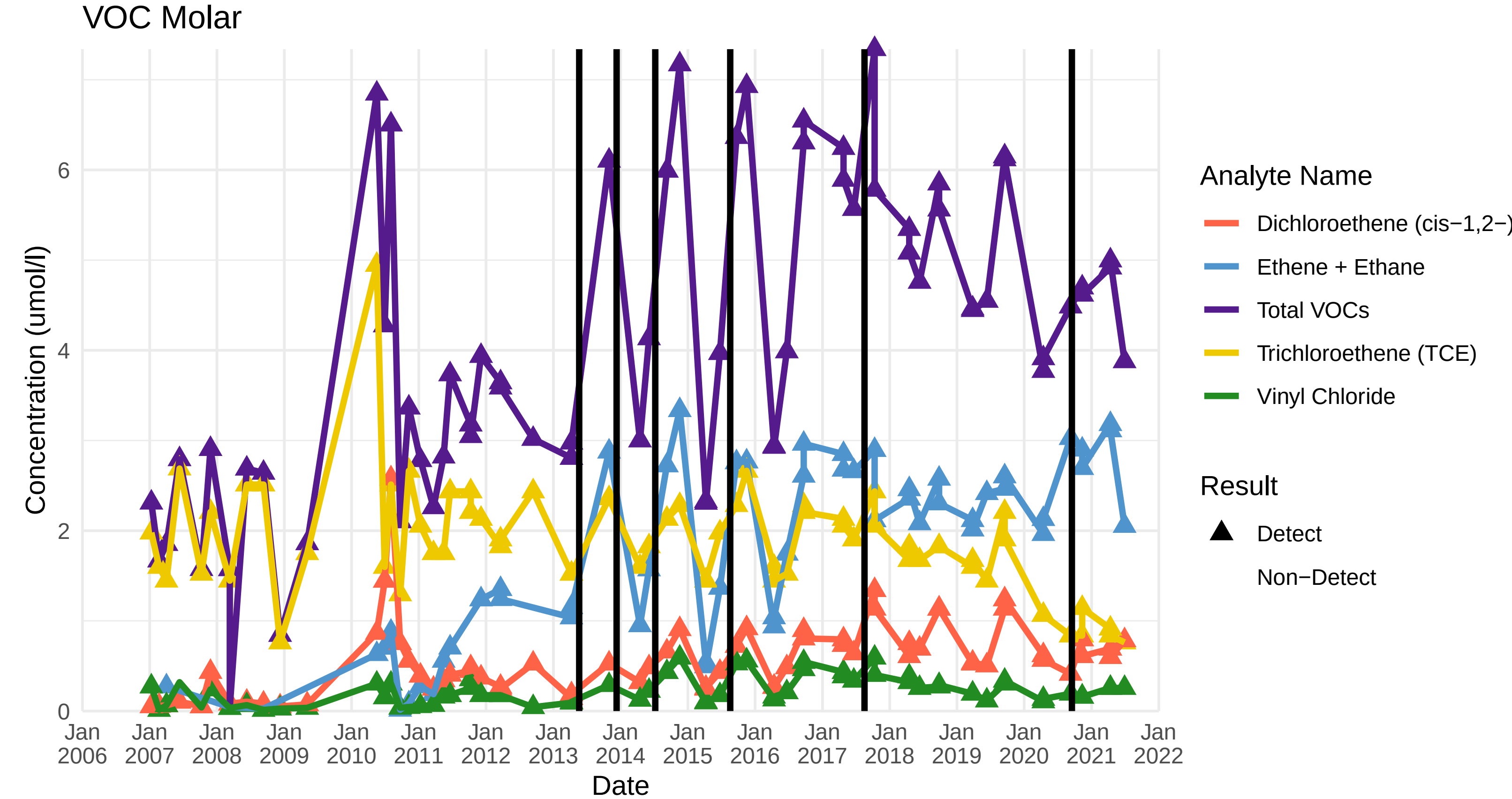
Notes:

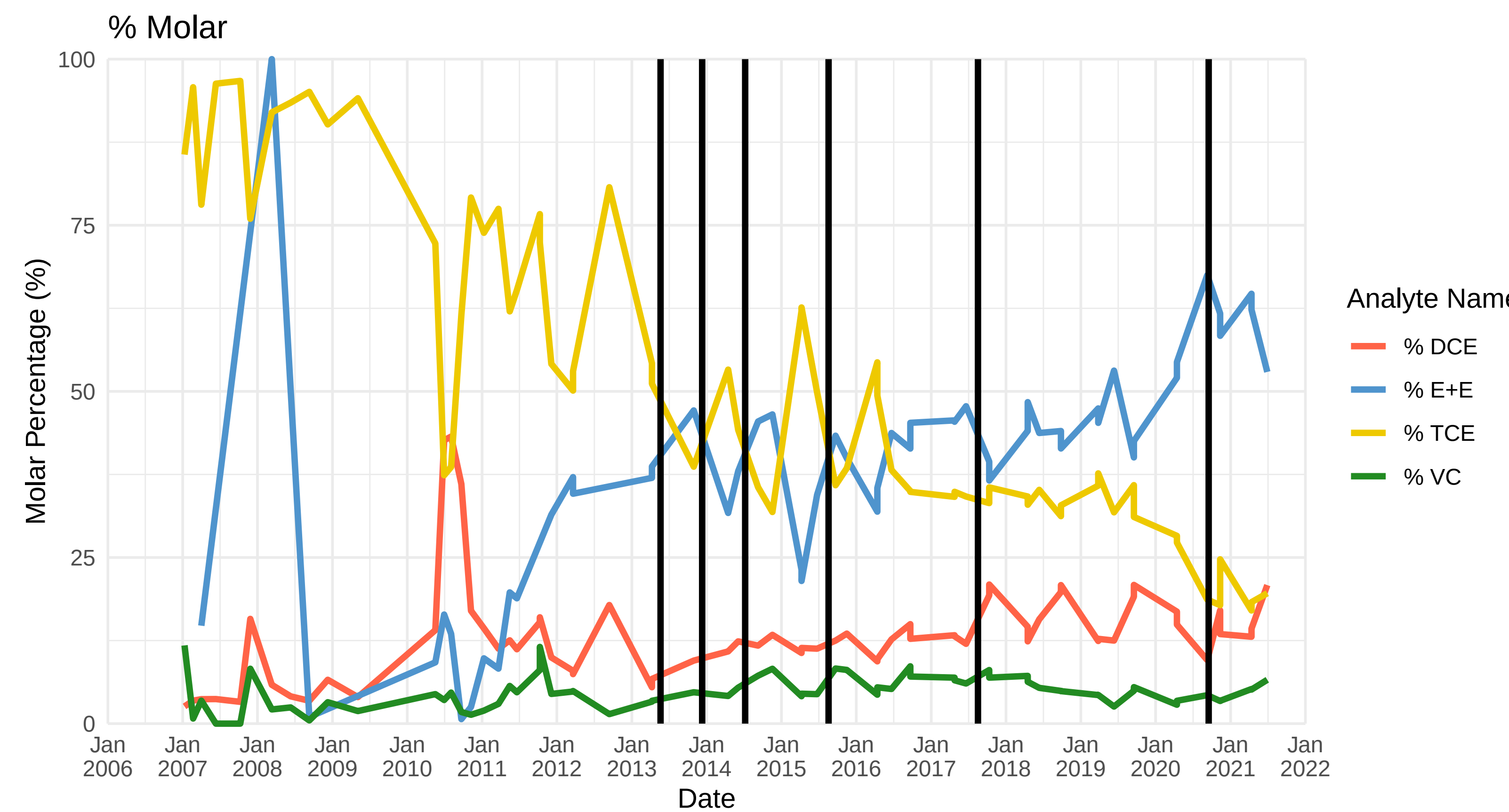
(1) Where applicable, non−detects are plotted at reporting limit and are shown with hollow symbols. Summed (total) concentrations are plotted at zero.

(2) Black vertical lines indicate amendment injection events.

(3) Reporting limits can fluctuate based on sample dilutions performed by the lab due to varying concentrations of other compounds, some of which may not be shown in these time series, matrix interference like the presence of amendment oil droplets, or other factors.







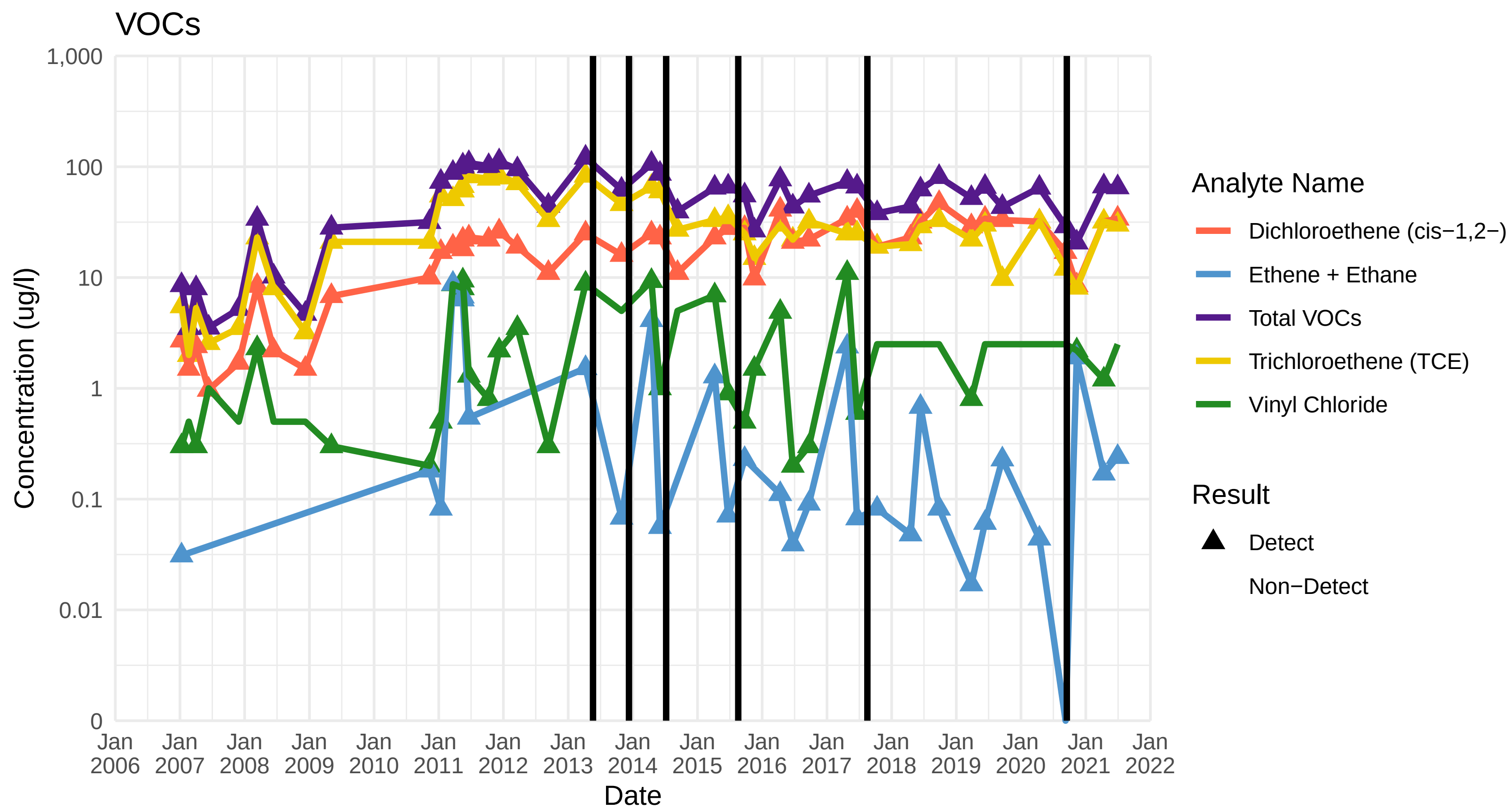
BP−5A

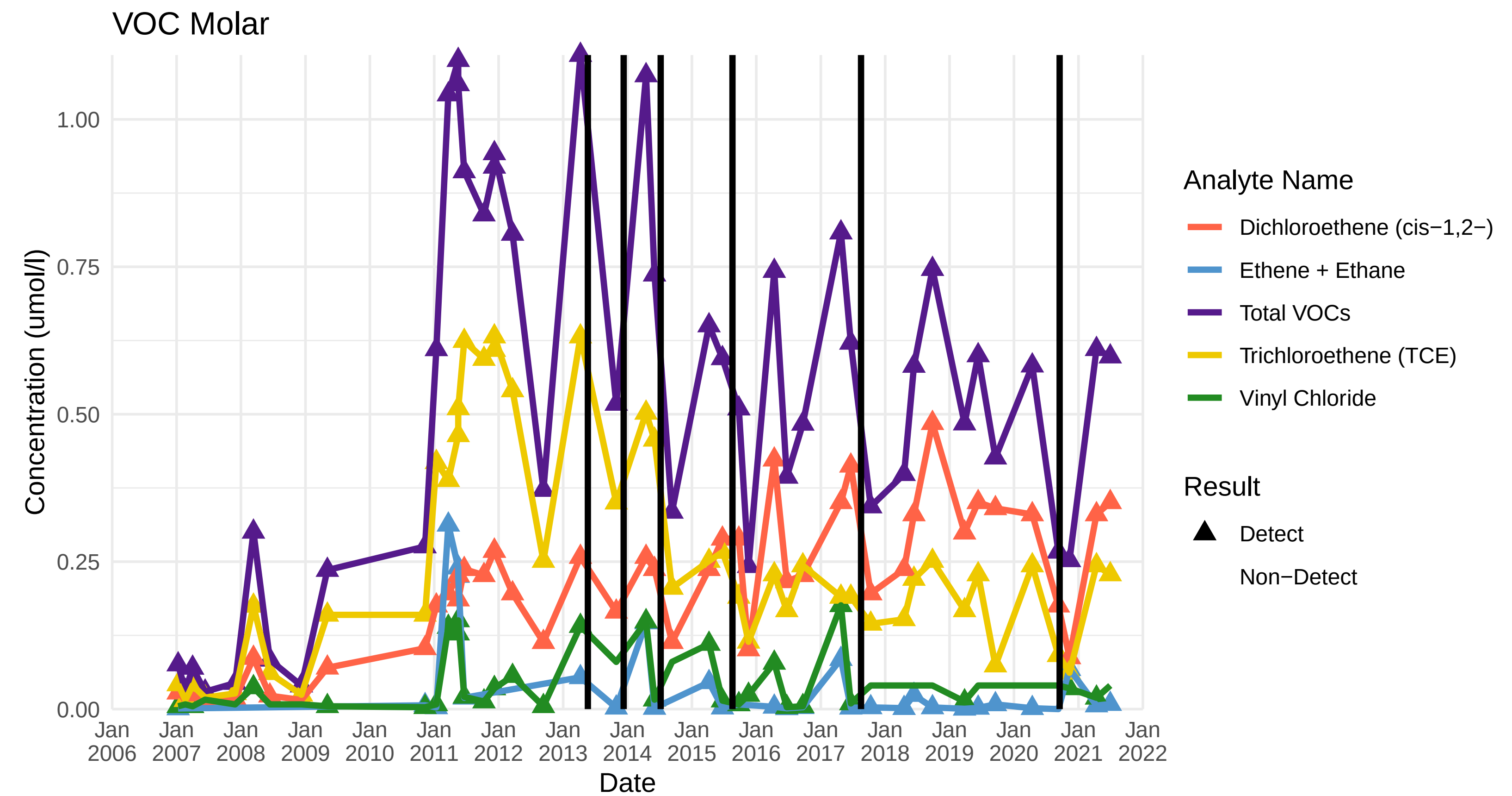
Notes:

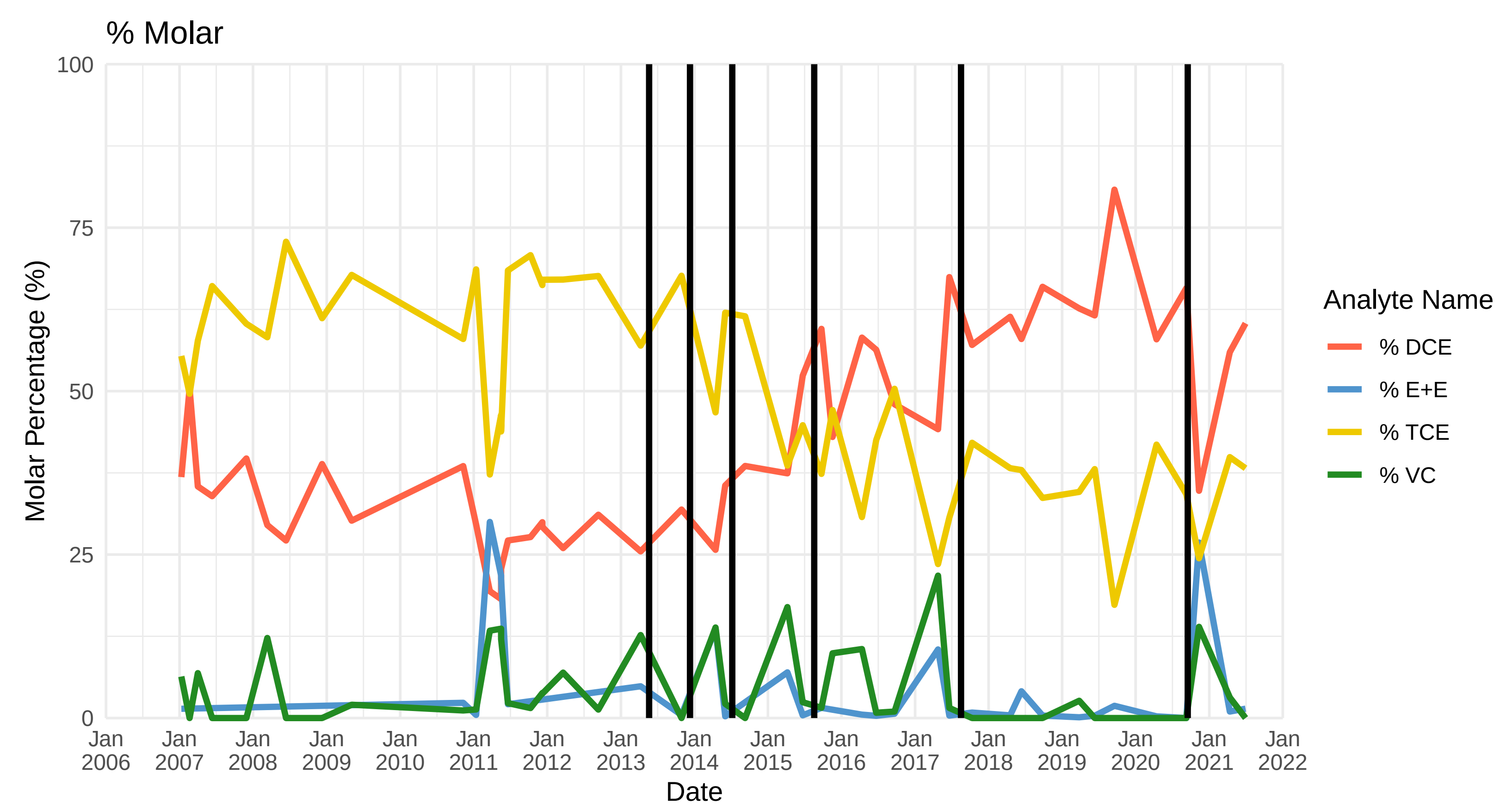
(1) Where applicable, non−detects are plotted at reporting limit and are shown with hollow symbols. Summed (total) concentrations are plotted at zero.

(2) Black vertical lines indicate amendment injection events.

(3) Reporting limits can fluctuate based on sample dilutions performed by the lab due to varying concentrations of other compounds, some of which may not be shown in these time series, matrix interference like the presence of amendment oil droplets, or other factors.







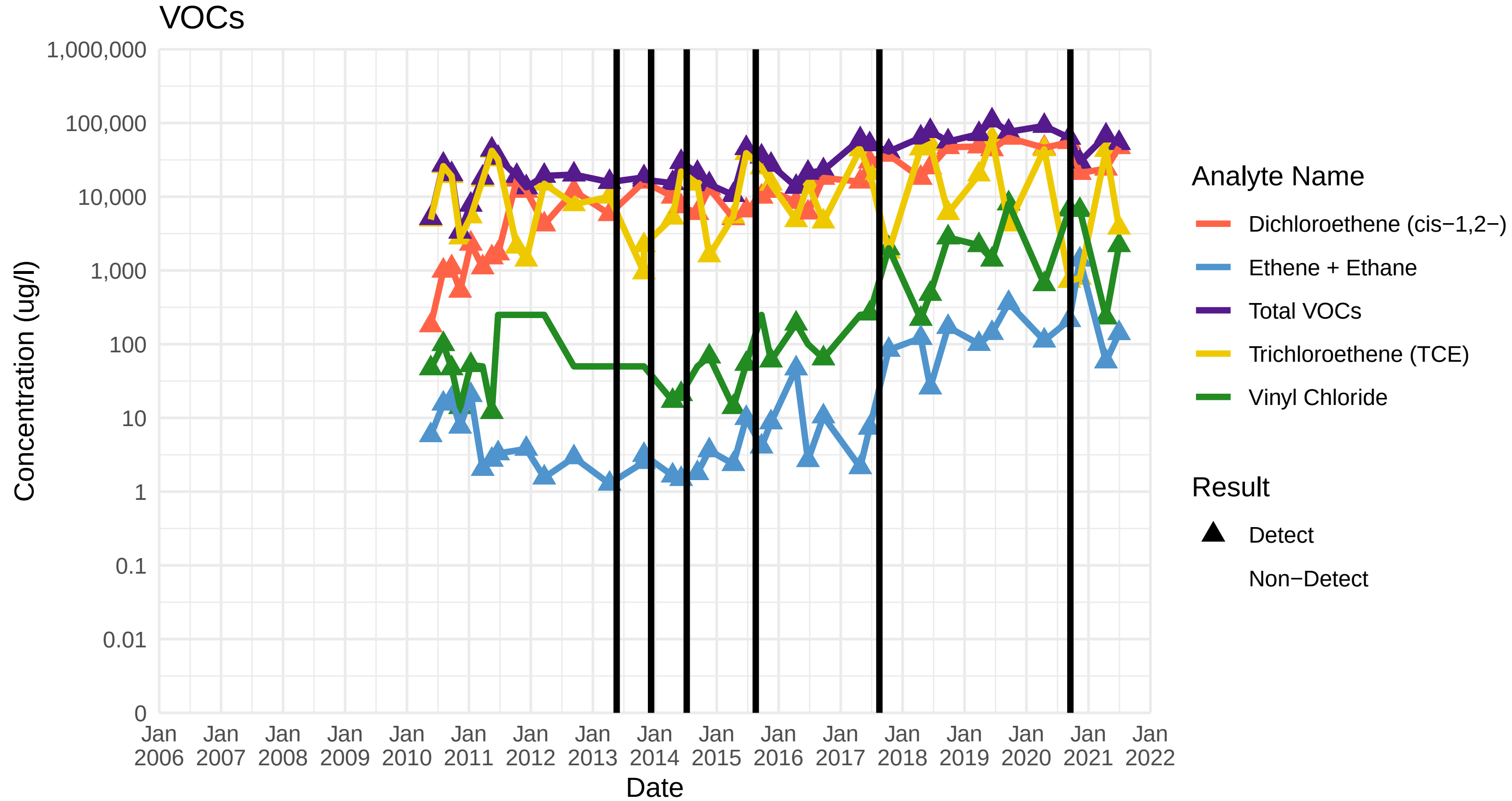
BP−6A

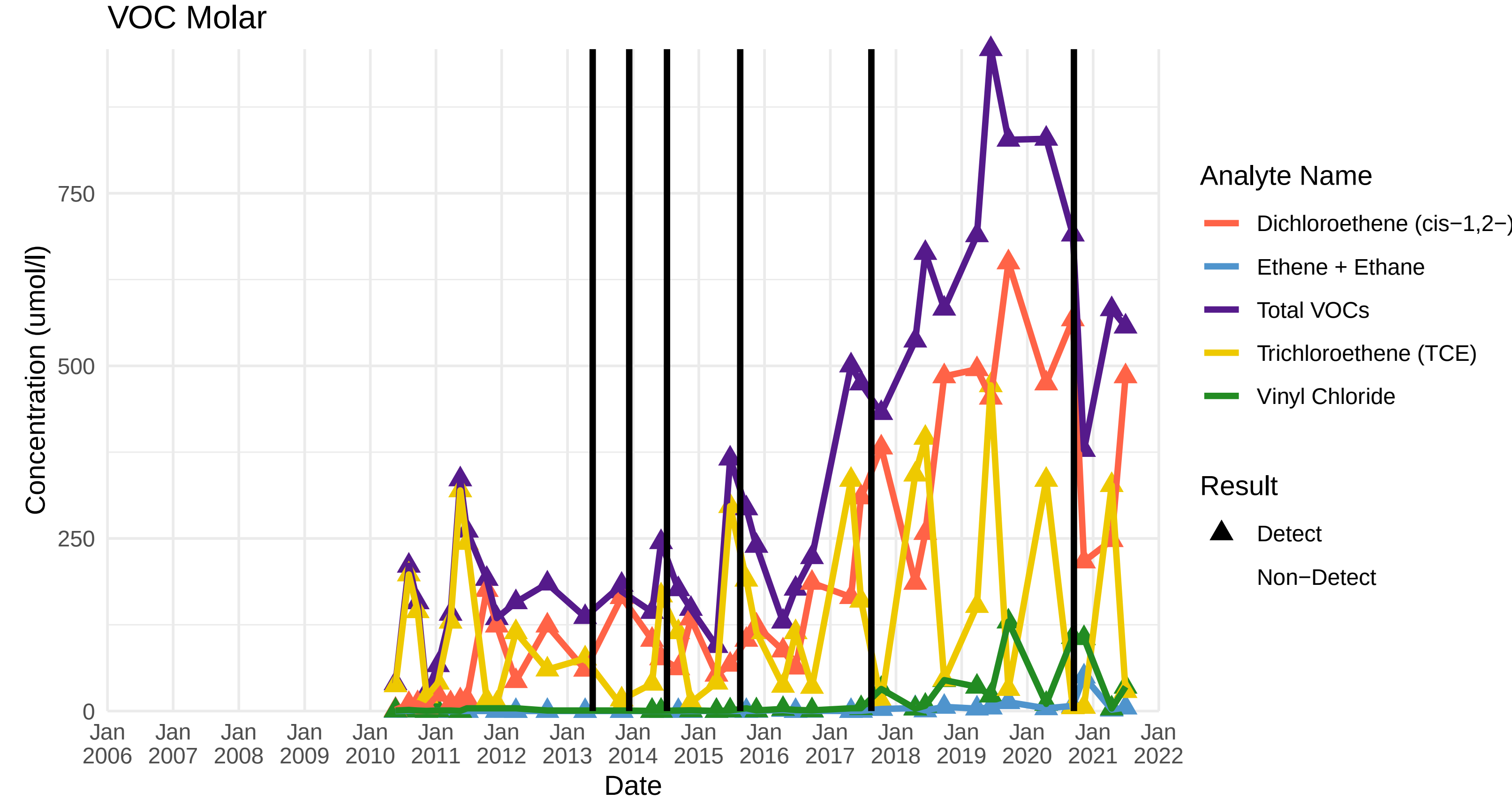
Notes:

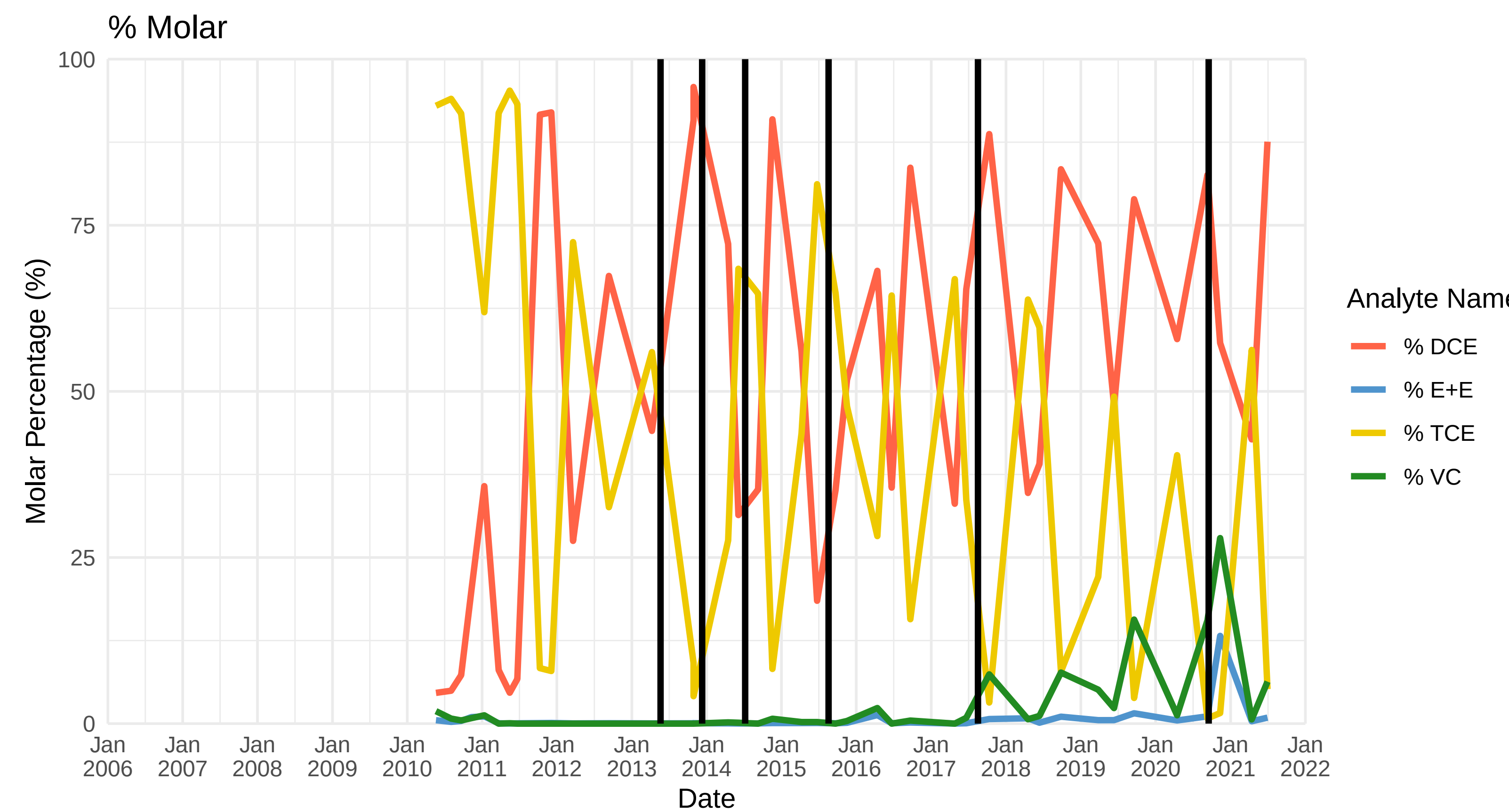
(1) Where applicable, non−detects are plotted at reporting limit and are shown with hollow symbols. Summed (total) concentrations are plotted at zero.

(2) Black vertical lines indicate amendment injection events.

(3) Reporting limits can fluctuate based on sample dilutions performed by the lab due to varying concentrations of other compounds, some of which may not be shown in these time series, matrix interference like the presence of amendment oil droplets, or other factors.







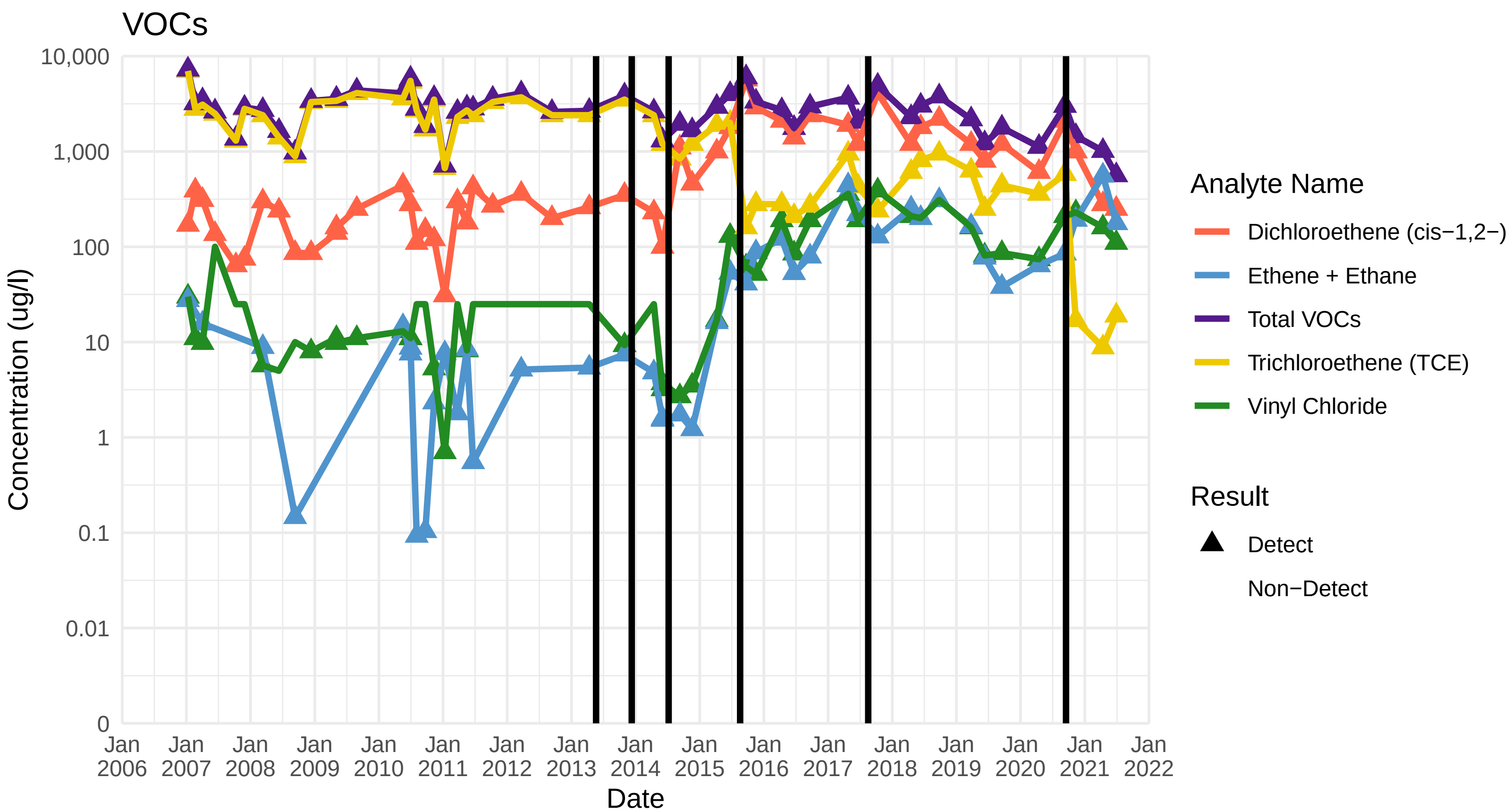
BP−9A

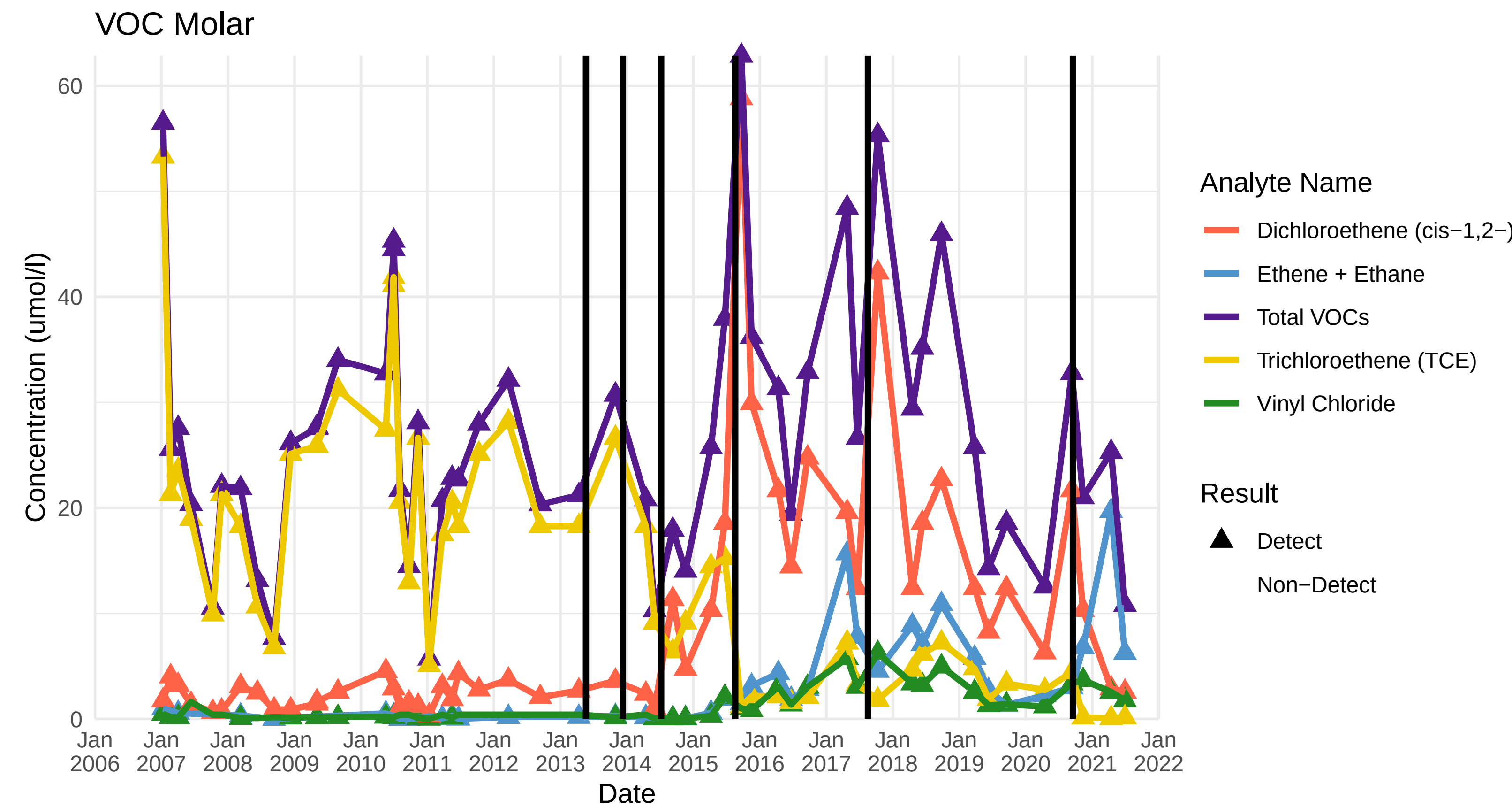
Notes:

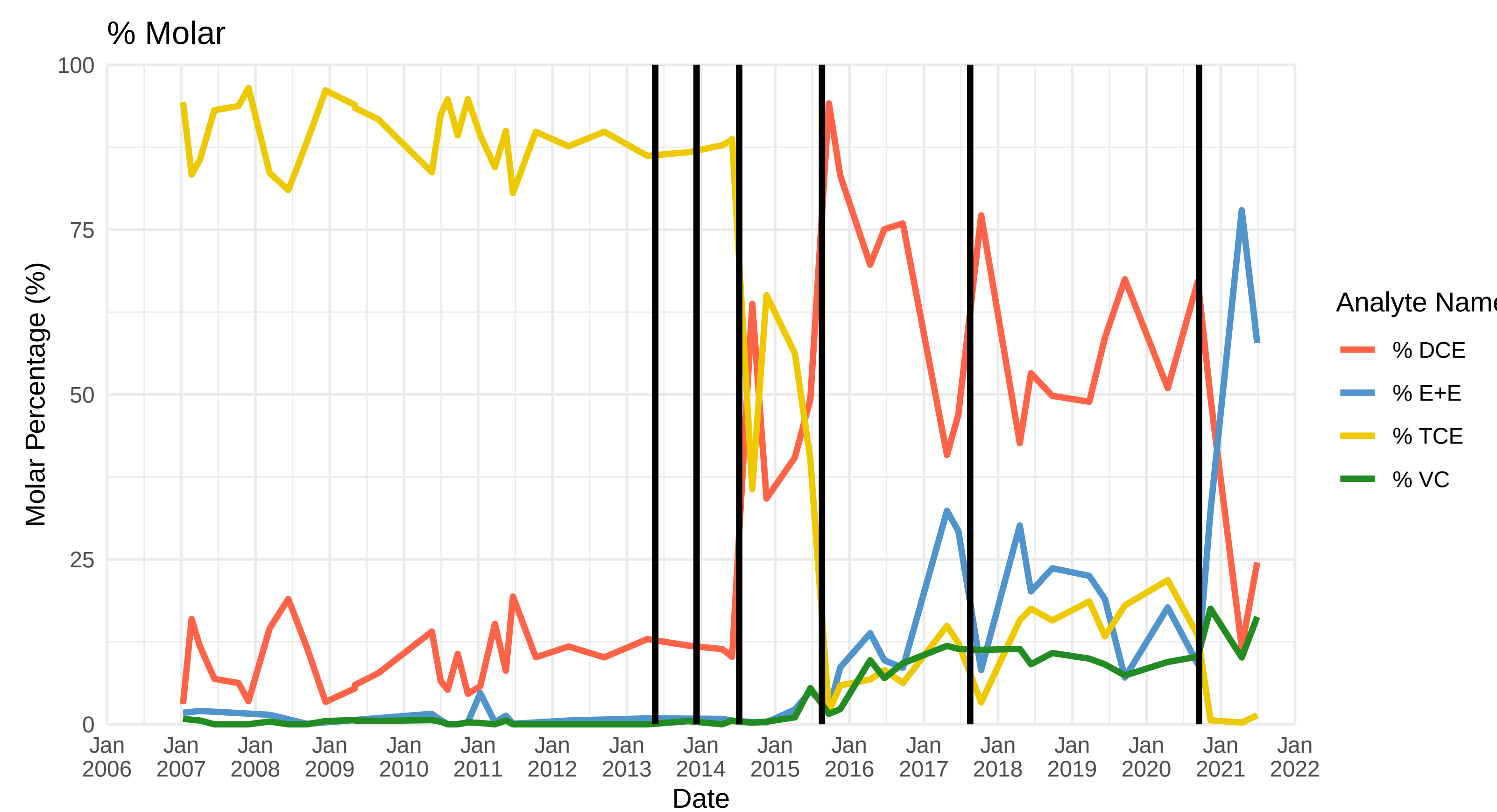
(1) Where applicable, non−detects are plotted at reporting limit and are shown with hollow symbols. Summed (total) concentrations are plotted at zero.

(2) Black vertical lines indicate amendment injection events.

(3) Reporting limits can fluctuate based on sample dilutions performed by the lab due to varying concentrations of other compounds, some of which may not be shown in these time series, matrix interference like the presence of amendment oil droplets, or other factors.







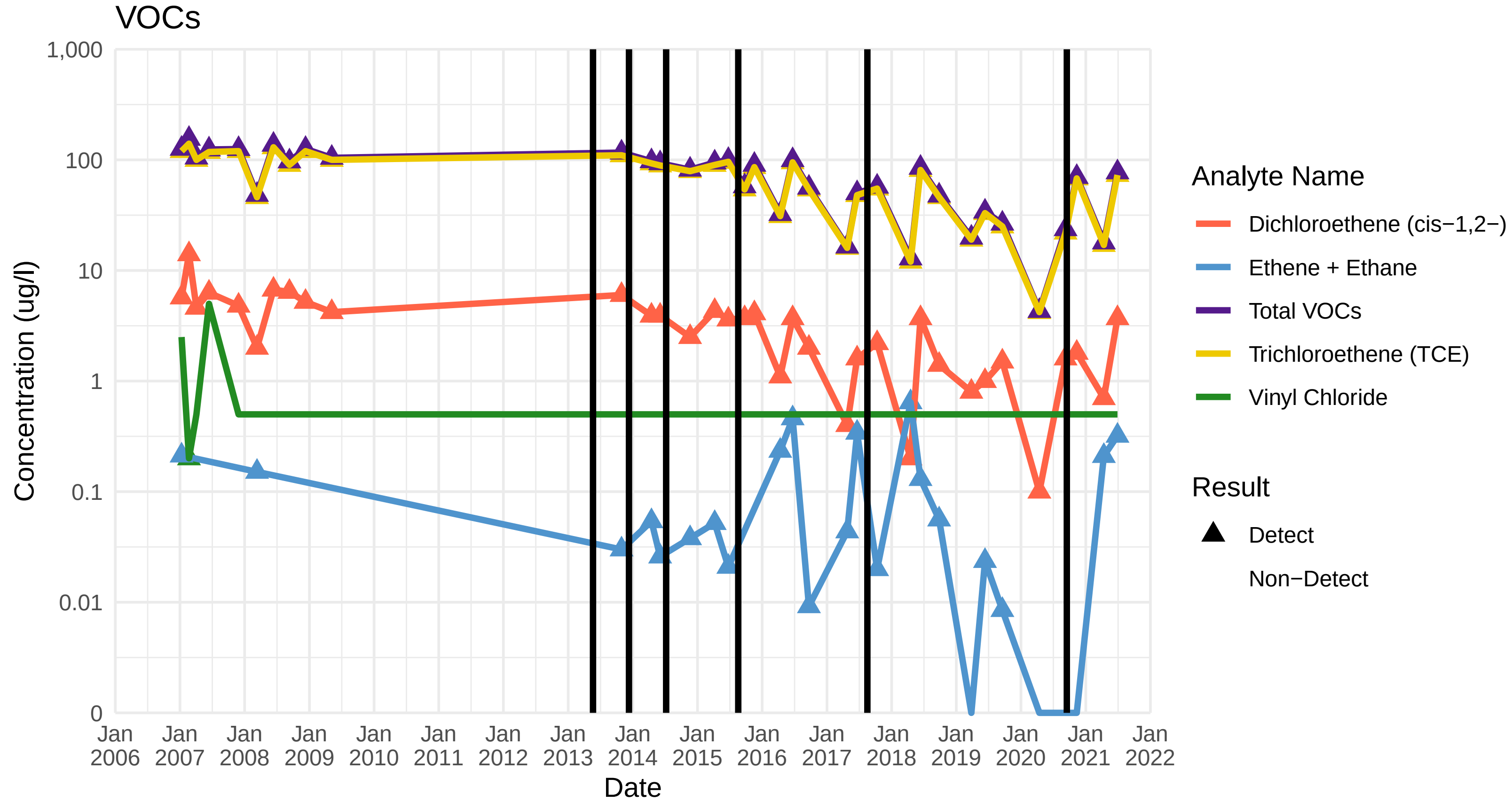
BP−13A

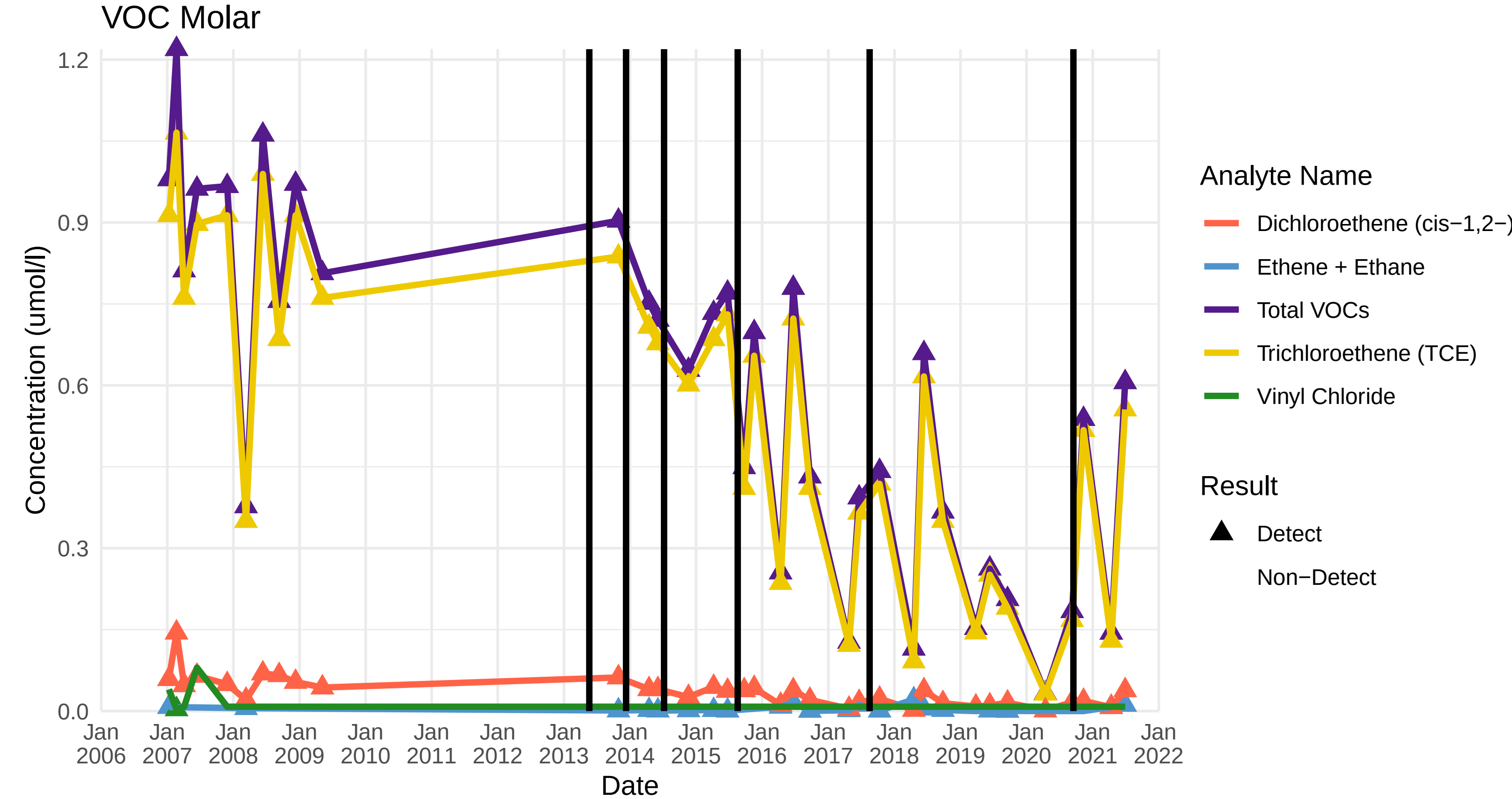
Notes:

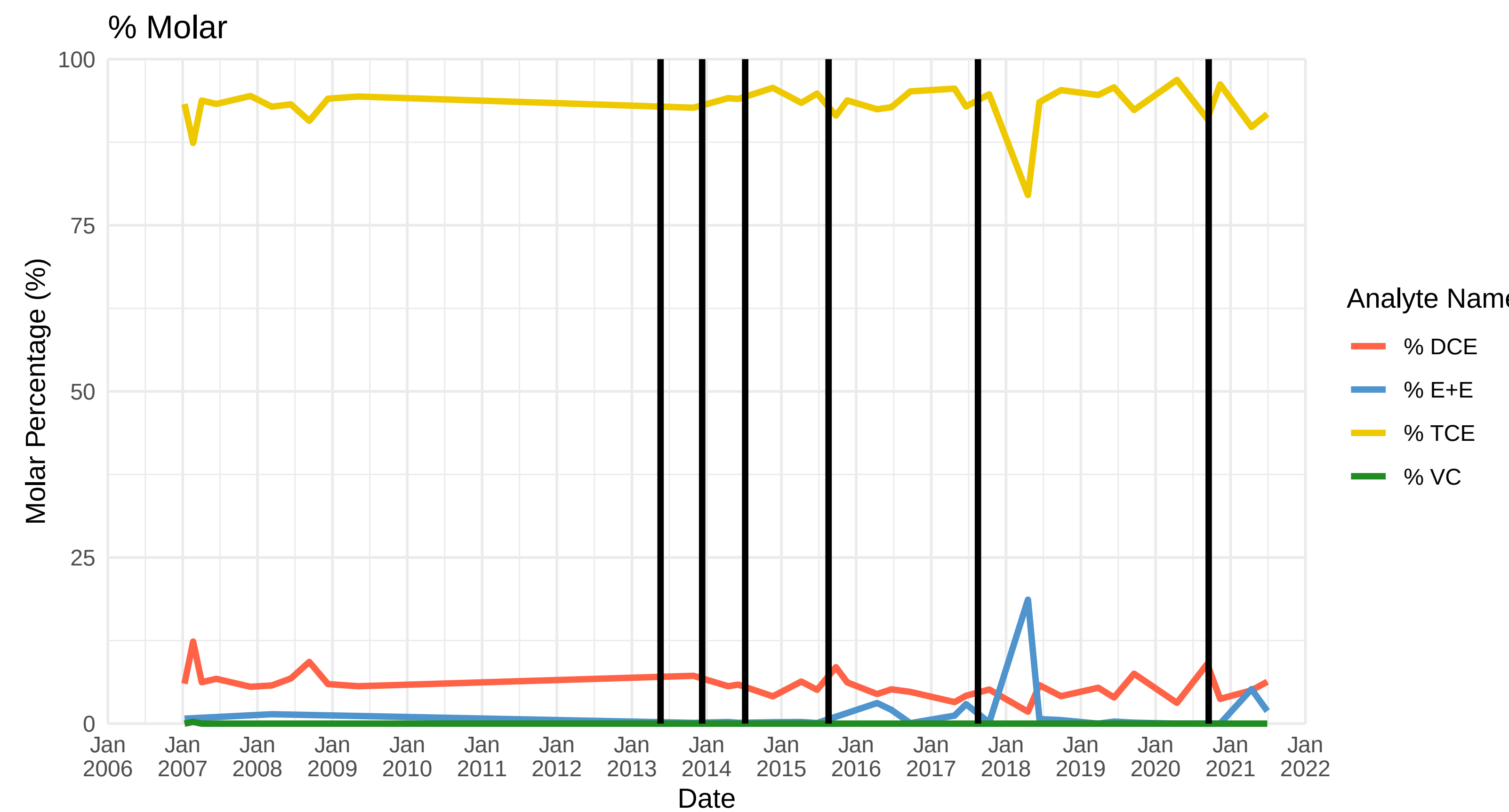
(1) Where applicable, non−detects are plotted at reporting limit and are shown with hollow symbols. Summed (total) concentrations are plotted at zero.

(2) Black vertical lines indicate amendment injection events.

(3) Reporting limits can fluctuate based on sample dilutions performed by the lab due to varying concentrations of other compounds, some of which may not be shown in these time series, matrix interference like the presence of amendment oil droplets, or other factors.







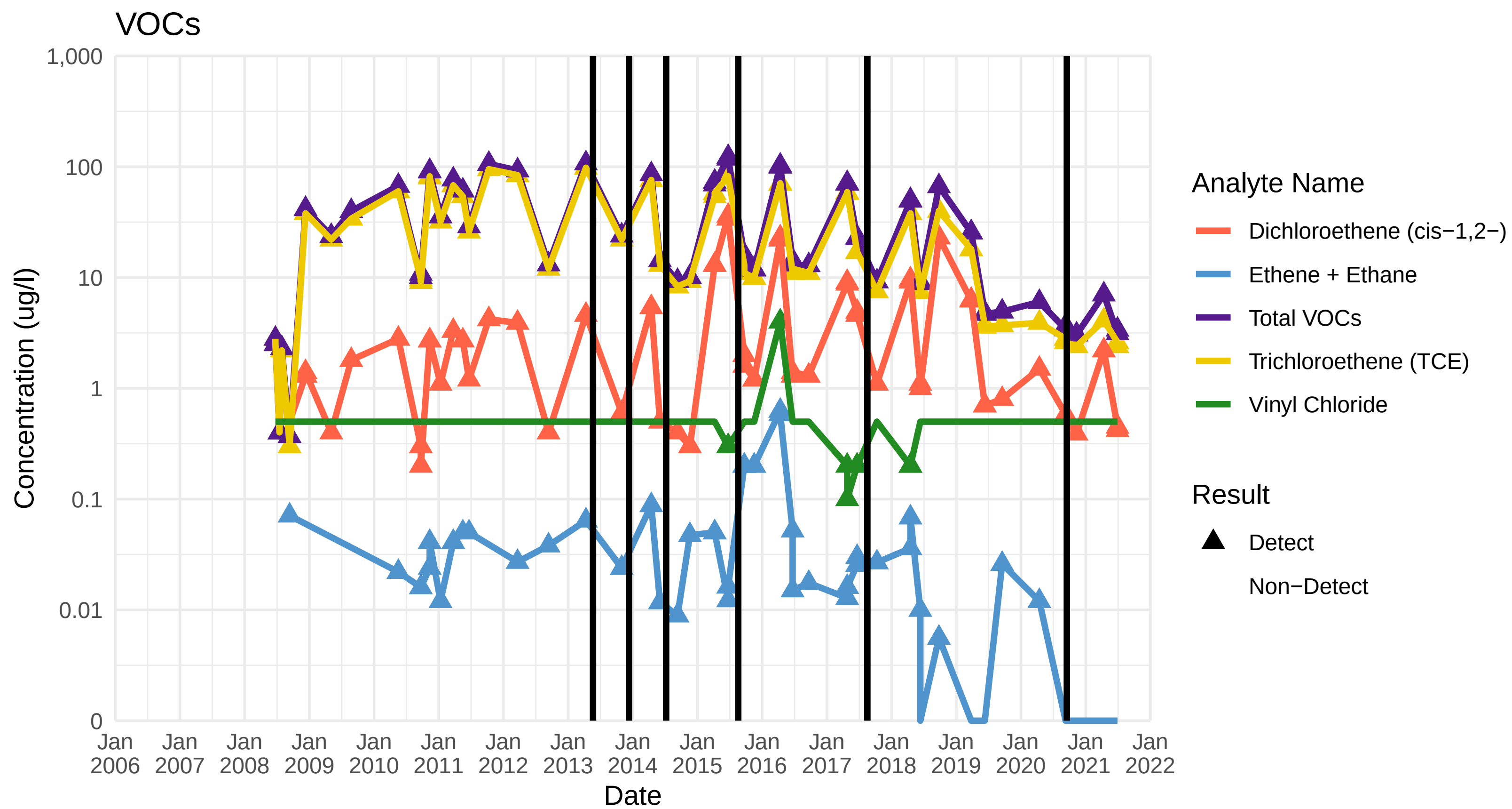
BP−31A

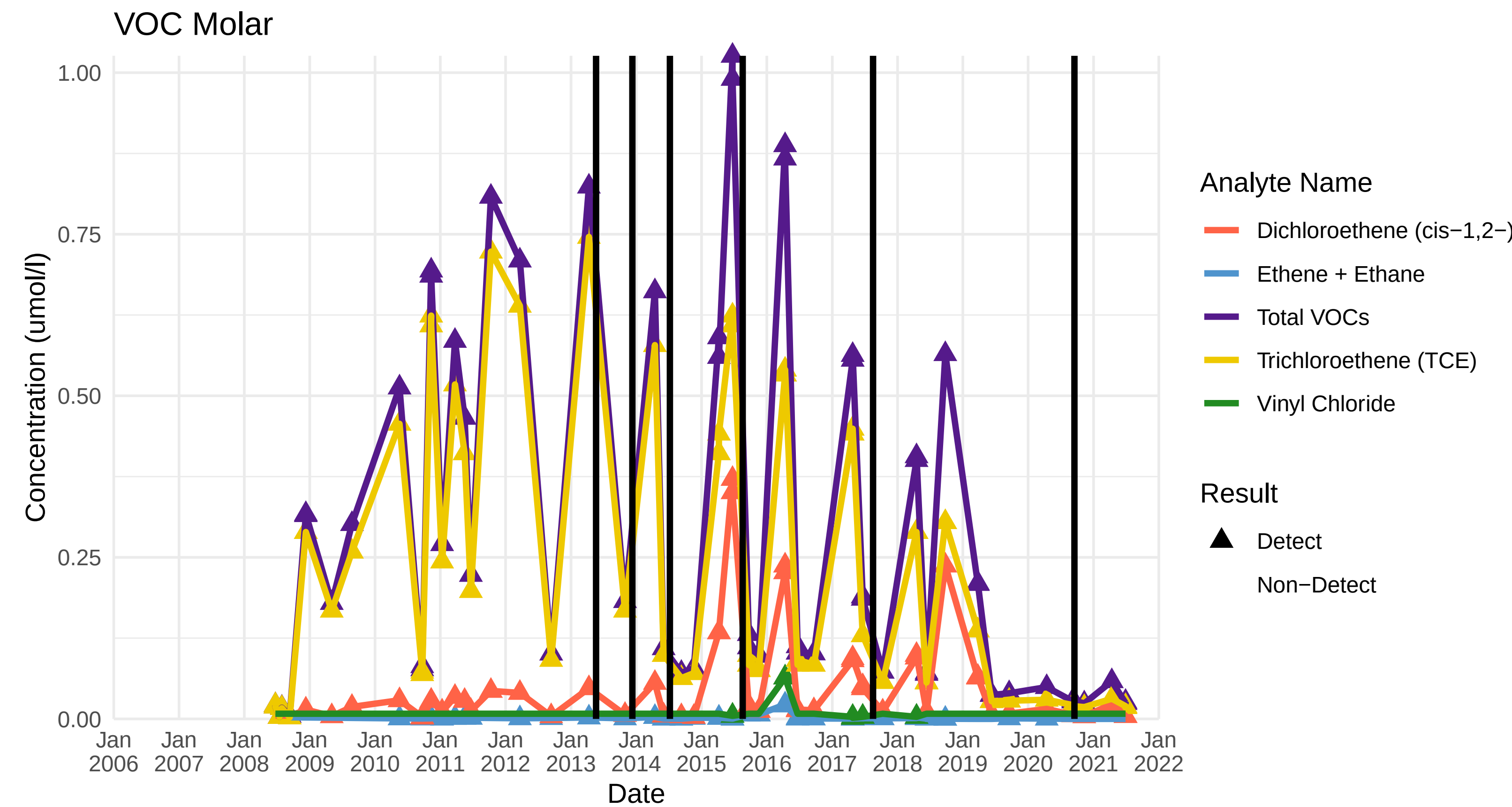
Notes:

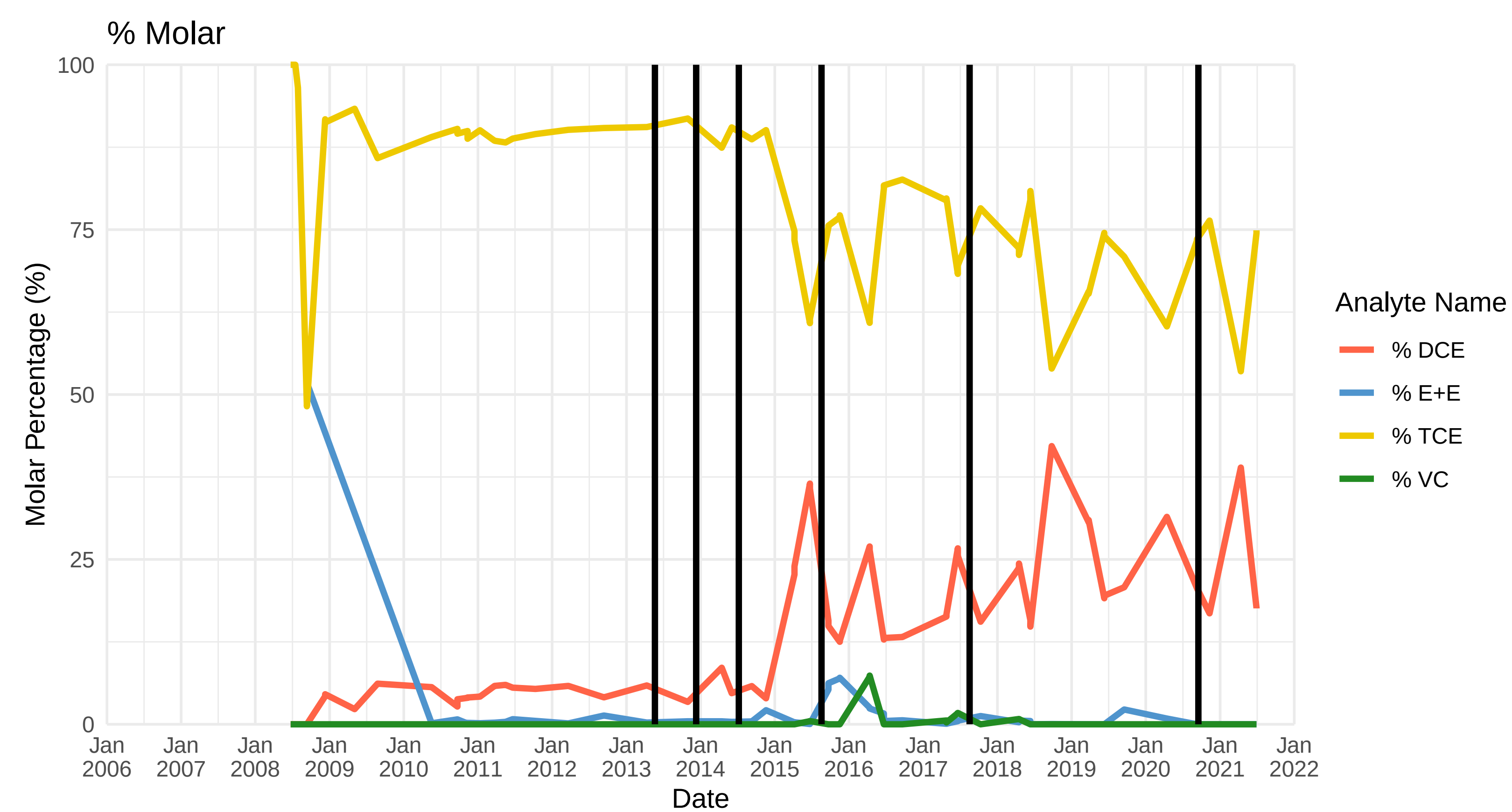
(1) Where applicable, non−detects are plotted at reporting limit and are shown with hollow symbols. Summed (total) concentrations are plotted at zero.

(2) Black vertical lines indicate amendment injection events.

(3) Reporting limits can fluctuate based on sample dilutions performed by the lab due to varying concentrations of other compounds, some of which may not be shown in these time series, matrix interference like the presence of amendment oil droplets, or other factors.







BP−34A

Notes:

(1) Where applicable, non−detects are plotted at reporting limit and are shown with hollow symbols. Summed (total) concentrations are plotted at zero.

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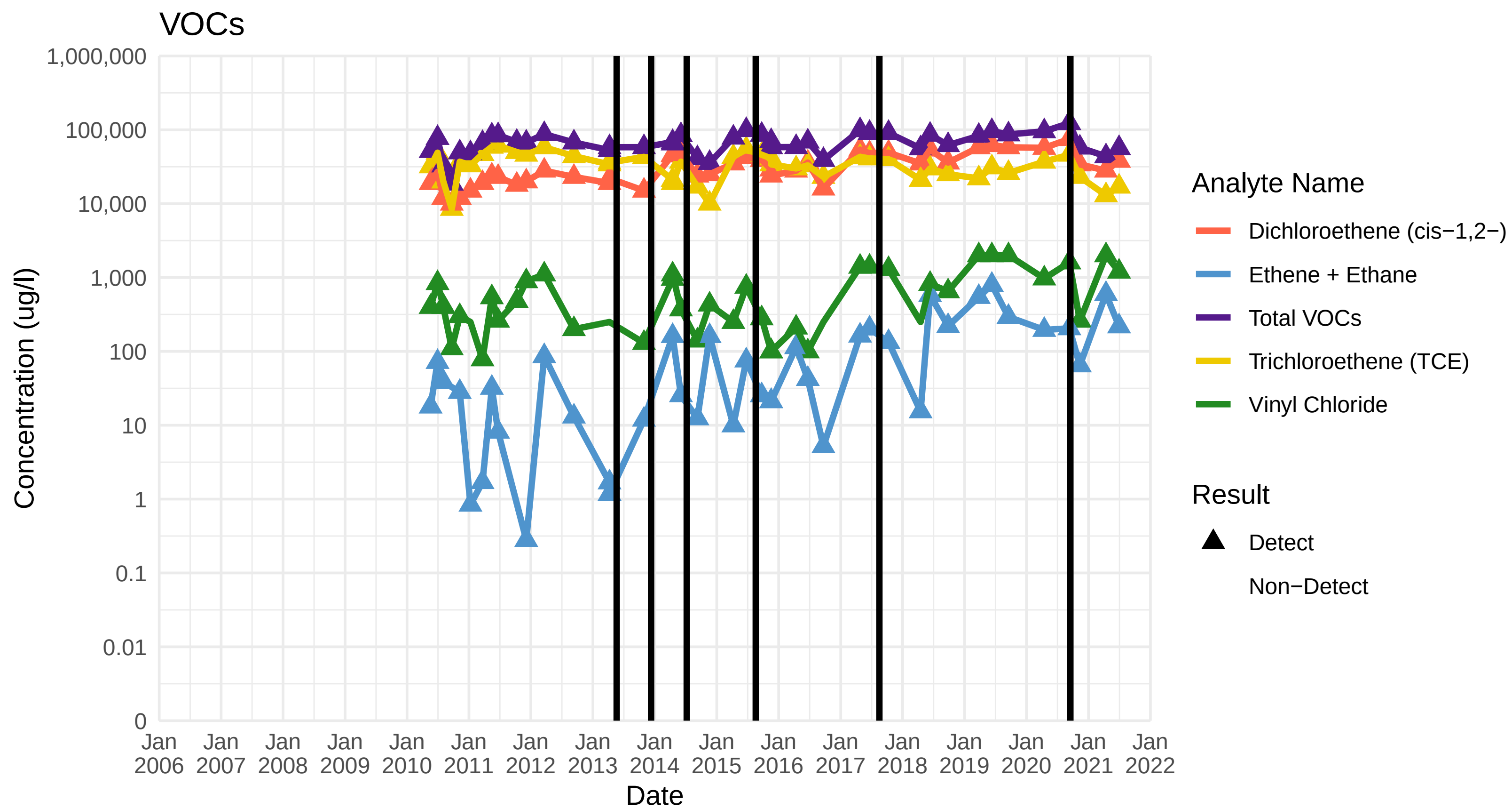

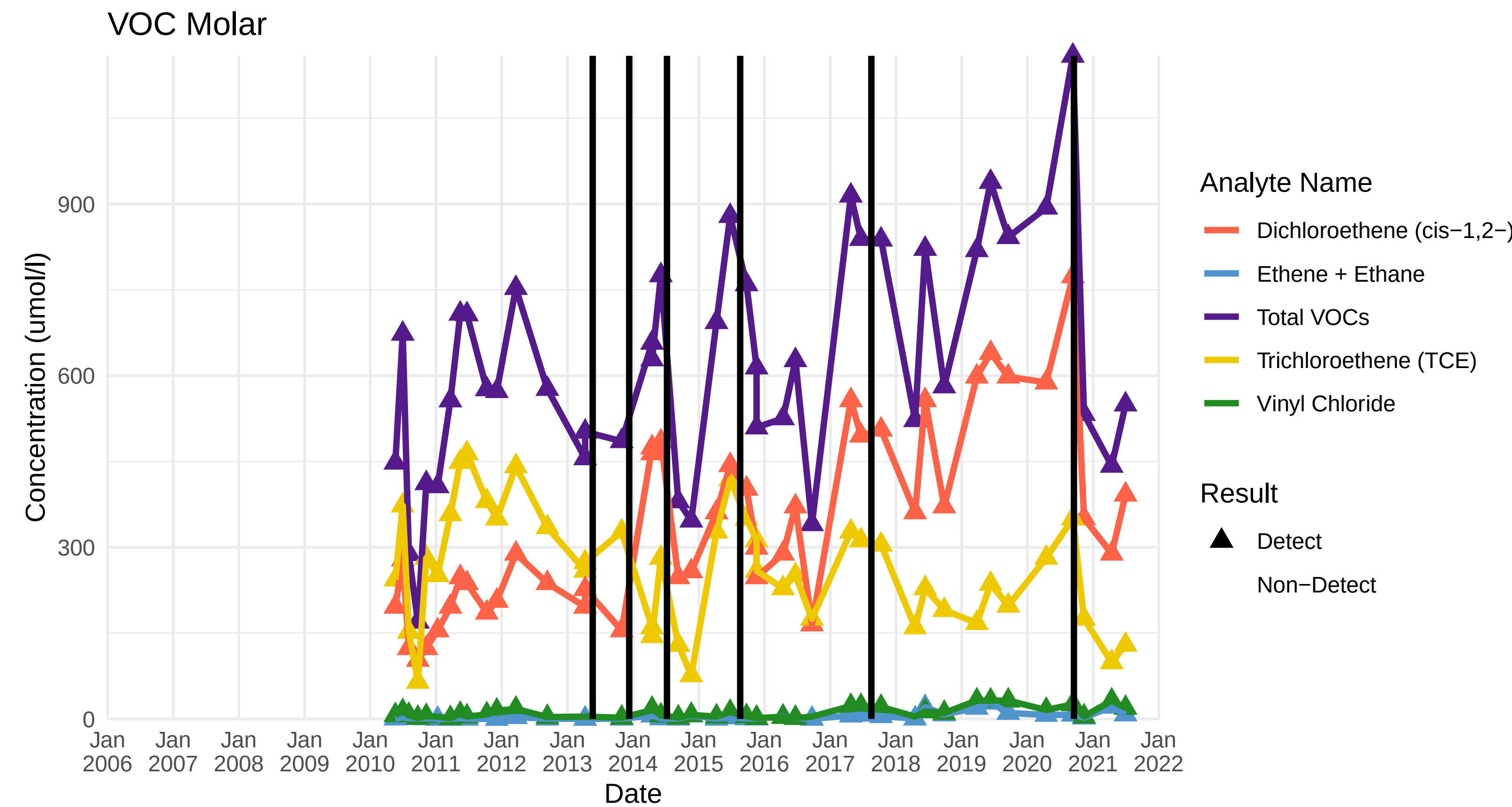

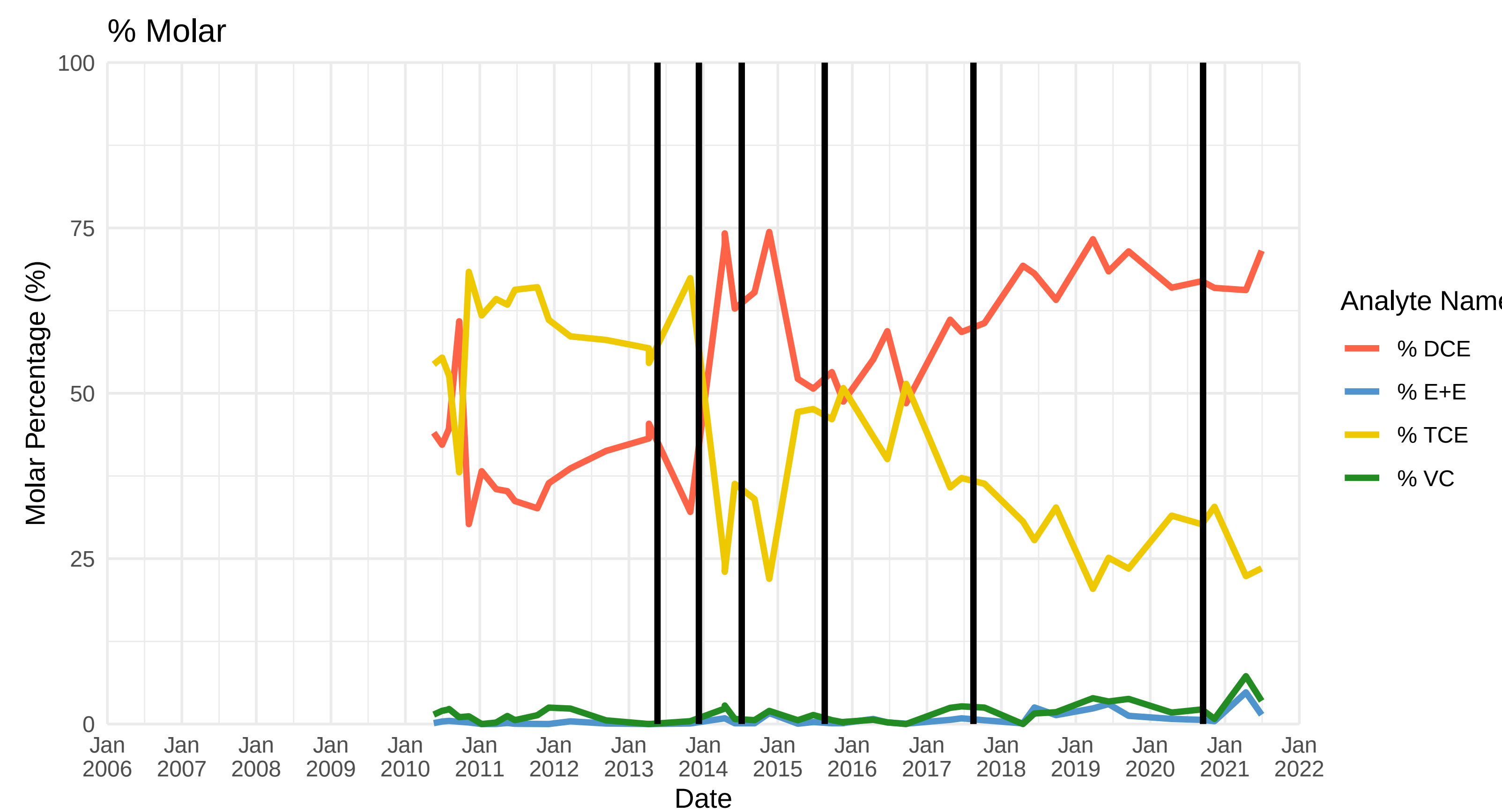

BP−35A

Notes:

(1) Where applicable, non−detects are plotted at reporting limit and are shown with hollow symbols. Summed (total) concentrations are plotted at zero.

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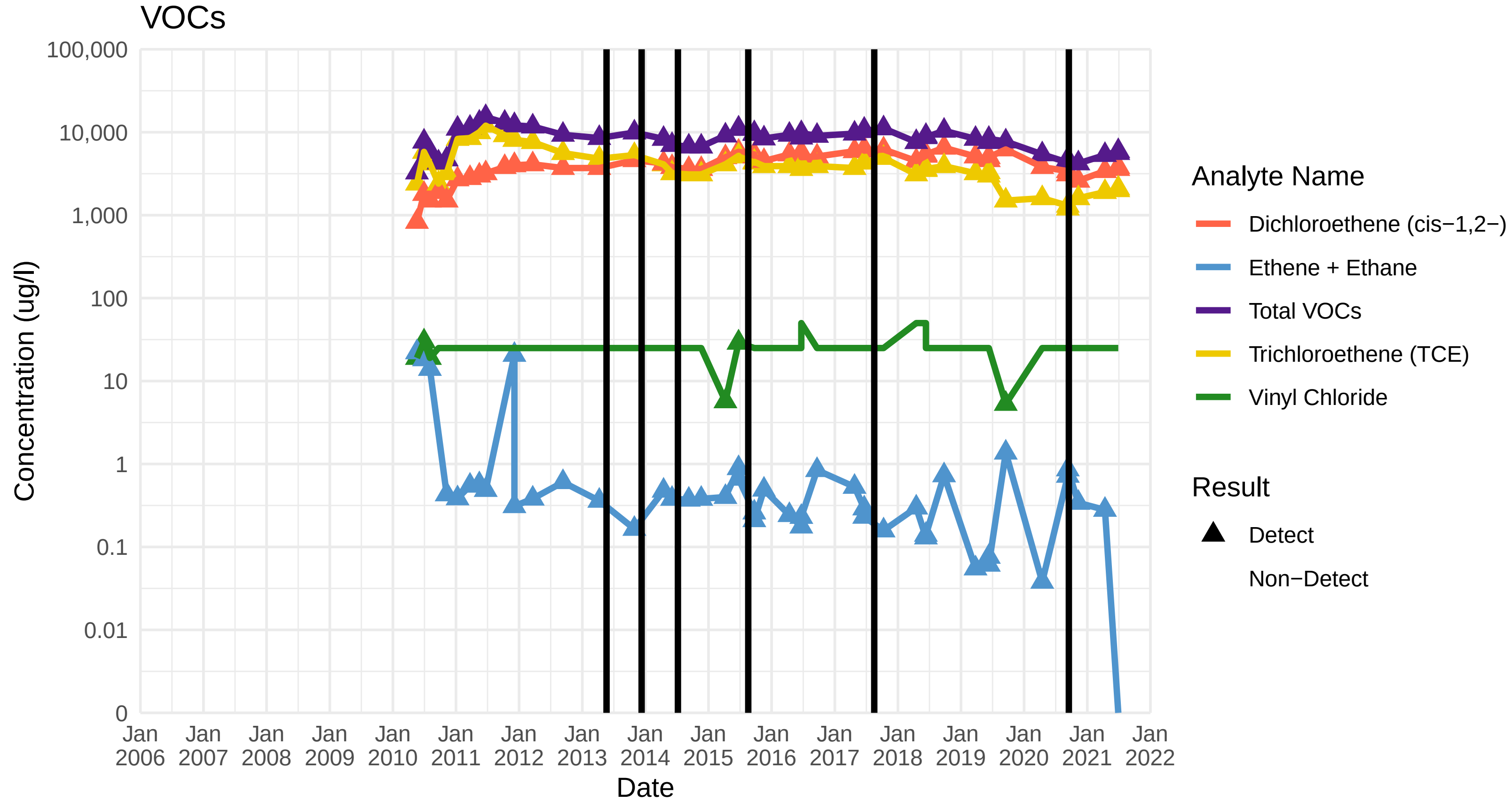
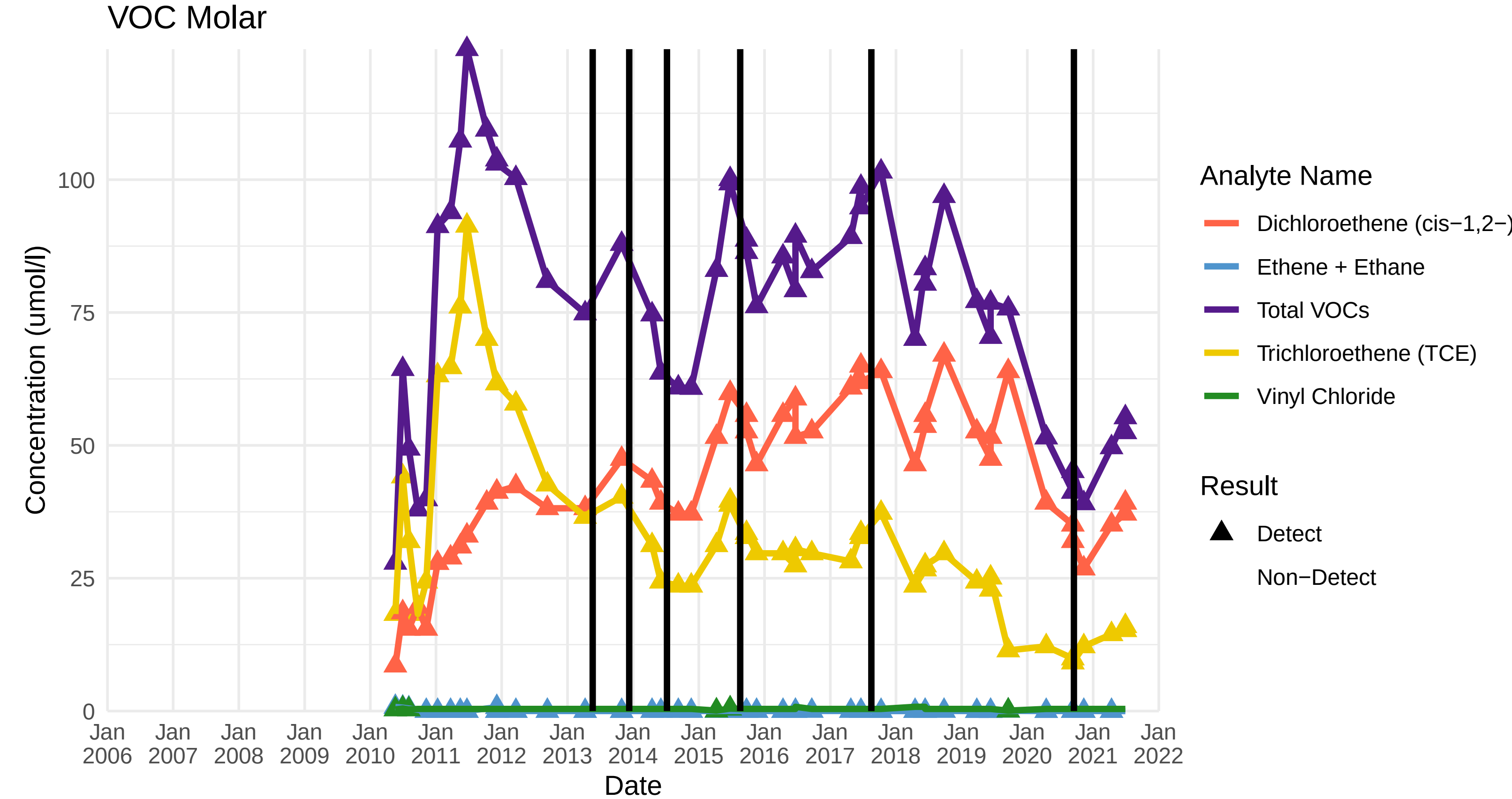
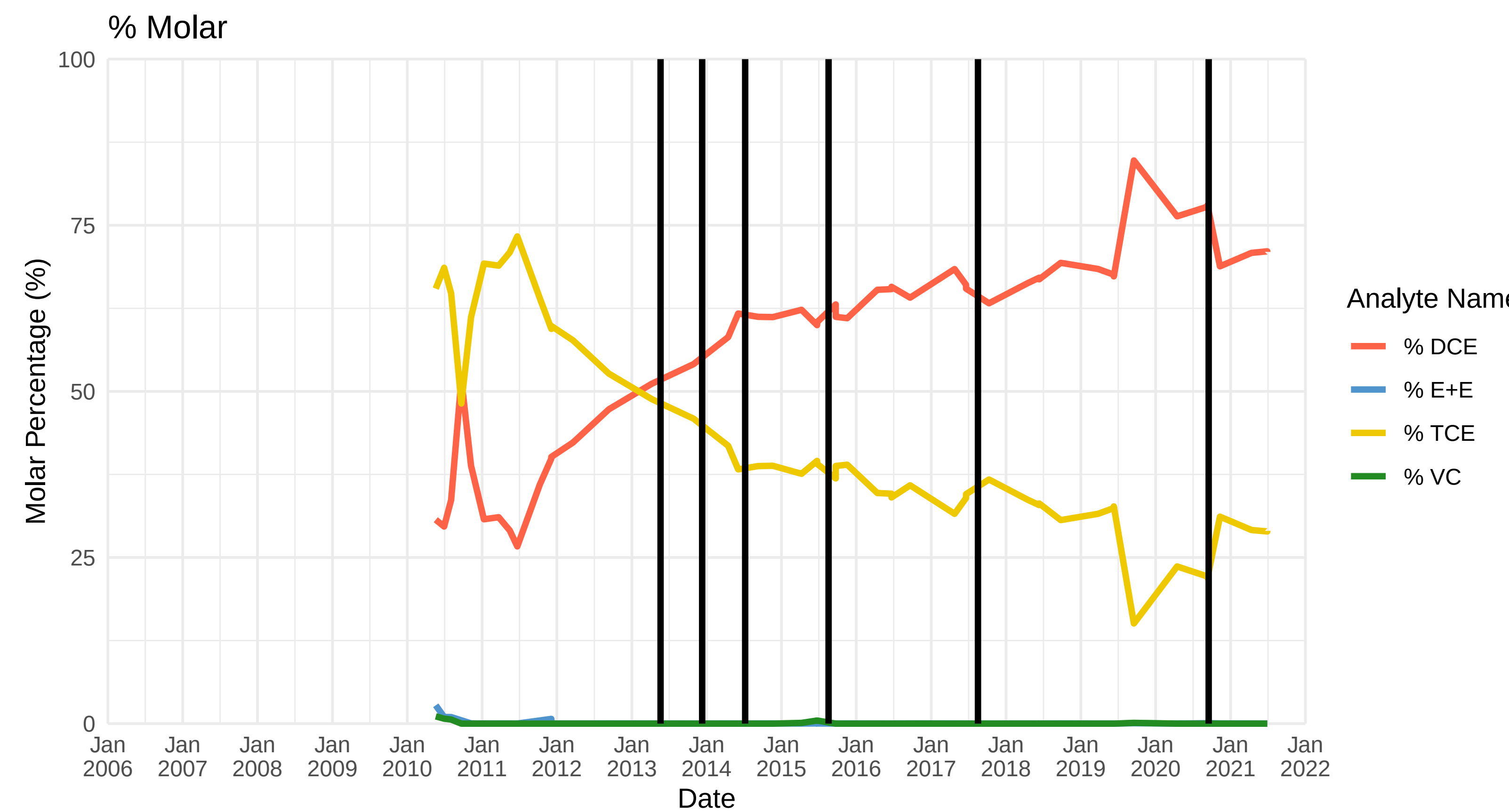
(3) Reporting limits can fluctuate based on sample dilutions performed by the lab due to varying concentrations of other compounds, some of which may not be shown in these time series, matrix interference like the presence of amendment oil droplets, or other factors.







BP−36A

Notes:

(1) Where applicable, non−detects are plotted at reporting limit and are shown with hollow symbols. Summed (total) concentrations are plotted at zero.

(2) Black vertical lines indicate amendment injection events.

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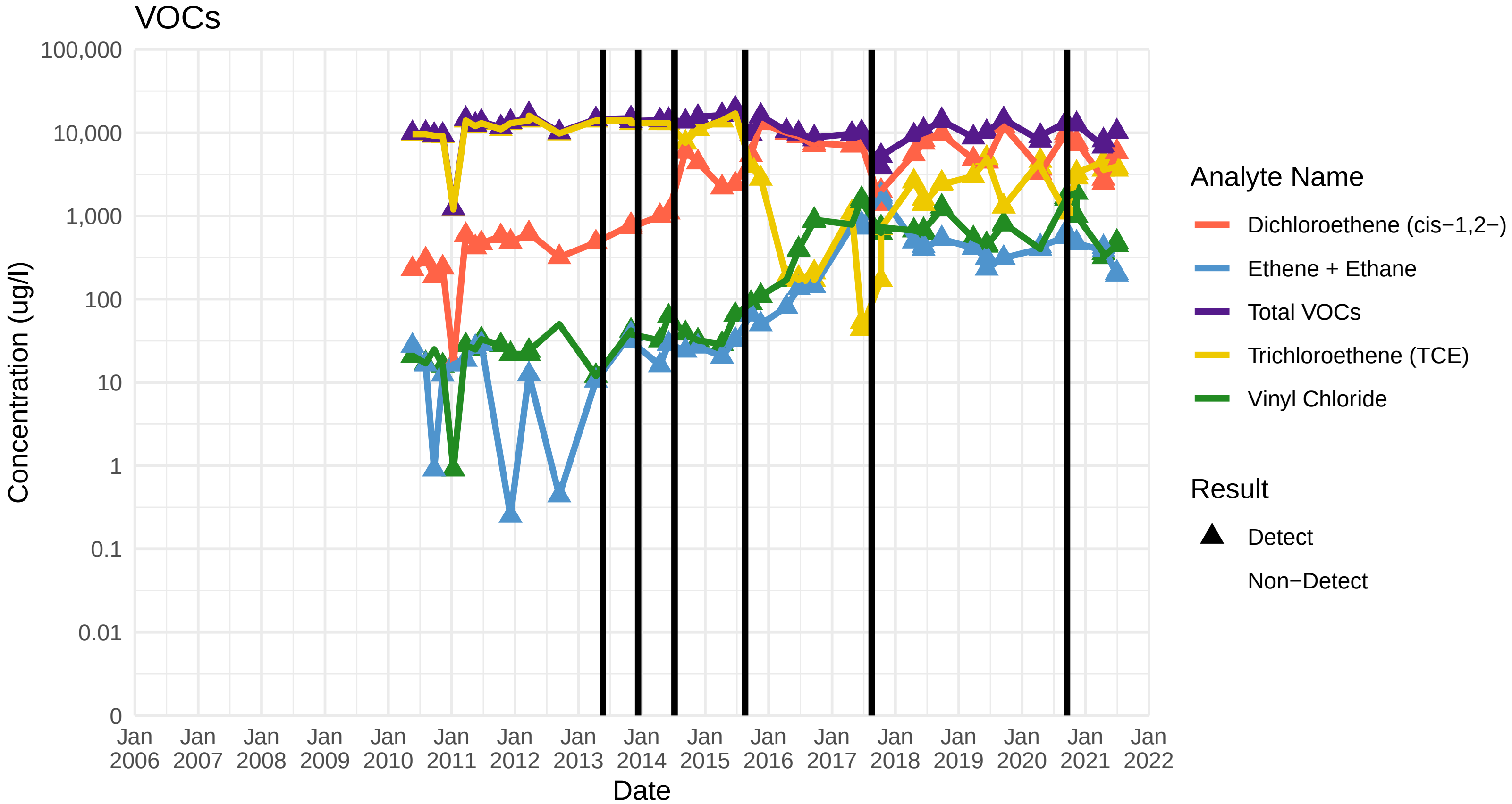

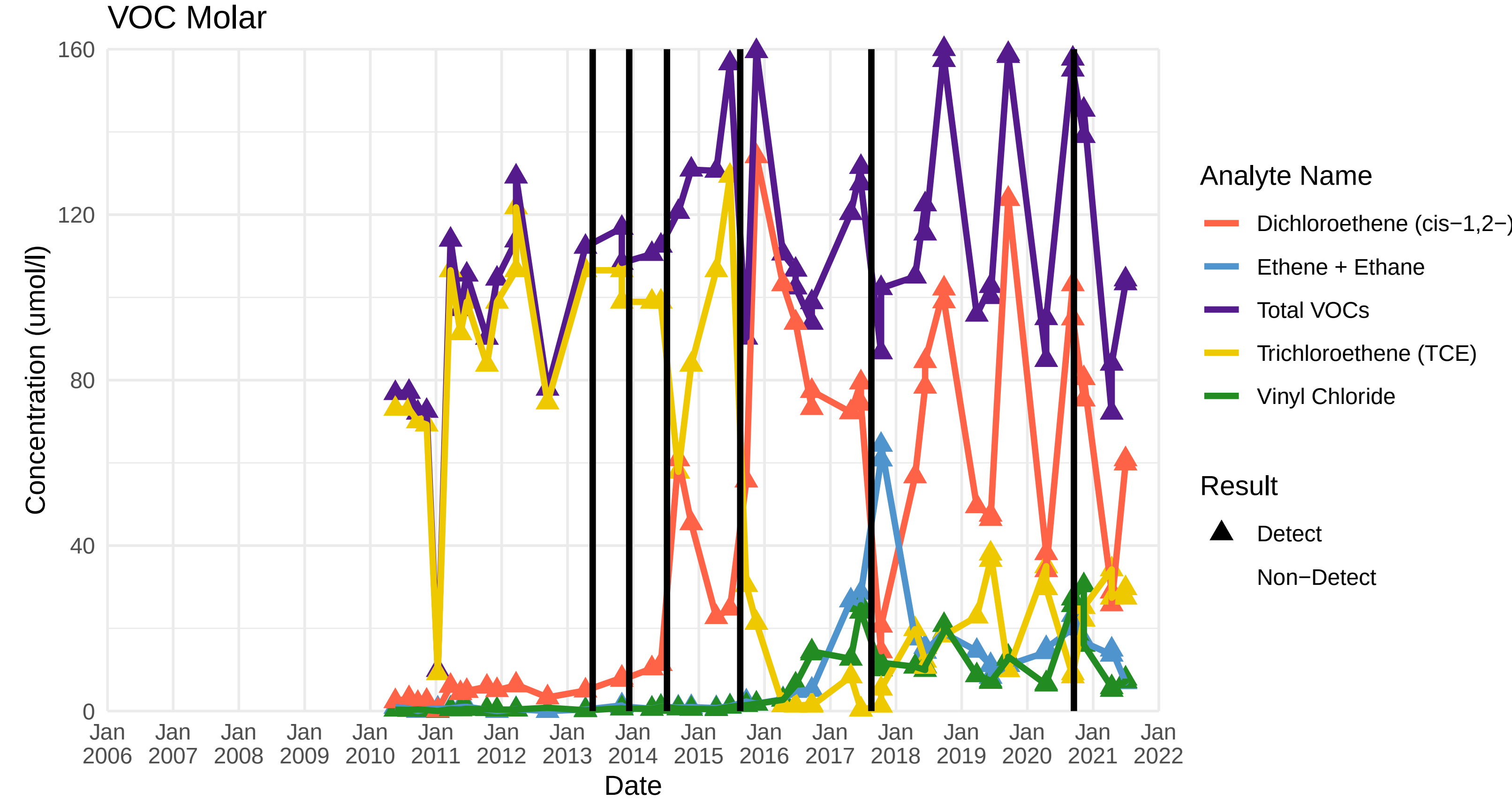

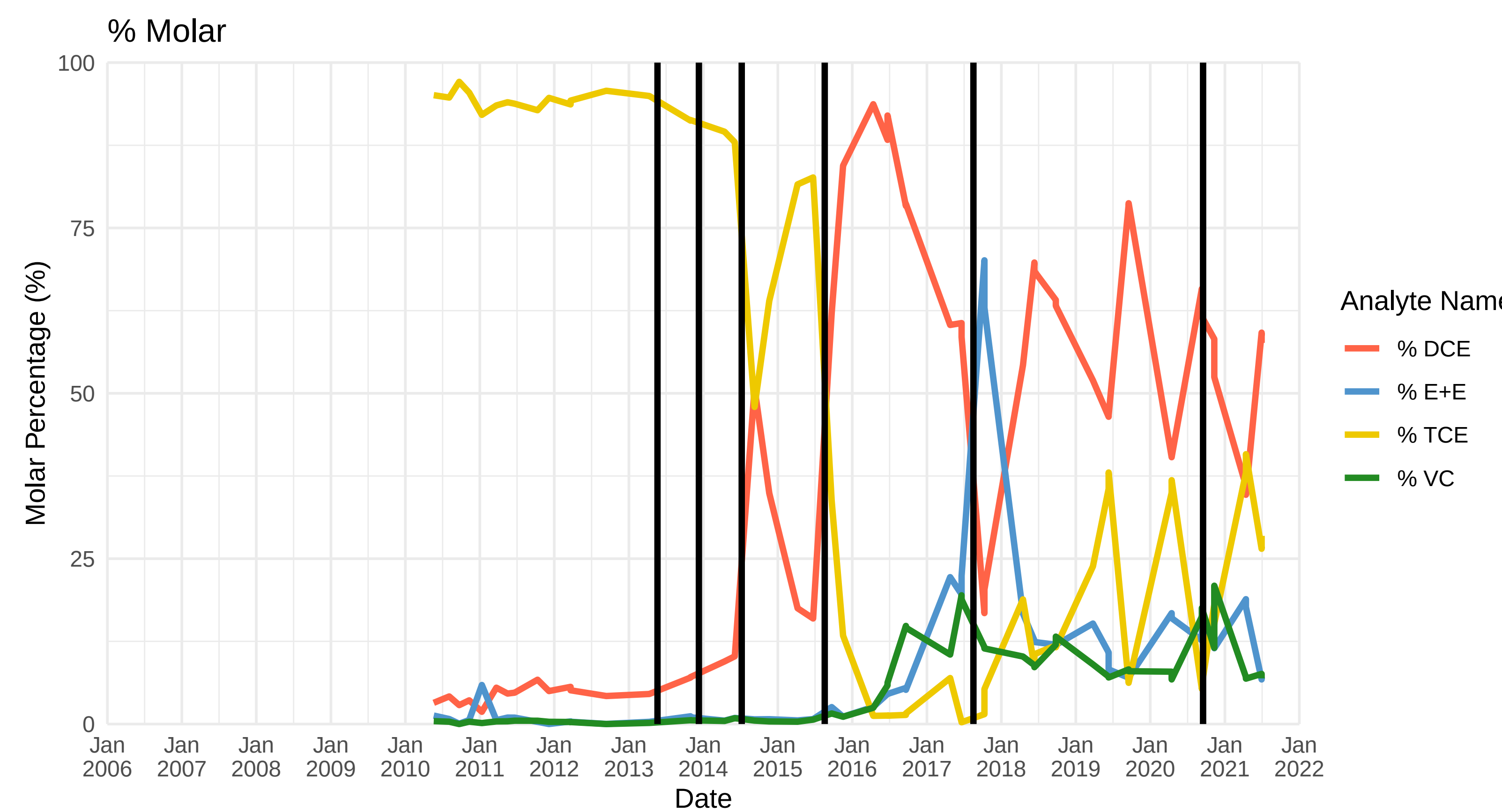

BP−37A

Notes:

(1) Where applicable, non−detects are plotted at reporting limit and are shown with hollow symbols. Summed (total) concentrations are plotted at zero.

(2) Black vertical lines indicate amendment injection events.

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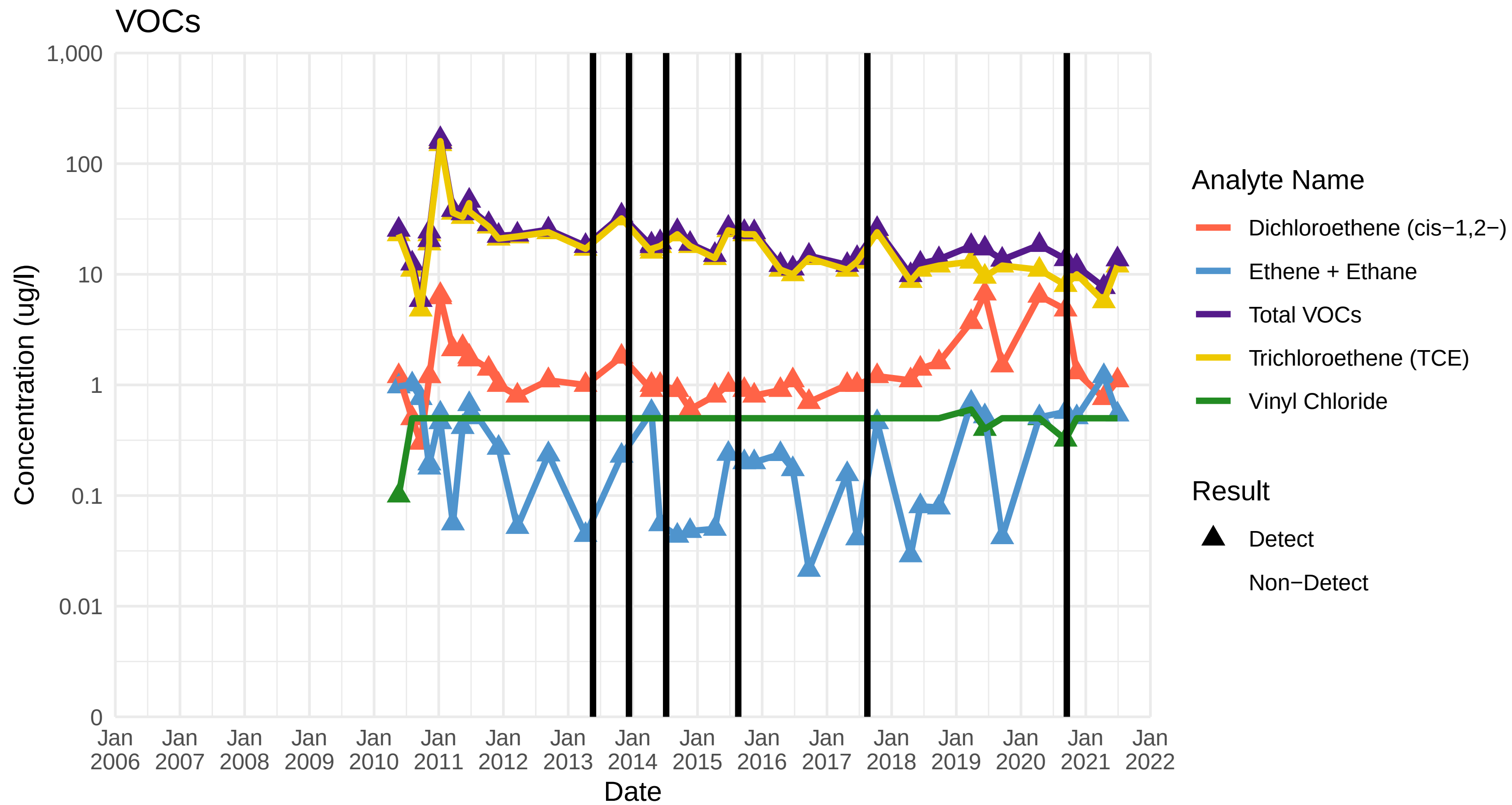

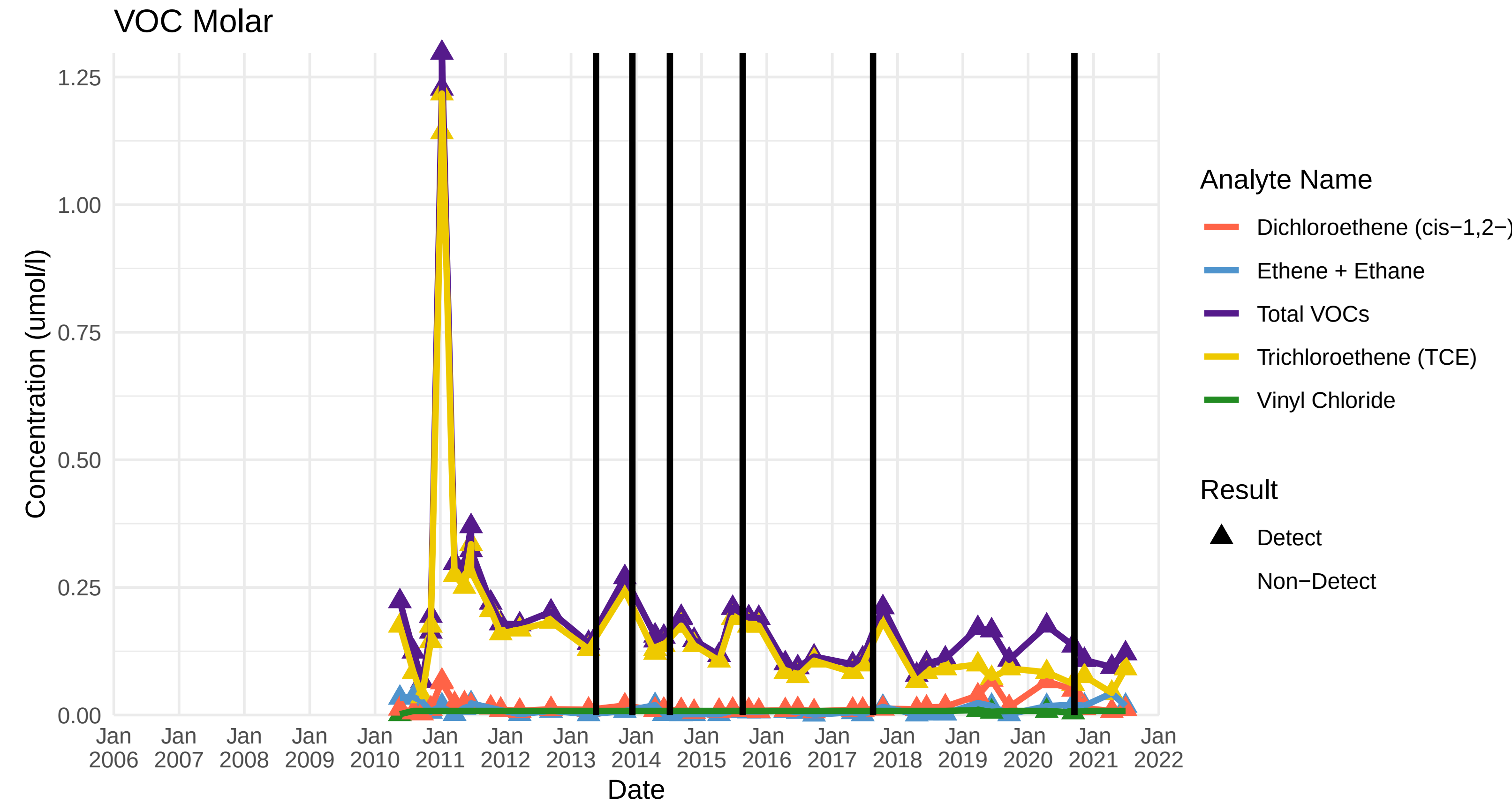

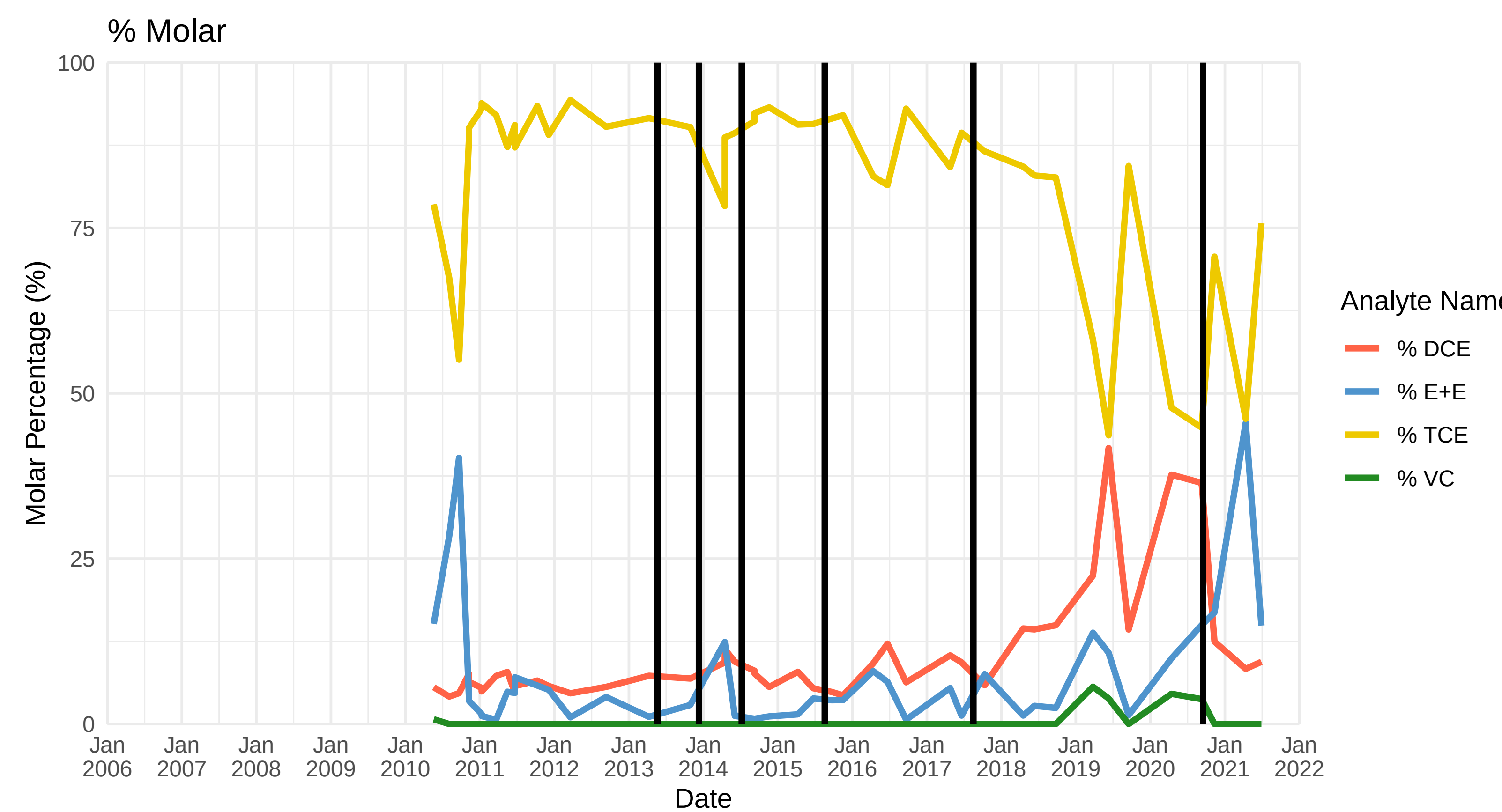

BP−38A

Notes:

(1) Where applicable, non−detects are plotted at reporting limit and are shown with hollow symbols. Summed (total) concentrations are plotted at zero.

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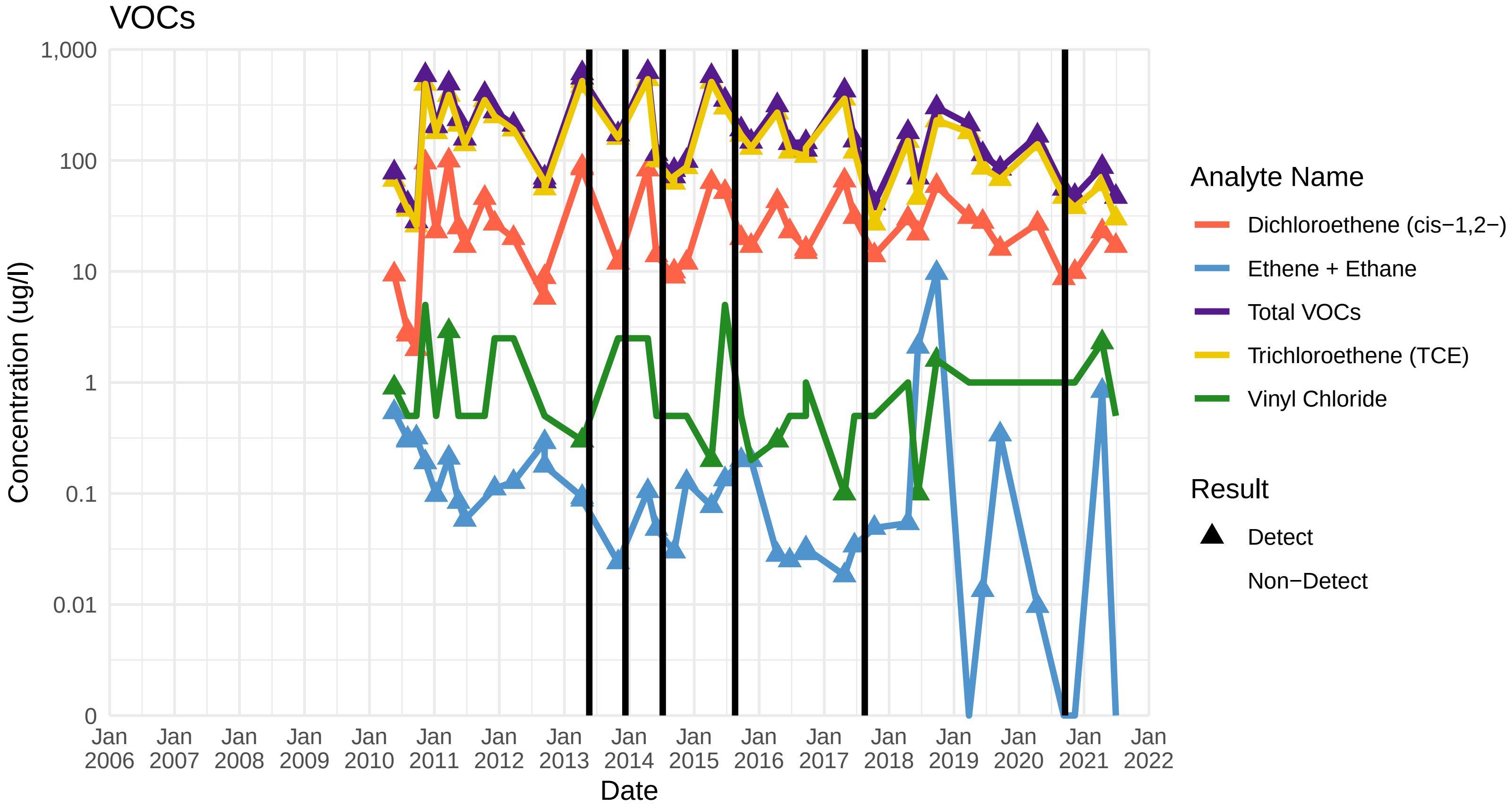

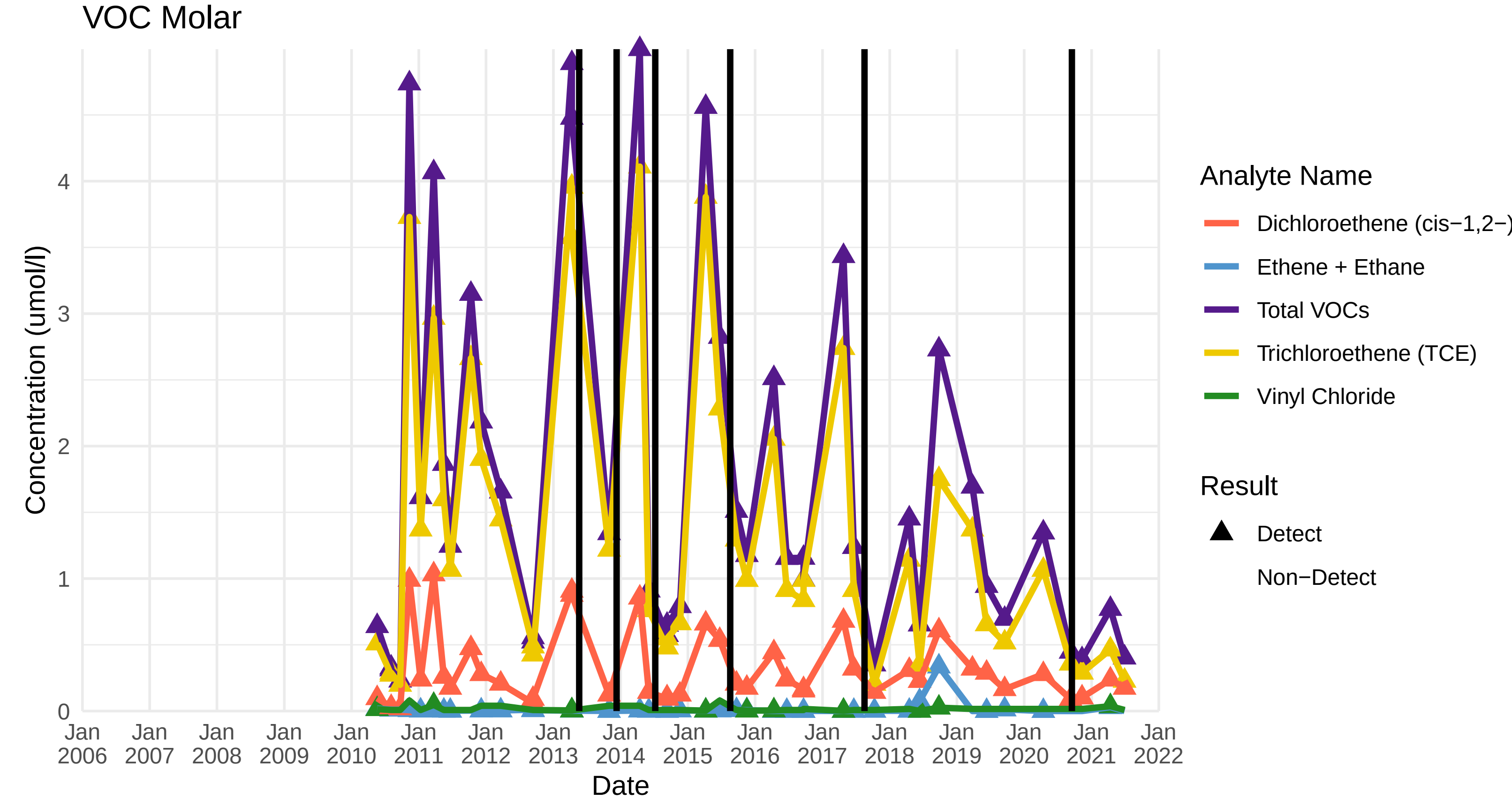

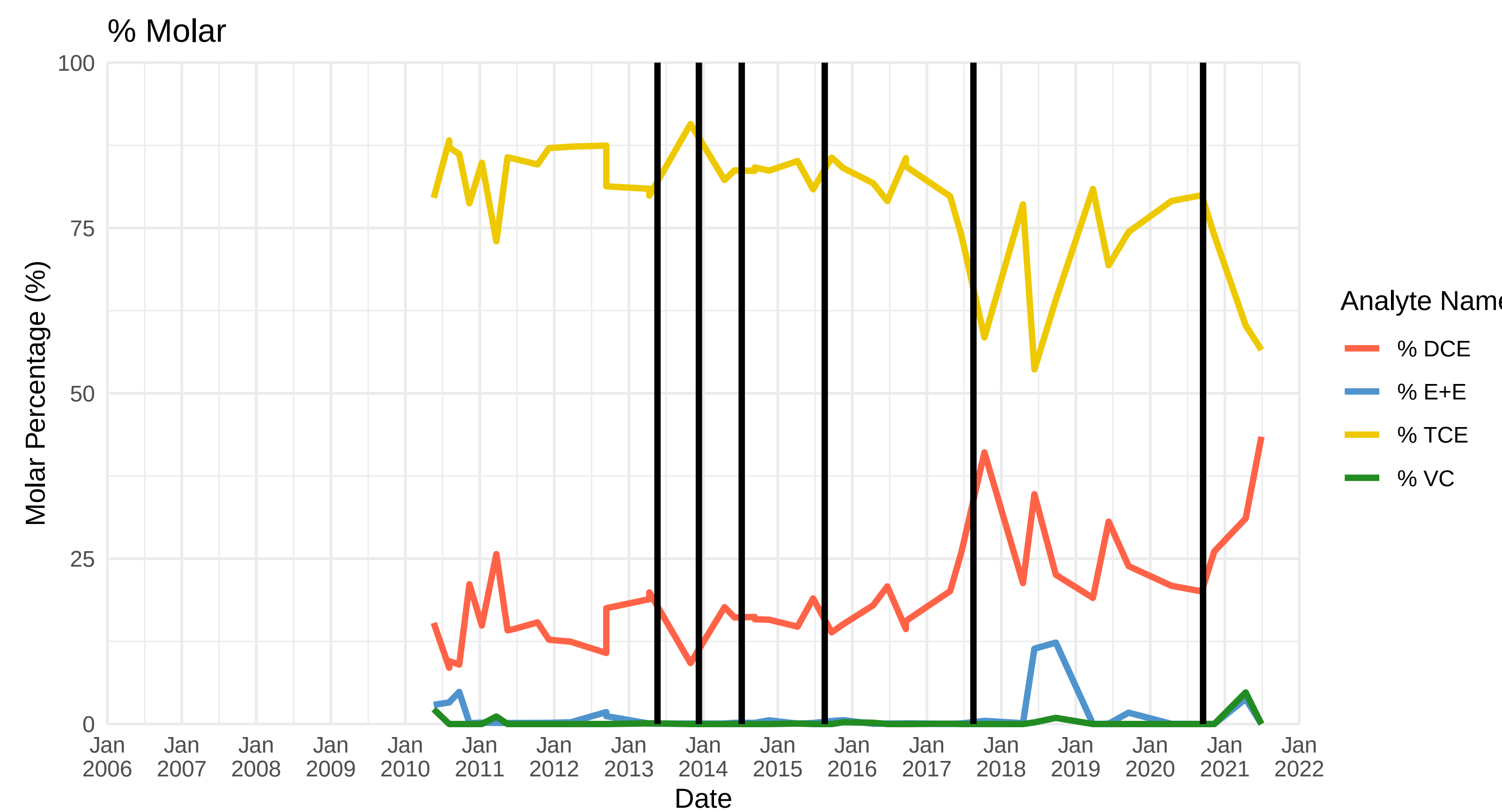

BP−39A

Notes:

(1) Where applicable, non−detects are plotted at reporting limit and are shown with hollow symbols. Summed (total) concentrations are plotted at zero.

(2) Black vertical lines indicate amendment injection events.

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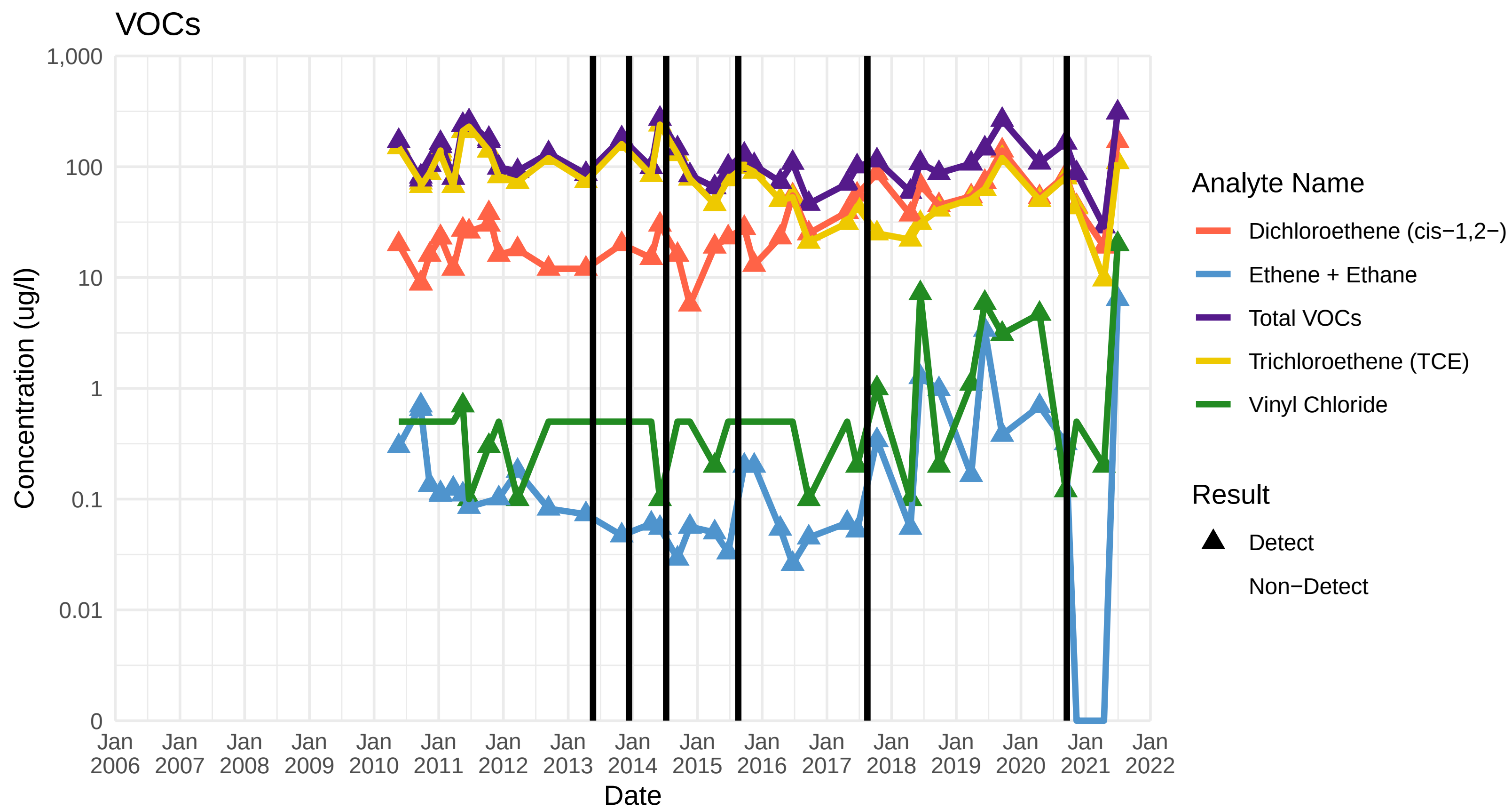

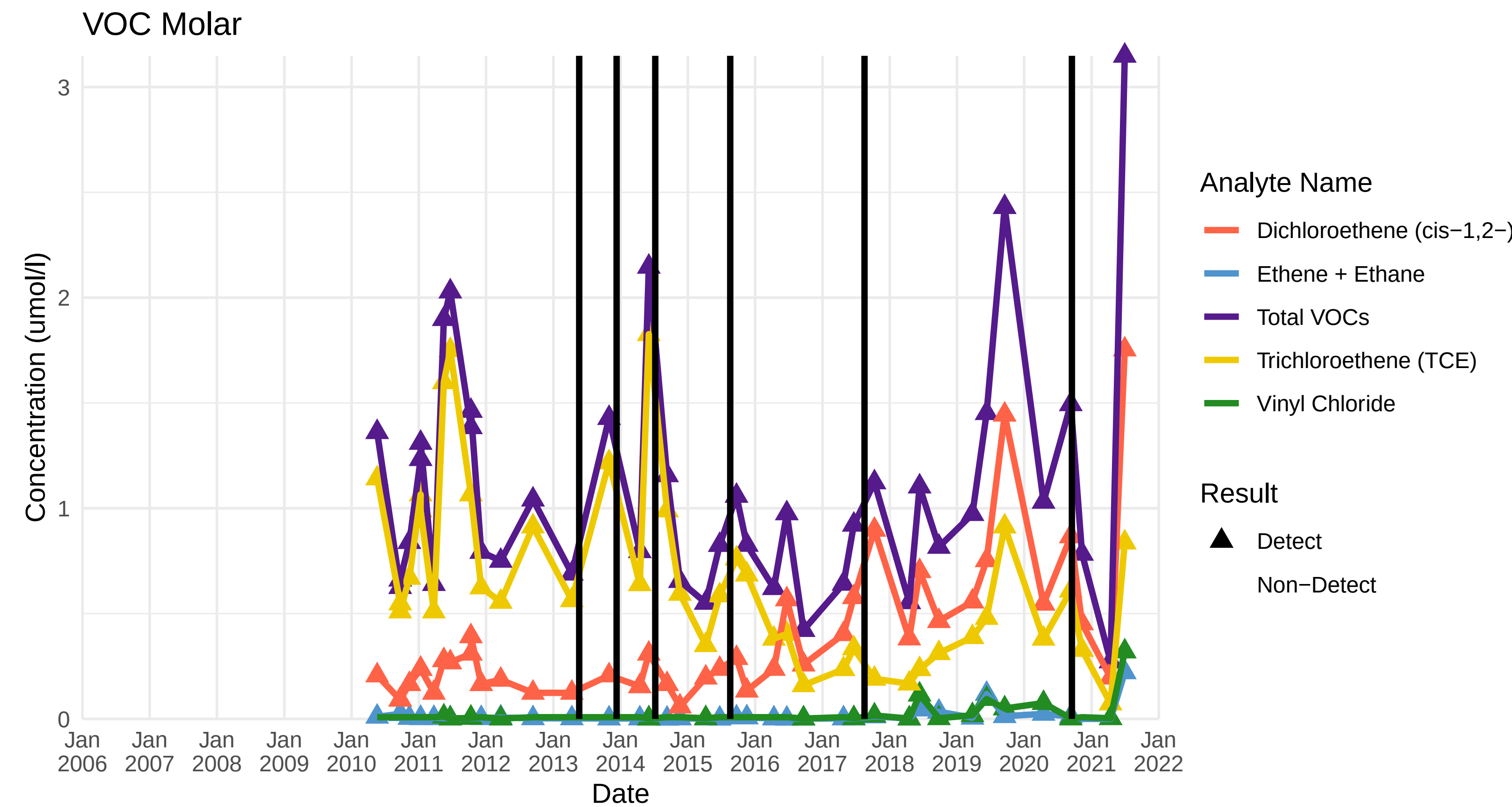

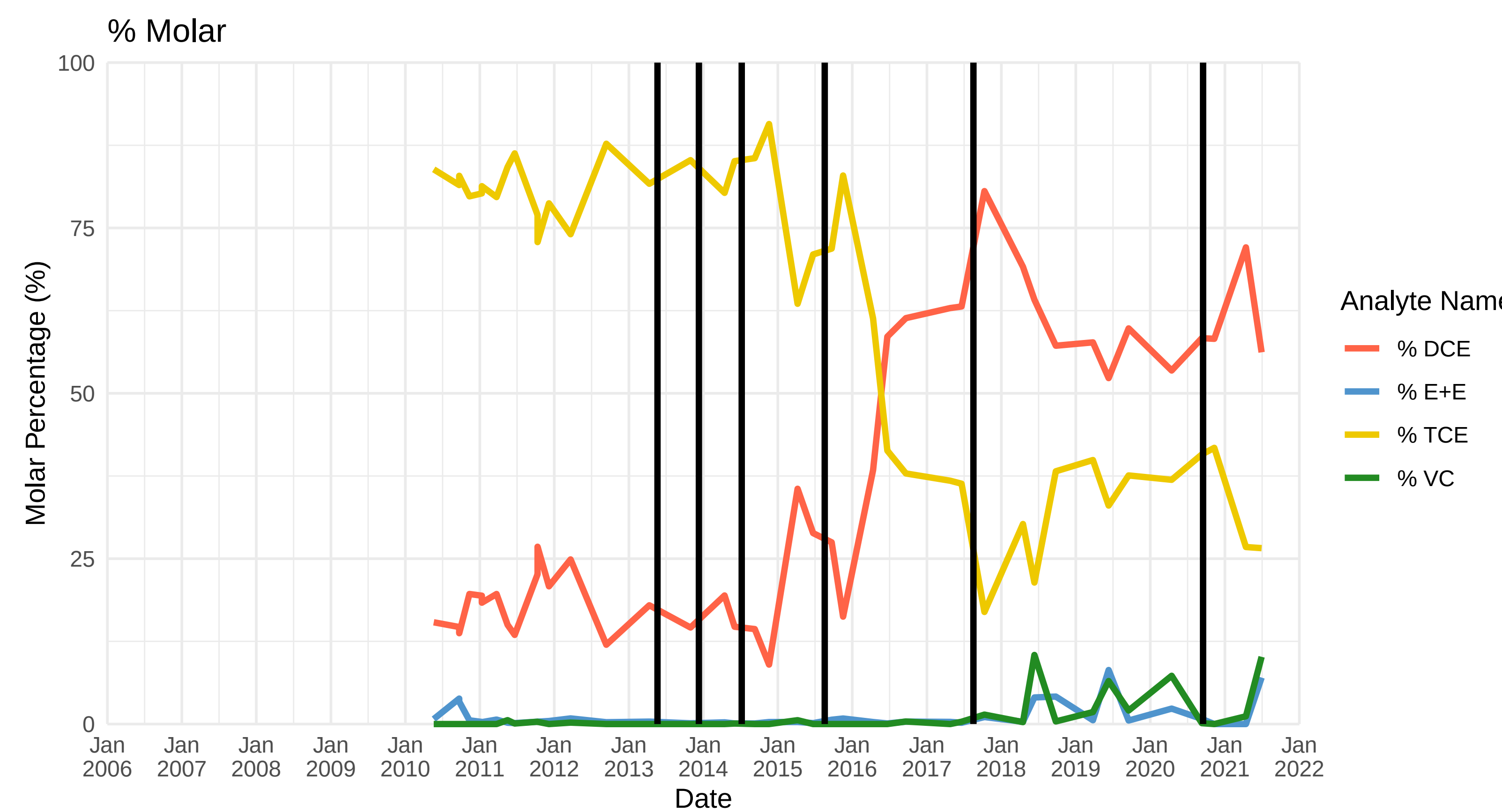

APPENDIX C

INTERACTIVE REDOX FIGURES – APRIL 2020 TO JUNE 2021

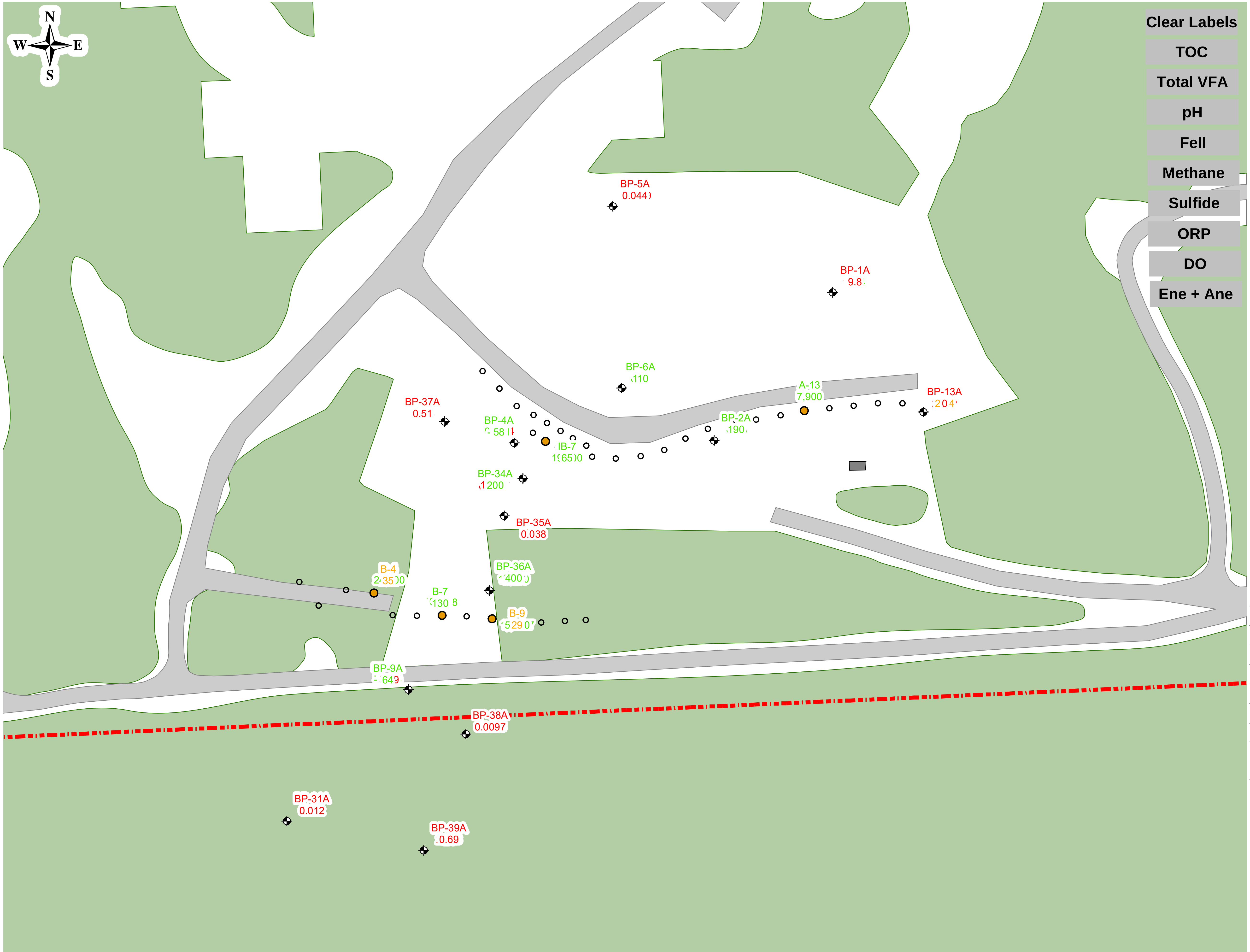

Figure 3

April 2020 Assessment of Reducing Conditions

IBM Gun Club - Former Burn Pit Area
Union, New York

Drawn By: H. Pothier
Designed By: E. Bosse
Reviewed By: B. Green
Project No: 3526.05
Date: June 2020

Figure Narrative

This figure supports a multiple lines of evidence assessment of what proportion of the primary and secondary source rock are under sulfate reducing and methanogenic conditions. Green labels indicate conditions conducive to reductive dehalogenation. Orange labels indicate reductive dehalogenation may be possible, but conditions are less conducive. Red labels indicate conditions where reductive dehalogenation is less likely.

Posted data is from the April 2020 sampling round.

Legend

DO mg/L	>5	2-5	<=2
ORP mV	>100	0-100	<=0
Sulfide µg/L	<10	10-50	>=50
Methane µg/L	<0.5	0.5-20	>=20
FeII mg/L	<1		>=1
pH SU	<6.3 or >7.5		6.3-7.5
Total VFA mg/L	<1		>=1
TOC mg/L	<4		>=4
Ethane + Ethene µg/L	<10	10-50	>=50

30 15 0 30 60
Feet

SANBORN HEAD

Figure 3

September 2020 Assessment of Reducing Conditions

IBM Gun Club - Former Burn Pit Area

Union, New York

Drawn By: H. Pothier
Designed By: E. Bosse
Reviewed By: B. Green
Project No: 3526.05
Date: October 2020

Figure Narrative

This figure supports a multiple lines of evidence assessment of what proportion of the primary and secondary source rock are under sulfate reducing and methanogenic conditions. Green labels indicate conditions conducive to reductive dehalogenation. Orange labels indicate reductive dehalogenation may be possible, but conditions are less conducive. Red labels indicate conditions where reductive dehalogenation is less likely.

Posted data is from the September 2020 sampling round.

Legend

DO mg/L	>5	2-5	<=2
ORP mV	>100	0-100	<=0
Sulfide µg/L	<10	10-50	>=50
Methane µg/L	<0.5	0.5-20	>=20
FeII mg/L	<1		>=1
pH SU	<6.3 or >7.5		6.3-7.5
Total VFA mg/L	<1		>=1
TOC mg/L	<4		>=4
Ethane + Ethene µg/L	<10	10-50	>=50

30 15 0 30 60
Feet

SANBORN HEAD

Last Edited By: hpothier

Path: P:\3500s\3526.02\Graphics Files\GIS\Figures\GeoChem Redox_2020.mxd

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Last Edited By: hpothier

Path: P:\3500s\3526.02\Graphics Files\GIS\Figures\GeoChem Redox_2020.mxd

Figure 3

November 2020 Assessment of Reducing Conditions

IBM Gun Club - Former Burn Pit Area

Union, New York

Drawn By: H. Pothier
Designed By: E. Bosse
Reviewed By: B. Green
Project No: 3526.05
Date: January 2021

Figure Narrative

This figure supports a multiple lines of evidence assessment of what proportion of the primary and secondary source rock are under sulfate reducing and methanogenic conditions. Green labels indicate conditions conducive to reductive dehalogenation. Orange labels indicate reductive dehalogenation may be possible, but conditions are less conducive. Red labels indicate conditions where reductive dehalogenation is less likely.

Posted data is from the November 2020 sampling round.

Legend

DO mg/L	>5	2-5	<=2
ORP mV	>100	0-100	<=0
Sulfide µg/L	<10	10-50	>=50
Methane µg/L	<0.5	0.5-20	>=20
FeII mg/L	<1		>=1
pH SU	<6.3 or >7.5		6.3-7.5
Total VFA mg/L	<1		>=1
TOC mg/L	<4		>=4
Ethane + Ethene µg/L	<10	10-50	>=50

SANBORN HEAD

Last Edited By: hpothier

Path: P:\3500s\3526.02\Graphics Files\GIS\Figures\GeoChem Redox_2021.mxd

Figure 3

April 2021 Assessment of Reducing Conditions

IBM Gun Club - Former Burn Pit Area

Union, New York

Drawn By: H. Pothier
Designed By: E. Bosse
Reviewed By: B. Green
Project No: 3526.05
Date: June 2021

Figure Narrative

This figure supports a multiple lines of evidence assessment of what proportion of the primary and secondary source rock are under sulfate reducing and methanogenic conditions. Green labels indicate conditions conducive to reductive dehalogenation. Orange labels indicate reductive dehalogenation may be possible, but conditions are less conducive. Red labels indicate conditions where reductive dehalogenation is less likely.

Posted data is from the April 2021 sampling round.

Legend

	Red	Orange	Green
DO mg/L	>5	2-5	<=2
ORP mV	>100	0-100	<=0
Sulfide µg/L	<10	10-50	>=50
Methane µg/L	<0.5	0.5-20	>=20
FeII mg/L	<1		>=1
pH SU	<6.3 or >7.5		6.3-7.5
Total VFA mg/L	<1		>=1
TOC mg/L	<4		>=4
Ethane + Ethene µg/L	<10	10-50	>=50

30 15 0 30 60

Feet

SANBORN HEAD

Figure 3

June 2021 Assessment of Reducing Conditions

IBM Gun Club - Former Burn Pit Area

Union, New York

Drawn By: H. Pothier/ Z. Svoboda
Designed By: E. Bosse
Reviewed By: B. Green
Project No: 3526.05
Date: August 2021

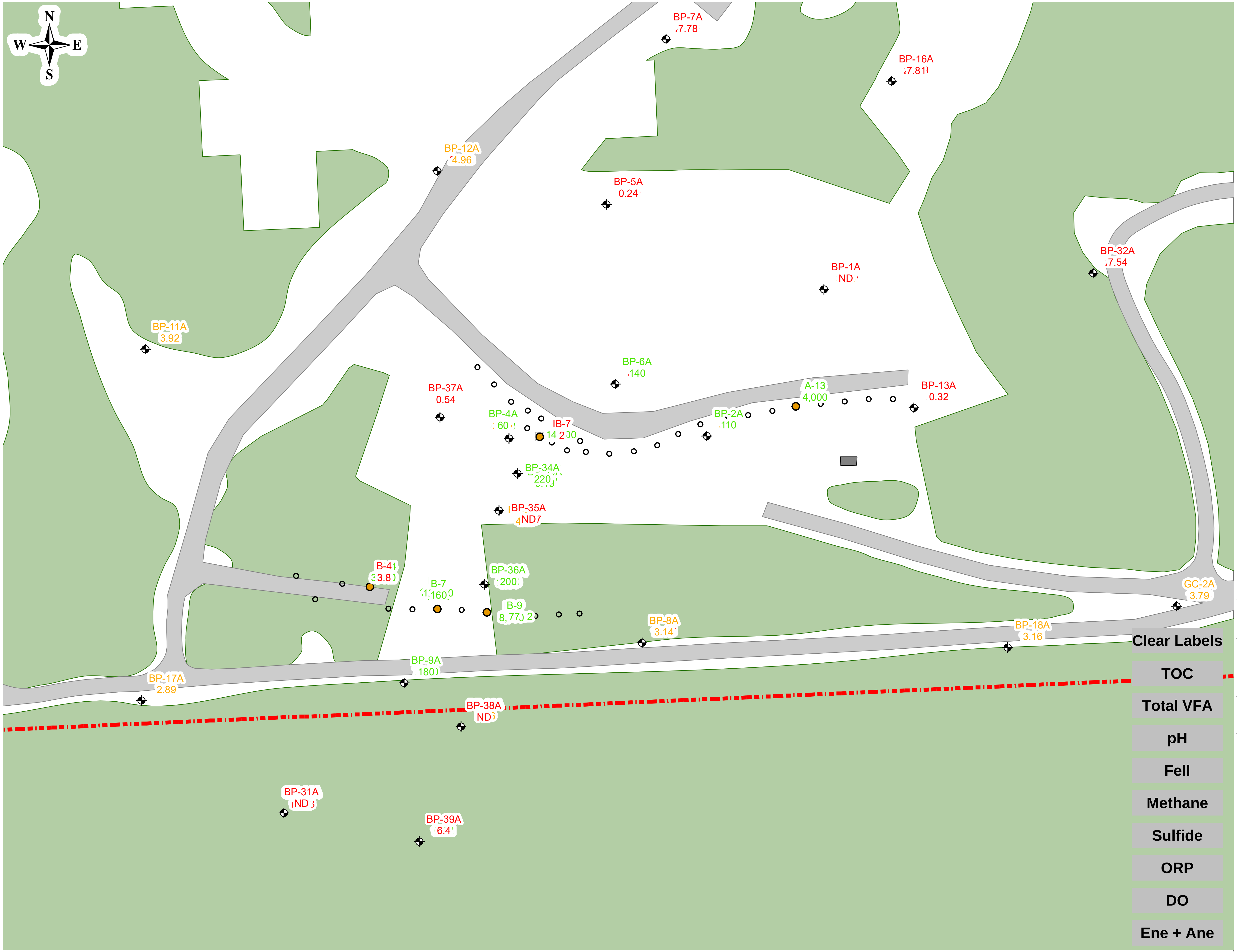


Figure Narrative

This figure supports a multiple lines of evidence assessment of what proportion of the primary and secondary source rock are under sulfate reducing and methanogenic conditions. Green labels indicate conditions conducive to reductive dehalogenation. Orange labels indicate reductive dehalogenation may be possible, but conditions are less conducive. Red labels indicate conditions where reductive dehalogenation is less likely.

Posted data is from the June 2021 sampling round.

Legend

DO mg/L	>5	2-5	<=2
ORP mV	>100	0-100	<=0
Sulfide µg/L	<10	10-50	>=50
Methane µg/L	<0.5	0.5-20	>=20
FeII mg/L	<1		>=1
pH SU	<6.3 or >7.5		6.3-7.5
Total VFA mg/L	<1		>=1
TOC mg/L	<4		>=4
Ethane + Ethene µg/L	<10	10-50	>=50

30 15 0 30 60

Feet

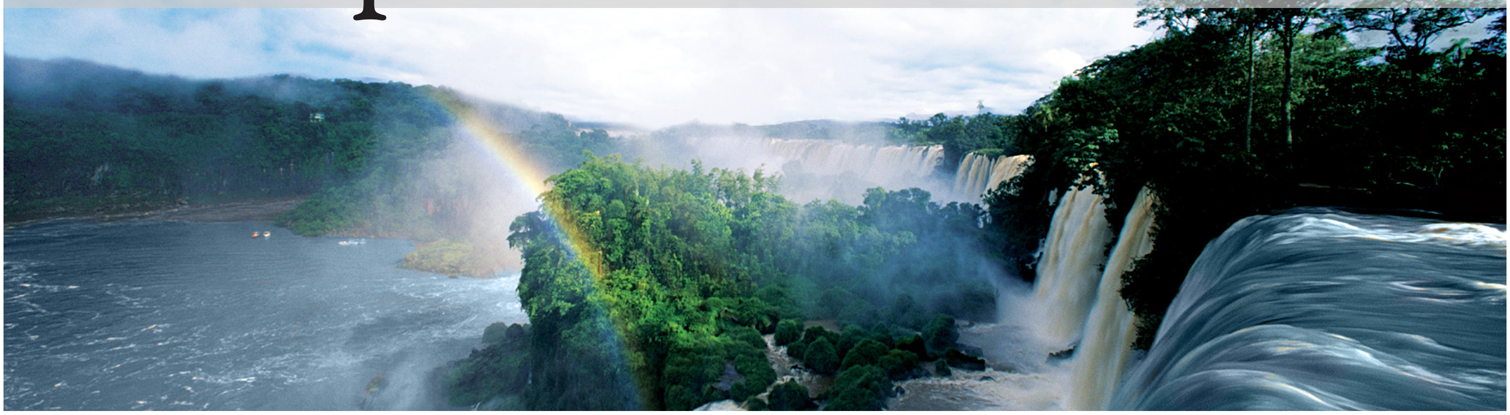
SANBORN HEAD

APPENDIX D

EOS REMEDIATION PRODUCT SPECIFICATION SHEETS

CoBupH$_{Mg}$

Long-lasting pH control and adjustment of aquifers for enhanced bioremediation and metals immobilization



A safe, easy-to-use, long-lasting, colloidal buffer that can be mixed with any EOS® emulsified oil product or used alone

Product Advantages

- Long-term pH adjustment
- Minimized risk of overshooting pH
- Can be combined with EOS® electron donors
- Ships in small containers
- Easily diluted with water in the field

EOS Remediation

Experience you can rely on, Products you can trust™

+1 919.873.2204
www.eosremediation.com

Brad Elkins
BElkins@eosremediation.com

CoBupH$_{Mg}$

Description

CoBupH$_{Mg}$ is a premium colloidal suspension of alkaline solids providing long-term, slow release adjustment of pH in acidic aquifers to optimum levels for biodegradation and immobilization of some dissolved metals. CoBupH$_{Mg}$'s patented formulation provides:

- Equilibrium pH of ~10 in a 10:1 dilution (DI water:CoBupH$_{Mg}$), minimizing the risk of overshooting the pH by buffer addition
- Micron scale, negatively charged particles promote distribution from the injection point
- Can be used in combination with our emulsified oil products.

Chemical & Physical Properties

<u>Alkaline Colloidal Suspension Concentrate:</u> CoBupH$_{Mg}$	<u>Typical</u>
Alkaline Buffer (% by wt.)	45
Dispersant (% by wt.)	1
Stabilizer (% by wt.)	0.5
Specific Gravity	1.37
pH (Standard Units) - 10:1 dilution (DI water: CoBupH$_{Mg}$)	~10
Mean Particle Size (μm)	0.6
OH- equivalence (eq. OH- per lb. CoBupH$_{Mg}$)	7±0.5

Packaging

Shipped in 5-gallon pails (50 lbs.)

Handling & Storage

CoBupH$_{Mg}$ is shipped as a ready-to-use concentrated suspension of alkaline solids that can be easily diluted with water in the field. CoBupH$_{Mg}$ has a low viscosity and is amenable to pumping with commonly available pumps. Before dilution, agitate to ensure product is adequately mixed. Dilution ratios typically range from 1:1 to 4:1 (water: CoBupH$_{Mg}$) depending on site conditions; CoBupH$_{Mg}$ injections should be followed with additional chase water to maximize distribution.

For best performance, use CoBupH$_{Mg}$ within 60 days of delivery and store at a temperature of 40°F (4°C) to 100°F (38°C).

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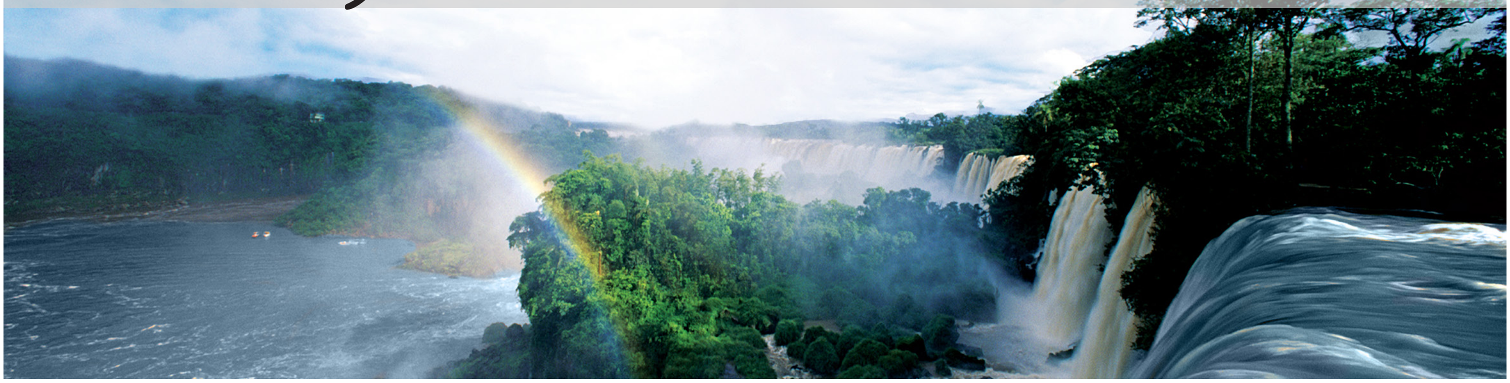
BAC-9

A microbial consortium of *Dehalococcoides mccartyi* enriched to degrade PCE and TCE completely to ethene



Enriched bioaugmentation culture capable of degrading chlorinated solvents to innocuous compounds via halorespiration

Product Advantages

- High cell concentration: 10^{11} Cells/L
- Direct injection for in situ treatment of chlorinated ethenes
- Degrades: PCE, TCE, cis & trans-DCE, VC, Freon 113, mixed plumes containing 1,1,1-TCA & 1,1,2-TCA, dichloroethane isomers, CT, chloroform, and bromine compounds

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BAC-9

Technical Information

Bioaugmentation Cultures & Media

Description

BAC-9 is an enriched bioaugmentation culture capable of degrading chlorinated solvents to innocuous compounds efficiently via halorespiration.

Applications:

- Direct injection for *in situ* treatment of chlorinated ethenes
- Inoculation of on-site bioreactors
- Degrades: tetrachloroethylene (PCE), trichloroethene, (TCE), dichloroethene isomers (cis & trans-DCE), vinyl chloride (VC), Freon 113, mixed plumes containing trichloroethane (1,1,1-TCA & 1,1,2-TCA), dichloroethane isomers, carbon tetrachloride (CT), chloroform, and bromine compounds (carbon tetrabromide, bromoform, ethylene dibromide (EDB) and bromoethane)

Chemical & Physical Properties

Bioaugmentation Culture: BAC-9	Typical
Microbial consortium including *Dehalococcoides mccartyi* and enzymes in a water-based medium	10^{11} Cells/L

Packaging

Shipped in 19 liter pressurized soda keg. Orders greater than 19 liters are concentrated up to 10-fold to significantly reduce shipping and supply costs for your project. Actual volumes and concentration factor will be written on a hang tag attached with the keg.

See the EOS® website for an instructional video on BAC-9 handling and injection procedure.

Handling & Storage

BAC-9 is shipped overnight direct to your site in a chilled cooler. Your BAC-9 delivery includes: instruction manual, delivery cylinder (request 1, 2 or 3.5 liter) with quick connects and ¼" ID tubing hose barbs. An inert gas (Nitrogen or Argon) cylinder, regulator, and additional tubing to reach the injection point are required but not included.

BAC-9 must be stored at 4°C (40°F) and can remain usable for up-to three weeks from delivery.

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