Department of Energy
Savannah River Operations Office
P.O. Box A
Aiken. South Carolina 29802

AUG 2 1 2025

Ms. Susan B. Fulmer, P. G., Manager
Federal Remediation Section
Division of Site Assessment, Remediation and Revitalization
Bureau of Land and Waste Management
South Carolina Department of Environmental Services
2600 Bull Street
Columbia, South Carolina 29201

Mr. Jon Richards
Savannah River Site Remedial Project Manager
Superfund and Emergency Management Division
U. S. Environmental Protection Agency, Region 4
61 Forsyth Street, SW
Atlanta, Georgia 30303

Dear Ms. Fulmer and Mr. Richards:

SUBJECT: Savannah River Site's Responses to the Regulatory Comments on the Effectiveness Monitoring Report (EMR) for the P-Area Groundwater (PAGW) Operable Unit (OU) Zero Valent Iron Permeable Reactive Barrier (ZVI-PRB) Removal Action (U) - April 2023 through March 2024 (SRNS-RP-2024-00914, Revision 0, December 2024) SEMS Number: 81

The U. S. Department of Energy (DOE) is submitting the subject information for your review. The *Effectiveness Monitoring Report (EMR) for the P-Area Groundwater (PAGW) Operable Unit (OU) Zero Valent Iron Permeable Reactive Barrier (ZVI-PRB) Removal Action (U) - April 2023 through March 2024* (SRNS-RP-2024-00914 Revision 0, December 2024) was submitted to the South Carolina Department of Environmental Services (SCDES) and U.S. Environmental Protection Agency (EPA) for review on January 16, 2025. The EPA's comments and SCDES' approval on the Revision 0 report were received on March 27, 2025, and May 15, 2025, respectively. Please review the enclosure and provide your response within thirty (30) days of receipt. The effort and time that the EPA and the SCDES have given on the subject operable unit are greatly appreciated.

Questions from you or your staff may be directed to me at (803) 952-6211, or the DOE Program Manager, April Coffman, at (803) 508-0490.

Sincerely,

MATTHEW BAKER
Digitally signed by MATTHEW BAKER
Date: 2025.08.20 09:46:57 -04'00'

Matthew R. Baker
Acting FFA Remedial Project Manager
DOE-Savannah River Operations Office
Remediation, Deactivation, and Decommissioning Division

RDDD-25-159

AUG 2 1 2025

Ms. Susan Fulmer
Mr. Jon Richards 2

Enclosure:
SRS Responses to USEPA Comments on the Effectiveness Monitoring Report (EMR) for the P-Area Groundwater (PAGW) Operable Unit (OU) Zero Valent Iron Permeable Reactive Barrier (ZVI-PRB) Removal Action (U) - April 2023 through March 2024 (SRNS-RP-2024-00914 Revision 0, December 2024) SEMS Number: 81

cc w/o encl:
M. Reece, SCDES-Columbia
H. J. Porter, SCDES-Columbia
J. Blalock, SCDES-Columbia
S. French, SCDES-Columbia
R. G. Stewart, SCDES-Columbia
M. Mehta, SCDES-Columbia
G. O'Quinn, SCDES-Midlands Aiken Environmental Affairs Office
T. G. Corley, SCDES-Midlands Aiken Environmental Affairs Office
C. L. Robertson, SCDES-Midlands Aiken Environmental Affairs Office
E. G. Downing, SCDES-Midlands Aiken Environmental Affairs Office
H. L. Herlong, SCDES-Midlands Aiken Environmental Affairs Office

cc w/encl:
H. Cathcart, SCDES-Columbia
M. McRae, TechLaw, Inc.

SRS Responses to USEPA Comments on the Effectiveness Monitoring Report (EMR) for the P-Area Groundwater (PAGW) Operable Unit (OU) Zero Valent Iron Permeable Reactive Barrier (ZVI-PRB) Removal Action (U), April 2023 Through March 2024
SEMS Number: 81, SRNS-RP-2024-00914, Revision 0, December 2024,
Savannah River Site, Aiken, South Carolina

Comments Received March 27, 2025

GENERAL COMMENTS

1. It is unclear if additional characterization is warranted to determine whether groundwater may be bypassing the zero-valent ion (ZVI) permeable reactive barrier (PRB). It is noted that the observed volatile organic compound (VOC) concentrations, trends and groundwater chemistry at the PRW004 and the PRW007 well clusters may indicate bypass of the ZVI-PRB is occurring. Specifically:

   a. PRW004DL and PRW004DU are located immediately downgradient of the ZVI-PRB, and first quarter 2024 (1Q24) concentrations of trichloroethene (TCE) are elevated above the maximum contaminant level (MCL) of 5 micrograms per liter (µg/L) at 101 µg/L and 10.4 µg/L, respectively. The TCE concentrations in PRW004DL and PRW004DU have been increasing since 2022 (see Figure 12, Time-Series Plot for TCE at UAZ Monitoring Well Clusters for P002U, PW002 and PRW004). The EMR indicates that the elevated and rebounding concentrations observed at the PRW004 well cluster are likely due to back diffusion from low-permeability sediments downgradient of the ZVI-PRB, however, it is also possible that slow groundwater velocities or preferential flow paths may be contributing to incomplete treatment or localized bypass of the ZVI-PRB.

   b. The PRW007 well cluster is located on the downgradient of the ZVI-PRB. Appendix A (PAGW OU RA EMR Analytical Data 2023-2024) indicates total iron remained below the method detection limit (MDL) at PRW007DL and ranged between 320 and 1790 micrograms per liter (ug/L) at PRW007DU, and oxidation-reduction potential (ORP) ranged between 84.7 and 346 millivolts (mV) at the PRW007 well cluster, suggesting that the reducing environment is not strongly ZVI-influenced. This geochemical combination is not the same fingerprint as other downgradient well clusters (i.e., PRW002 and PRW004) which had total iron ranging between 2580 and 21,600 ug/L and ORP ranging between -284 and 59.2. As water passes through the ZVI, iron corrodes and additional Fe^{2+} (ferrous iron) is produced in groundwater. So, elevated total iron is expected downgradient of the ZVI-PRB and a greater reducing environment is expected. As such, it is unclear whether there is evidence, based on the geochemical fingerprint at the PRW007 well cluster, that groundwater is bypassing the southern end of the ZVI-PRB and the bypass is contributing to the VOC concentrations and groundwater chemistry noted at the PRW007 well cluster.

To differentiate between back diffusion and potential bypass, additional characterization actions, such as conducting tracer tests to confirm flow paths or installation of an additional monitoring well on the southern side of the ZVI-PRB, could be performed to verify ZVI-PRB performance. Please revise the EMR to discuss whether additional characterization is needed to demonstrate that bypass is not occurring.

Comments Received March 27, 2025

Response: Agree

Soil sampling completed during the Pre-Design Investigation for the ZVI-PRB demonstrated the majority of TCE mass is entrained in low permeability sediments of the upper aquifer zone and in the tan clay confining zone. PRW004DU and PRW004DL are located immediately downgradient of high soil concentrations in the upper tan clay confining zone based on this data (Figure CR-1). In-wall monitoring wells are screened in the transmissive zones of the upper aquifer zone and partially in the upper tan clay confining zone, where the highest soil concentrations were observed. The in-wall monitoring wells consistently demonstrate near complete degradation of TCE in groundwater, within the low-permeability sediments and high TCE soil concentrations. The ZVI-PRB is not mobile and does not come in contact with TCE in the soil. Therefore, it is expected that TCE mass will preferentially diffuse into the clean groundwater front leaving the ZVI-PRB due to the reversed concentration gradient created. Back-diffusion of TCE mass entrained in the low-permeability sediments is still believed to be a major factor contributing to the detected TCE concentrations at monitoring wells immediately downgradient of the ZVI-PRB, however it is possible there are other contributing factors such as preferential flow paths through the barrier (decreased residence time), discontinuous sections of the ZVI-PRB (no contact with ZVI), or localized bypass to the south or below the barrier. SRS has considered this potential and is planning for actions to investigate this in 2026. Two planned actions are to install transducers in stations within the ZVI-PRB monitoring well network to collect high frequency water level data and assess the groundwater flow direction and potential mounding upgradient of the ZVI-PRB. The second plan is to complete hydraulic pulse interference testing (HPIT) to compare with HPIT done pre-construction of the ZVI-PRB and immediately following construction. These tests will provide some insight into the permeability of the barrier since completion of construction activities and identify if additional testing is warranted. Details of the test plans and reporting plans will be described in the 2025 EMR report.

No change to the 2024 EMR report is proposed.

Responsible Party: Adam Willey, adam.willey@srs.gov, 803-646-4944

2. Calcium analyses should be performed at monitoring locations on both the east and west side of the ZVI-PRB to support the conclusions of the treatability study. The treatability study determined that there were no observations of mineral precipitation causing loss of reactivity and no expectation of precipitation/clogging causing significant loss in permeability. Therefore, in regard to the elevated calcium concentrations, Section 4.3 (ZVI-PRB Health and Longevity) concludes that, "the performance of the ZVI-PRB is not anticipated to be impacted by the resulting calcium levels." However, calcium concentration data from the monitoring wells east and west of the ZVI-PRB is not presented to support these conclusions (see Table 4, Baseline Concentration Comparison with Most Recent Results for UAZ (1Q24)). Even small volumes of calcium leaching could have significant effects over time and the results of a

treatability study may not accurately reflect the complexity of the actual system performance. If calcium concentrations are found to decrease across the ZVI-PRB, this may indicate precipitation is occurring, however, if calcium concentrations are similar on both sides, this would support that minimal precipitation is occurring. *Please recommend additional calcium analysis at the monitoring locations on the east and west sides of the ZVI-PRB to support the statement that the performance of the ZVI-PRB is not likely impacted by calcium levels.*

Response: Agree

Calcium analysis will be added to sampling events beginning in third quarter of 2025. This data will not be reported in the next submittal of the ZVI-PRB report (reporting period includes second quarter of 2024 to first quarter of 2025), but will be available for discussion in the next full P-Area Groundwater Operable Unit monitoring report submittal.

No change to the 2024 EMR is proposed.

Responsible Party: Adam Willey, adam.willey@srs.gov, 803-646-4944

3. The EMR does not contain the reports issued by the laboratory for the analysis of the samples. *Please attach the laboratory data reports as an attachment.*

Response: Clarification

Laboratory reports on the analyses are not routinely submitted by SRS with monitoring reports. All data collected in support of monitoring at the PAGW ZVI-PRB conform to the Savannah River Site Area Completion Projects Quality Assurance Project Plan for Environmental Data Collection and Management (ERD-AG-2005-00001). This document was developed in agreement with United States Environmental Protection Agency and South Carolina Department of Environmental Services to integrate all technical and quality aspects of environmental data collection and management to provide consistent data objectives and document the comprehensive set of standard operating procedures for sampling, analysis, quality assurance/quality control, and data review. Validation reports are typically not submitted with groundwater Effectiveness Monitoring Reports (EMRs). Additionally, the Environmental Compliance and Area Completion Projects organization has a series of administrative procedures (e.g., WSRC-C1, Administrative Procedures, ER-AP-125, Soil and Groundwater Closure Projects Quality Assurance Program) and technical memorandums that further define the requirements and responsibilities within EC&ACP for implementation of the quality program.

No change to the 2024 EMR report is proposed.

Responsible Party: Adam Willey, adam.willey@srs.gov, 803-646-4944

SRS Responses to USEPA Comments on the Effectiveness Monitoring Report (EMR) for the P-Area Groundwater (PAGW) Operable Unit (OU) Zero Valent Iron Permeable Reactive Barrier (ZVI-PRB) Removal Action (U), April 2023 Through March 2024
SEMS Number: 81, SRNS-RP-2024-00914, Revision 0, December 2024,
Savannah River Site, Aiken, South Carolina

Comments Received March 27, 2025

4. The EMR indicates that the estimated groundwater flow velocity was calculated to be 77.3 meters per year (m/yr) (253.7 feet per year (ft/yr)) in 1Q24 (calculated on the hydraulic gradient estimated between PMW005DL and PRW006DU); however, it is unclear whether a single observation of hydraulic gradient in the northern portion of the ZVI-PRB is sufficient to demonstrate groundwater flow velocity across the entire ZVI-PRB. Reliance on a single data point may overlook localized seasonal changes in flow, particularly given concerns about reduced permeability. *Please revise the EMR to discuss why a single observation of hydraulic gradient in the northern portion of the ZVI-PRB is sufficient to accurately characterize groundwater flow across the ZVI-PRB and if the single observation is insufficient, propose additional locations where hydraulic gradients will be established in the future.*

Response: Agree

Future reporting for the ZVI-PRB will present a range of flow velocities across the ZVI-PRB based on the potentiometric surface and selected localized well pairs within the ZVI-PRB monitoring network. Additionally, SRS will be installing transducers to monitor water levels in ZVI-PRB monitoring wells in 2026. The purpose of this will be to assess flow through the barrier and whether mounding is occurring due to reduced permeability.

No change to the 2024 EMR report is proposed.

Responsible Party: Adam Willey, adam.willey@srs.gov, 803-646-4944

SRS Responses to USEPA Comments on the Effectiveness Monitoring Report (EMR) for the P-Area Groundwater (PAGW) Operable Unit (OU) Zero Valent Iron Permeable Reactive Barrier (ZVI-PRB) Removal Action (U), April 2023 Through March 2024
SEMS Number: 81, SRNS-RP-2024-00914, Revision 0, December 2024,
Savannah River Site, Aiken, South Carolina

Comments Received March 27, 2025

SPECIFIC COMMENTS

1. **Section 2.4, Removal Action Implementation and Monitoring Goals, Page 7 of 58:** The text states, "The implemented ZVI-PRB is anticipated to reduce the mass flux of TCE through the neck area of the PAGW [P-Area Groundwater] OU [operable unit] TCE plume by at least 80% [percent] in order to meet the RAO [remedial action objective];" however, the text does not discuss the estimated timeline for reaching the 80% reduction. *For clarity, please revise the EMR to discuss the RAO timeline and whether the results are within the estimated time ranges for achieving the RAO.*

Response: Agree

The removal action objective (RAO) for the non-time critical removal action is to reduce TCE mass in the groundwater plumes so that the mass flux to Steel Creek will be reduced to reach the maximum contaminant level in Steel Creek. In the Removal Site Evaluation Report (RSER)/Engineering Evaluation (EE)/Cost Analysis (CA) for this non-time critical removal action, it was assumed that a reduction of groundwater plume mass flux across the treatment zone of greater than 80% would be sufficient to meet the RAO (SRNS 2018). The ZVI-PRB was designed to exceed this reduction in the design objective (>90%) and in the safety factor applied to the design thickness in the Removal Action Design Plan (RADP) (SRNS 2019). A timeline to achieve this RAO was not proposed in the RSER/EE/CA or in the RADP, however five years of monitoring was proposed. The 2025 EMR report will be the fifth and final planned EMR for the non-time critical removal action. SRS intends to discuss the performance of the ZVI-PRB in relation to the RAO in this final EMR. Additionally, Savannah River National Laboratory is performing an independent review of the ZVI-PRB performance after five years of monitoring to supplement the final report by SRS.

No change to the 2024 EMR report is proposed.

SRNS, 2018. ***Removal Site Evaluation Report/Engineering Evaluation/Cost Analysis for Trichloroethylene Plumes Discharging to Steel Creek in P-Area Groundwater Operable Unit (NBN) (U)*****, SRNS-RP-2017-00372, Revision 1, March 2018, Savannah River Nuclear Solutions, LLC, Savannah River Site, Aiken, SC.**

SRNS, 2019. ***Removal Action Design Plan (RADP) with Effectiveness Monitoring Plan (EMP) for the P-Area Groundwater (PAGW) Operable Unit (OU)*****, SRNS-RP-2019-00105, Revision 1, July 2019, Savannah River Nuclear Solutions, LLC, Savannah River Site, Aiken, SC.**

Responsible Party: Adam Willey, adam.willey@srs.gov, 803-646-4944

2. **Section 3.0, Monitoring Results and Deviations, Page 10 of 58:** The text states, "The data quality level for permanent groundwater monitoring well stations and field duplicate samples is Verified and Validated (V&V) level data;" however, this section lacks a detailed narrative

on the findings of the data validation and data validation reports are not provided as supporting documentation. For example, Appendix A (PAGW OU RA EMR Analytical Data 2023-2024) indicates that several ferrous iron samples were rejected due to exceeding hold time, but it is unclear whether any other samples were affected. *Please revise the EMR to discuss the outcome of the data validation and provide data validation reports.*

Response: Clarification

Groundwater monitoring data reported for the P-Area Groundwater (PAGW) Zero-Valent Iron Permeable Reactive Barrier (ZVI-PRB) since 2019 have been Verified and Validated (V&V) level data. A summary of the regular sample data collected during the reporting period for each annual report is provided on Table A. For ease of reporting the data, data qualifiers are presented on the table as color-coded cells with an explanation provided at the bottom of the table. In the 2024 EMR report, the only rejected results were ferric and ferrous iron results in August 2023 and February 2024. There were no other samples affected.

All data collected in support of monitoring at the PAGW ZVI-PRB conform to the Savannah River Site Area Completion Projects Quality Assurance Project Plan for Environmental Data Collection and Management (ERD-AG-2005-00001). This document was developed in agreement with United States Environmental Protection Agency and South Carolina Department of Environmental Services to integrate all technical and quality aspects of environmental data collection and management to provide consistent data objectives and document the comprehensive set of standard operating procedures for sampling, analysis, quality assurance/quality control, and data review. Validation reports are typically not submitted with groundwater Effectiveness Monitoring Reports (EMRs). Additionally, the Environmental Compliance and Area Completion Projects organization has a series of administrative procedures (e.g., WSRC-C1, Administrative Procedures, ER-AP-125, Soil and Groundwater Closure Projects Quality Assurance Program) and technical memorandums that further define the requirements and responsibilities within EC&ACP for implementation of the quality program.

No change to the 2024 EMR report is proposed.

Responsible Party: Adam Willey, adam.willey@srs.gov, 803-646-4944

3. **Section 3.2.4, Field Measurements, Page 17 of 58:** The text indicates that pH levels at in-wall monitoring wells for the first quarter of 2024 were 12.6 to 13.3 and goes on to state, "Elevated pH levels associated with ZVI have been well documented at other sites and the elevated levels are not expected to have an impact on ZVI-PRB performance;" however, it is unclear whether this statement is accurate. Elevated pH conditions can result in precipitation of calcium, magnesium and iron minerals, which may decrease the permeability and effectiveness of the barrier and reactive surface over time (passivation). As such, if high pH persists within the barrier, additional investigations, such as hydraulic testing or tracer dye analysis downgradient and within the ZVI-PRB should be conducted to verify the statement.

Comments Received March 27, 2025

Please revise the EMR to clarify that elevated pH may have an impact on the ZVI-PRB performance and additional characterization may be required to assess performance of the ZVI if elevated pH conditions persist.

Response: Clarification

First quarter of 2024 (1Q24) pH measurements were higher than typical measurements recorded in PIW series wells. This may be a result of a pH probe out of calibration during the 1Q24 sampling event. In the second quarter of 2024 sampling event, pH averaged 10.8, which is consistent with pH levels observed throughout the four years of monitoring post-construction of the ZVI-PRB. The 1Q24 results were the last event reported in the 2024 EMR, therefore it was unclear if this was a true increasing trend for pH or an outlier at the time of reporting.

Although pH results in 1Q24 are likely outliers for the PIW series wells, pH is elevated (fourth quarter of 2023 average was 10.7) above baseline levels (4.5 to 5.5). The pH levels are consistent with pH observed at other field scale ZVI installations (Wilkin et. al. 2002). Although it is widely demonstrated in literature that elevated pH environments can lead to decreased reaction rates for ZVI degradation of chlorinated ethenes, there are also studies that suggest in the right geochemical environment, high pH can lead to increased degradation rates due to decreased dissolution of solid ZVI and iron hydroxide layers that increase available electron donor (Bae and Hanna 2015). Therefore, SRS believes the site specific treatability study in combination with the in-wall monitoring wells provide the best evidence of continued degradation by the PAGW OU ZVI-PRB to date. Monitoring well PIW003D is screened within a hot spot based on the soil TCE data (Figure CR-1). This monitoring well has detected TCE at low levels consistently since 2021 with no increasing trend observed (Figure CR-2). To date, in-wall monitoring wells continue to demonstrate near complete degradation of TCE, showing no indications of reduced effectiveness. Future reporting on the ZVI-PRB will discuss the impact of elevated pH on ZVI reactivity and potential for reduced effectiveness.

No change to the 2024 EMR report is proposed.

Responsible Party: Adam Willey, adam.willey@srs.gov, 803-646-4944

4. **Appendix A, PAGW OU RA EMR Analytical Data 2023-2024, PDF Page 69:** The table notes indicate that the yellow highlighted cells were, "Requested to be sampled but was not. See comments as to why not;" however, no comment cells providing explanations are included in the table. *Please include the comment cells, or include a note clarifying why these were omitted.*

Response: Agree

In the 2024 EMR, the only parameter with cells highlighted yellow was *Volume Purged.*

Comments Received March 27, 2025

Purge volumes for all sampling events and locations were recorded in the field and therefore no comment fields were generated for the matrix table. When producing the matrix table for the 2024 EMR, the purge volumes were not pulled into the matrix tables due to a change in how the database stores purge volume data. This led to the discrepancy between highlighted cells in the matrix table but no comment column. Future reports will ensure the purge volume data is provided and all missing, requested data is commented on in the matrix table or described in the report text.

No change to the 2024 EMR report is proposed.

Responsible Party: Adam Willey, adam.willey@srs.gov, 803-646-4944

5. *The EMR would benefit if bookmarks were included for quick reference to specific sections of the report.*

Response: Agree

Future reports will include bookmarks in the PDF for quick reference.

No change to the 2024 EMR report is proposed.

Responsible Party: Adam Willey, adam.willey@srs.gov, 803-646-4944

6. **List of Appendices, Page v of viii:** The title of Appendix A is listed as PAGW OU RA EMR Analytical Data 2022-2023; however, the analytical data presented is from 2023-2024. *Please revise the title of Appendix A to accurately describe the years of data analysis.*

Response: Agree

Future reports will have the correct titles in the List of Appendices.

No change to the 2024 EMR report is proposed.

Responsible Party: Adam Willey, adam.willey@srs.gov, 803-646-4944

SRS Responses to USEPA Comments on the Effectiveness Monitoring Report (EMR) for the P-Area Groundwater (PAGW) Operable Unit (OU) Zero Valent Iron Permeable Reactive Barrier (ZVI-PRB) Removal Action (U), April 2023 Through March 2024
SEMS Number: 81, SRNS-RP-2024-00914, Revision 0, December 2024,
Savannah River Site, Aiken, South Carolina

Comments Received March 27, 2025

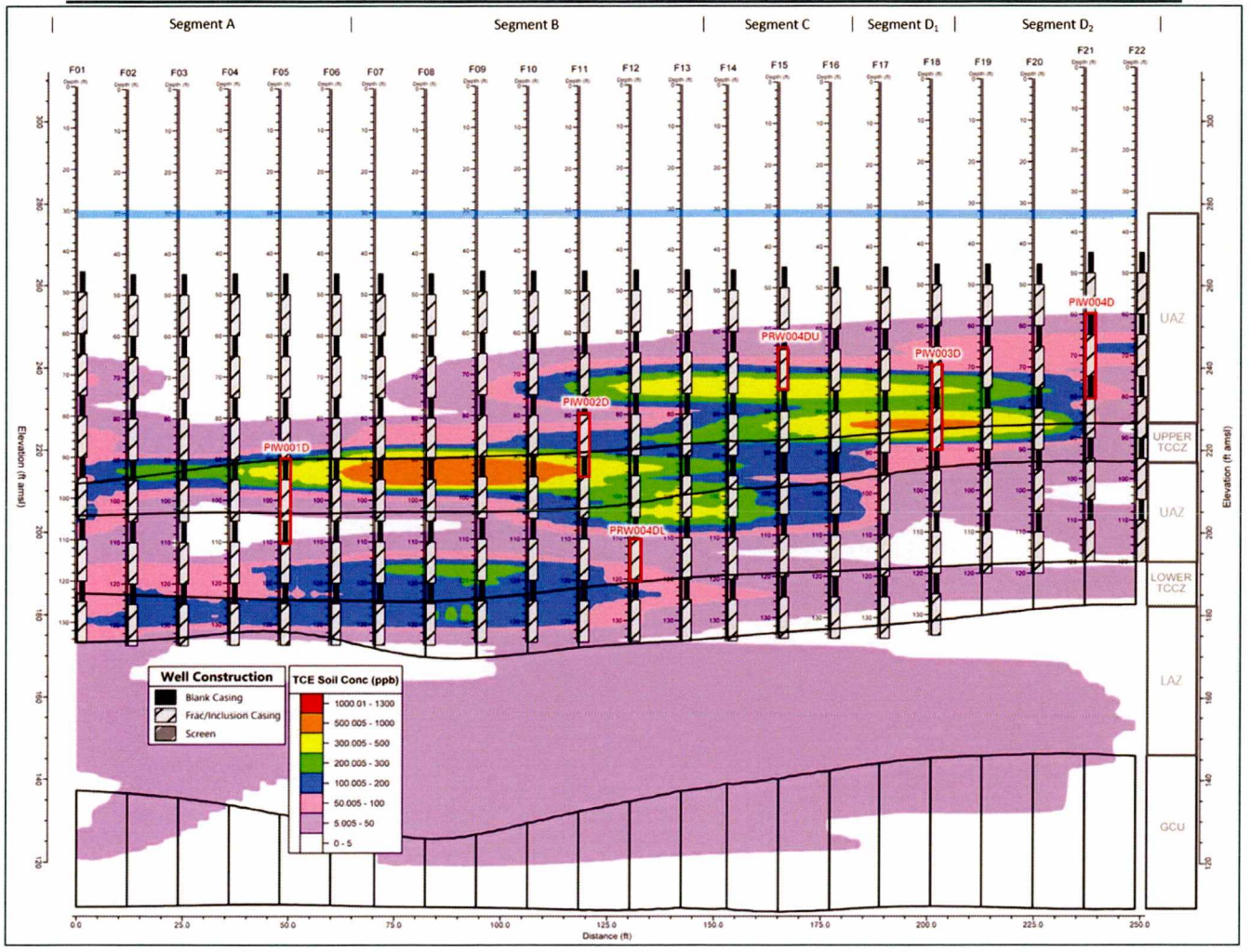

Figure CR-1. Cross-Section of the Zero-Valent Iron Permeable Reactive Barrier with TCE Soil Concentrations

Comments Received March 27, 2025

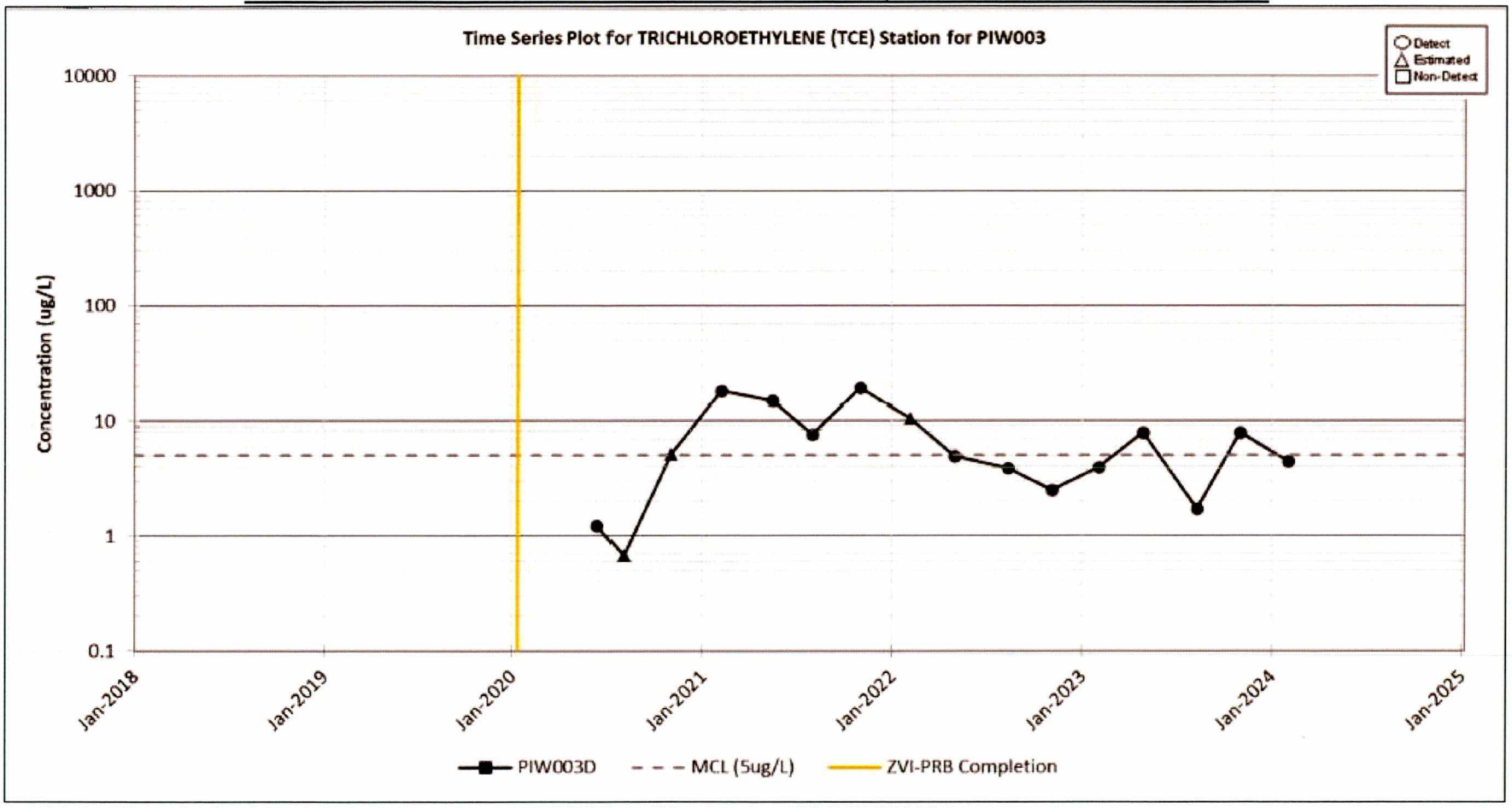

Figure CR-2. Time Series Plot for Trichloroethylene (TCE) at Monitoring Well PIW003D