

THE F.E. WARREN AFB SPILL SITE 7 IRON-FILINGS PERMEABLE REACTIVE BARRIER IS WORKING



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ABSTRACT The F.E. Warren AFB (FEW) Spill Site 7 (SS7) permeable reactive barrier (PRB) is performing as designed based on the first three quarters of monitoring results.

INTRODUCTION

Performance monitoring of the FEW, Wyoming SS7 iron-filings PRB (see Figure 1) was designed to confirm that the PRB is achieving its design and remedial action objectives by cleaning up trichloroethene (TCE) and its degradation products. This PRB was designed and constructed at FEW for the Air Force Center for Environmental Excellence. The PRB is 568 feet long with 15 vertical feet of iron below the historic low groundwater level. Following PRB installation in 1999, the system was left undisturbed for six months to allow conditions to equilibrate before a performance monitoring program was implemented. Results for the first three quarters of monitoring are summarized in this paper.

Primary objectives of the 1997 Interim Record of Decision (ROD) to address SS7 shallow groundwater contaminants were to 1) minimize future residential population's potential for ingestion, inhalation, and dermal exposure to groundwater indicator contaminants of concern (ICOCs) by reducing contaminant concentrations to maximum contaminant levels (MCLs) in the top 15 feet of groundwater, and 2) minimize contaminant loading to Diamond Creek. ICOCs for SS7 included TCE; cis-1,2-dichloroethene (cDCE); trans-1,2-DCE (tDCE); total DCE; and vinyl chloride, and their treatment goals are 5 micrograms per liter ($\mu\text{g/L}$), 70 $\mu\text{g/L}$, 100 $\mu\text{g/L}$, 300 $\mu\text{g/L}$, and 2 $\mu\text{g/L}$, respectively. The Interim ROD specified that a PRB would be constructed as an interim remedial action (IRA). Contaminants not treated by the IRA will be addressed by the FEW final groundwater remedial action.

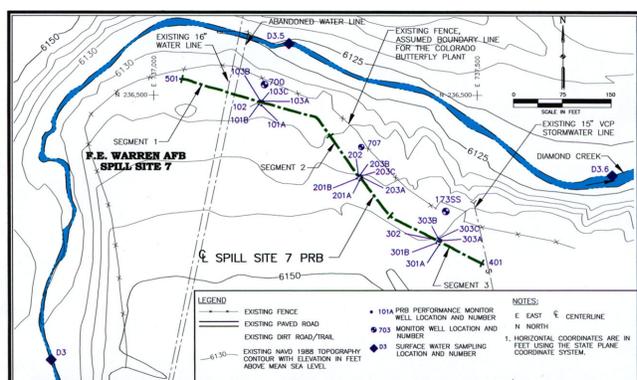


Figure 1 – Spill Site 7 Area Map

PRB PERFORMANCE MONITORING

Primary objectives of the SS7 PRB post-construction, long-term monitoring program are:

- ◆ Determine the effectiveness of the PRB in reducing groundwater ICOC concentrations to or below treatment goals.
- ◆ Determine the effectiveness of the PRB in reducing contaminant loading to Diamond Creek.

- ◆ Determine if non-ICOC chemicals that are by-products of the remediation process (e.g., pH, iron, chloride, etc.) impact Diamond Creek.
- ◆ Evaluate the effects of the PRB on groundwater flow paths and determine if contaminated groundwater is bypassing the PRB.

The SS7 performance monitoring program includes sampling groundwater for ICOCs and indicator parameters to assess cleanup. Surface water sampling is conducted to assess the SS7 contaminant plume

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impact on surface water in Diamond Creek. Groundwater level measurements are conducted to assess whether groundwater flow paths have been affected by installation of the PRB. Stream stage measurements are conducted to help evaluate the impact of groundwater flux and surface water discharge.

Groundwater Monitoring: Performance monitoring well (PMW) clusters were placed in locations (approximately at each PRB segment midpoint) that were considered representative of contaminant concentrations and groundwater flow conditions along each PRB segment (see Figure 1). Upgradient wells are approximately 2 feet from the PRB and are used to measure influent ICOC concentrations. Monitoring wells within the PRB are used to document degradation of ICOCs within the PRB. Downgradient wells are within approximately 0.75 feet of the PRB and allow evaluation of treated groundwater while minimizing the effects of contaminant desorption from saturated soil.

The “A” wells are intended to monitor potential underflow of ICOCs beneath the PRB and ICOC concentrations below the upper 15 feet of groundwater. The “B” wells are used to monitor the PRB mid-section. The “C” wells are intended to monitor the lower PRB portion. Wells PMW-401 and PMW-501 are located at the PRB ends to determine if contaminated groundwater is bypassing the PRB ends.

Surface Water Monitoring: One of the primary IRS objectives is to minimize contaminant loading to Diamond Creek. Diamond Creek surface concentrations are monitored by sampling at surface water Sampling Locations D3, D3.5, and D3.6 (see Figure 1). Location D3 serves as an upstream (background) sampling point and Locations D3.5 and D3.6 were chosen as the most likely areas to receive contaminated groundwater discharge based on contaminant flow paths.

RESULTS

Analytical results are presented in the following sections with respect to individual PRB segments and PRB ends. An emphasis is given to TCE in this paper because TCE is regarded as the primary ICOC.

Indicator Contaminants of Concern: A comparison of Segments 1, 2, and 3 TCE concentrations in wells upgradient, within, and immediately downgradient of the PRB are presented on Figures 2, 3, and 4.

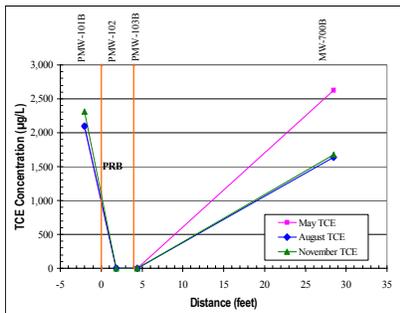


Figure 2
Segment 1 TCE Concentrations

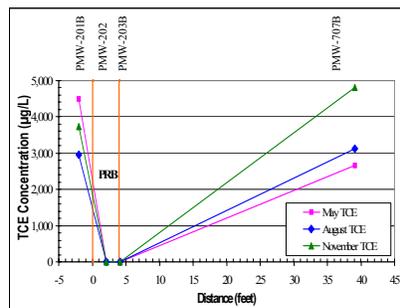


Figure 3
Segment 2 TCE Concentrations

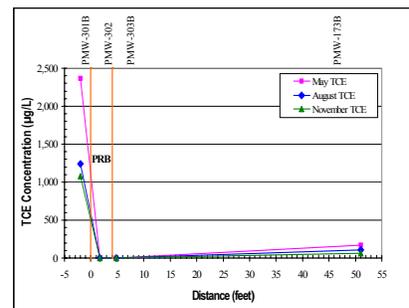


Figure 4
Segment 3 TCE Concentrations

Segment 1: Upgradient (influent) TCE concentrations have ranged from 2,100 to 2,310 µg/L during the three quarterly sampling events (see Figure 2). No detectable TCE concentrations have been reported in wells located within and immediately downgradient of the PRB. Well MW-700B, located approximately 30 feet downgradient of the PRB has TCE concentrations comparable to those in upgradient wells.

Segment 2: As illustrated on Figure 3, upgradient (influent) TCE concentrations have ranged from 2,960 to 4,500 µg/L. No detectable TCE concentrations have been reported in wells located within and immediately downgradient of the PRB. Well MW-707B, located approximately 40 feet downgradient of the PRB has TCE concentrations comparable to those in upgradient wells.

Wells PMW-201A and PMW-203A located beneath the PRB have detectable TCE concentrations that exceed treatment goals. These concentrations, ranging as high as 455 µg/L upgradient and 226 µg/L

downgradient, have been relatively consistent during each quarter of sampling. Therefore, they are believed to reflect existing contamination not addressed by the IRA and are not attributed to underflow caused by PRB installation.

Segment 3: As illustrated on Figure 4, upgradient (influent) TCE concentrations have ranged from 1,080 to 2,370 µg/L. No detectable TCE concentrations have been reported in wells located within and immediately downgradient of the PRB. Well MW-173B, located approximately 50 feet downgradient of the PRB, has TCE concentrations considerably lower than those in upgradient wells. These lower concentrations are assumed to reflect untreated TCE concentrations. Concentrations of *c*DCE and *t*DCE are below treatment goals in all Segment 3 PMW wells.

Well PMW-301A located beneath the PRB has detectable TCE concentrations above treatment goals. These concentrations have varied each sampling quarter with values of 124, 463, and 347 µg/L in May, August, and November 2000, respectively. It is unclear at this time if variable concentrations reflect existing contamination not addressed by the IRA, or the PRB in this area may be affecting contaminant flow. PMW-303A (downgradient and beneath the PRB) TCE concentrations are below treatment goals. PMW-303A does contain elevated concentrations of *c*DCE and vinyl chloride. The *c*DCE concentrations have been decreasing each quarter from a high of 121 µg/L in May 2000 to below treatment goals in subsequent quarters. Vinyl chloride concentrations have been consistently around 5 µg/L.

PRB Ends: Elevated TCE concentrations were reported in PMW-401 (east of Segment 3) and PMW-501 (west of Segment 1). Because there were detections in these areas before PRB installation and there is no evidence that the PRB has adversely impacted groundwater flow, these contaminants are assumed to represent the original plume. The SS7 PRB is an IRA, and remaining contamination will be addressed as part of the FEW final groundwater remedial action.

ICOC concentrations downgradient of the PRB are expected to decrease as sufficient pore volumes of groundwater flush through the system and the effects of desorption diminish through time. Concentration trends of *c*DCE and *t*DCE in Segments 1, 2, and 3 resemble TCE distributions and meet treatment goals.

Diamond Creek Contaminant Loading: Diamond Creek TCE concentrations increase as they flow past SS7. This suggests that TCE-contaminated groundwater is discharging directly into Diamond Creek from SS7. Elevated TCE concentrations observed at upstream Location D3 originate from another source. A decrease in or leveling off of downstream concentrations at Locations D3.5 and D3.6 is not expected until after a decrease is observed in monitoring wells located midway between the PRB and Diamond Creek.

Effects on Groundwater Flow Paths: Groundwater level measurements collected in upgradient, in-PRB, and downgradient wells reveal a relatively flat and uniform hydraulic gradient across the PRB. Groundwater levels measured in wells located along the ends of Segment 1 and Segment 3 have groundwater elevations that are also consistent with a relatively flat and uniform hydraulic gradient. Based on these results, there is no evidence that the PRB has disrupted natural groundwater flow paths.

CONCLUSIONS

In brief, the SS7 PRB performance monitoring program results are encouraging. The effectiveness of reactive iron to reduce ICOC concentrations below treatment goals is easily demonstrated by comparing results in upgradient, in-PRB, and downgradient wells. The following is a summary of conclusions:

- ◆ Groundwater-level measurements from each quarter reveal a relatively flat and uniform hydraulic gradient across the PRB, indicating that the PRB has not disrupted natural groundwater flow.
- ◆ All performance monitoring of wells within and immediately downgradient of the iron have resulted in ICOC concentrations below detection limits.
- ◆ Concentrations 30 to 50 feet downgradient of the iron remain comparable to upgradient concentrations, likely due to desorption. Desorption effects are expected to diminish over time as sufficient groundwater flushes through the system, causing a decrease in concentrations over time.