REGENESIS®

PlumeStop Barrier Protects Drinking Water Supply Wells

Case Study: Innovative Remedial Approach Addresses Large PCE Plume at a Bedrock Site Under the CERCLA-Regulatory Framework

Overview

PlumeStop Protects Private Drinking Water Supply Wells in a Bedrock Aquifer

PlumeStop® Colloidal Activated Carbon was used in a permeable reactive barrier (PRB) to halt the movement of chlorinated solvents in groundwater emanating from historic releases at a former chemical manufacturing facility in Texas. The chlorinated solvent plume, comprised of tetrachloroethene (PCE) and associated daughter products, had migrated offsite and impacted private water supply wells screened in a bedrock aquifer.

EA Engineering, Science, and Technology, Inc., PBC (EA Engineering), a leading multi-disciplinary environmental and engineering consulting firm, contracted REGENESIS to implement the solution. PlumeStop was to be applied as part of an *in situ* bioremediation (ISB) PRB near the distal end of the plume to promote sorption-enhanced natural attenuation of the contaminants.

REGENESIS® Remediation Services (RRS) installed the PRB using a responsive, highly-adaptive, phased approach based on information obtained during the remediation implementation. Although the overall contaminant distribution and plume extent had been well defined, localized geological variabilities impacting contaminant flux at the PRB required remedial design flexibility and real-time adjustments during the application.

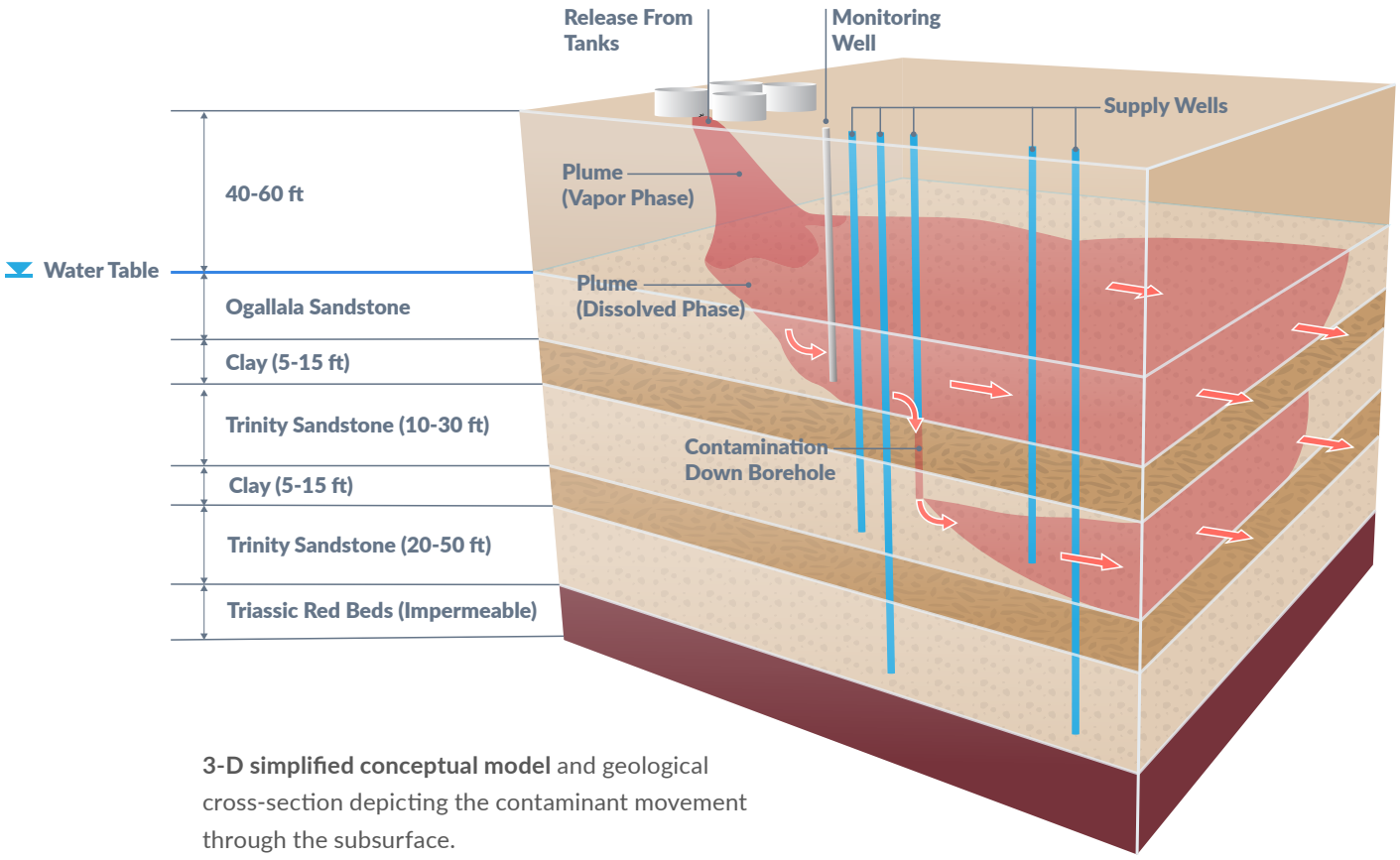
Following its installation, the PlumeStop PRB achieved the project objective, reducing PCE and chlorinated solvent daughter products below the most stringent drinking water maximum contaminant levels (MCLs) and protecting offsite private water supply wells. The pragmatic and adaptive, phased remedial approach employed by the REGENESIS/EA Engineering project team was instrumental to the project's success.

Background

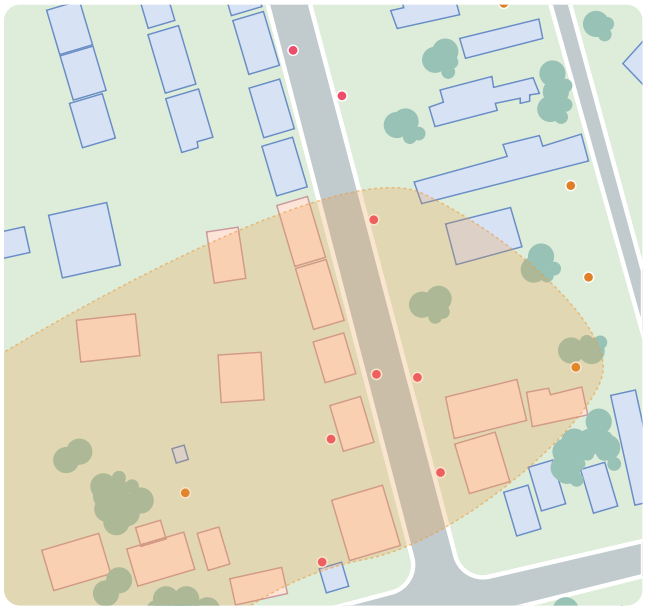
Site Goals Included Prevention of Further PCE Plume Migration and Reducing Exposure Risk in a Bedrock Aquifer

In the 1980s, a chemical manufacturing facility in west Texas released more than 600 gallons of PCE and other chlorinated solvents into the subsurface. The PCE leached into groundwater more than 50 feet below ground surface (bgs), forming a chlorinated solvent contaminant plume in bedrock which migrated along with groundwater northeastward from the facility. PCE breakdown products trichloroethene (TCE) and cis-1,2-dichloroethene (DCE) were also formed in the plume.

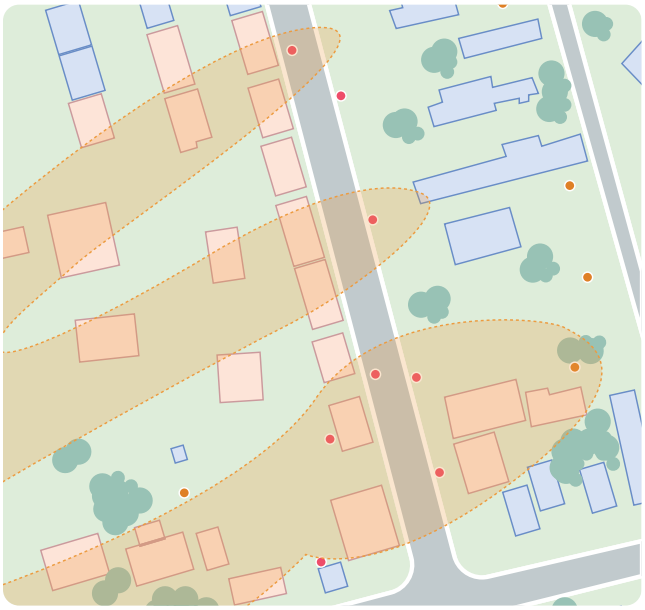
Private water supply wells became impacted when old abandoned water wells were not properly plugged and acted as conduits allowing the contaminants to migrate through the complex caliche sandstone units (i.e., sands cemented with calcium carbonate) to depths of more than 100 feet below ground surface (bgs). These sandstone units are separated by relatively thin clay-dominant caliche layers. The private supply wells had been pumping from both the Trinity units.



3-D simplified conceptual model and geological cross-section depicting the contaminant movement through the subsurface.



Initial estimated extent of leading edge of PCE plume prior to further delineation from discrete sampling along barrier transect.



Areal map depicting the true extent of the PCE plume following delineation efforts.

Remediation Timeline

- 2011 — Decision Document signed specifying a cleanup strategy
- 2014 — Remediation Activities Begin
- 2017 — Phase 1 of PlumeStop Applications Begin
- 2019 — Phase 2 of PlumeStop Applications
- 2020 — Phase 3 of PlumeStop Applications

In 2011, a Decision Document was signed specifying a cleanup strategy. Active remediation began three years later. Near the source area, soil vapor extraction was used to treat contaminants in the vadose zone, while ISB electron donor and bioaugmentation substrates were applied to address contaminants in the Ogallala Sandstone. In addition, leaky private wells and boreholes thought to be contributing to the vertical plume migration were either plugged or replaced.

With the source reduction mechanisms in place, attention was directed toward the distal plume section. Here, the goal was to prevent further migration of PCE and daughter products, thus protecting the private supply wells over the long term.

After reviewing various treatment approaches, PlumeStop in a PRB application was selected to cut off contaminants near the downgradient extent of the 1,300 feet long chlorinated solvent plume. In modeling the sorption-enhanced natural attenuation of the chlorinated solvents, the effective longevity of the barrier was initially estimated at 15 years, providing sufficient time for the upgradient plume treatment to reduce the influx of contaminants at the PRB location.

Contaminant Details

Contaminants	PCE, TCE, and cis-DCE
Maximum Total Concentration	44 µg/L
Groundwater Velocity	up to 430 ft/yr *(confirmed by passive flux sampling)*

PlumeStop PRB Details

Barrier Length	440 ft
Total Injection Wells	39
Treatment Interval	82-103 ft bgs

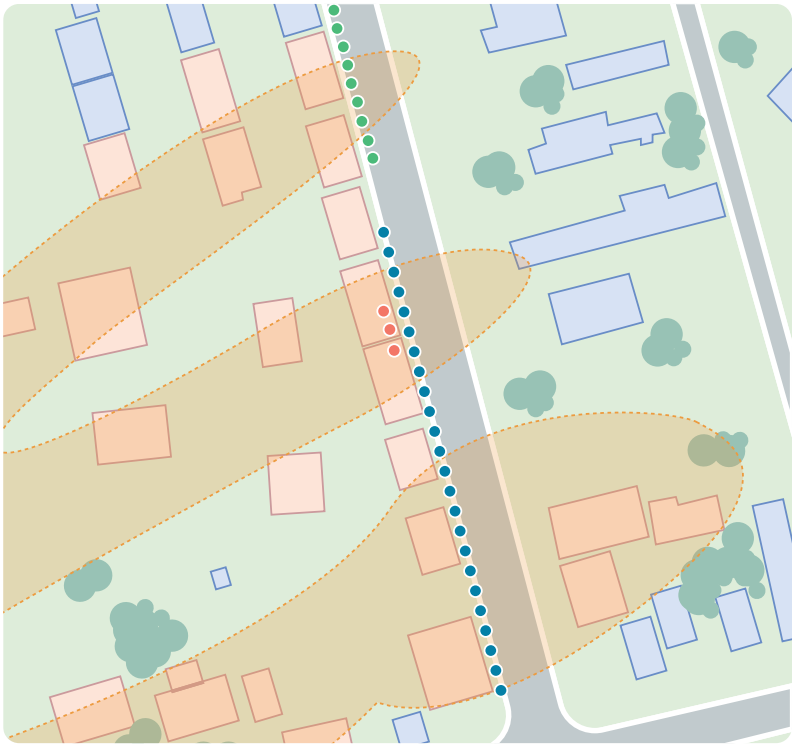
PlumeStop Applications

Phase 1 *Initial Application* March/April 2017	34,250 gallons
Phase 2 *Vertical PRB Extension* March 2019	4,350 gallons
Phase 3 *Lateral PRB Extension and Dosing Adjustment* June 2020	68,450 gallons

PlumeStop PRB Remedial Implementation:
A Phased Approach Optimized PRB Construction

RRS completed the PRB application over three phases spanning from 2017 to 2020, injecting over 100,000 gallons of PlumeStop in total. The remediation phases included:

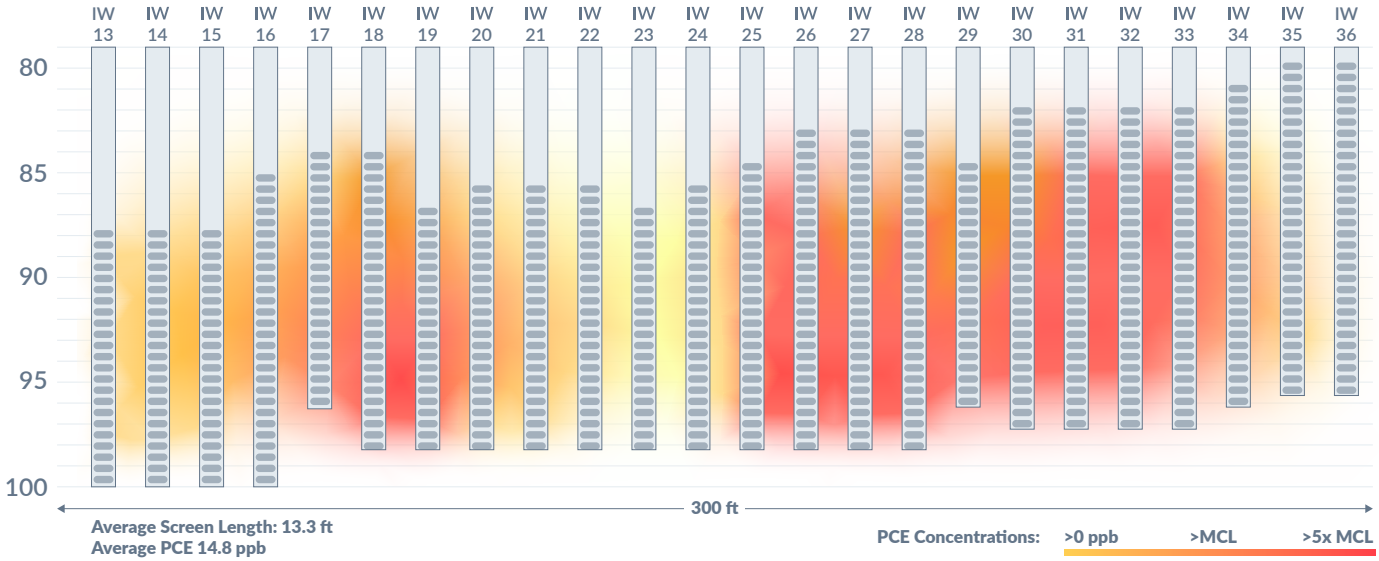
- The initial PRB application near the distal plume boundary (2017),
- A limited second phase application, which involved the installation of three new injection wells drilled slightly deeper to extend the treatment in the first Trinity Sandstone Unit (2019), and
- A third phase application extended the barrier in the northern direction. The third phase also increased the PlumeStop dose throughout a section of the original PRB, based on passive flux sampling data indicating significantly higher contaminant flux than modeled initially (2020).



Areal map depicting the location of the three PlumeStop PRB installation phases. Plume boundary shown as it existed prior to application, following discrete sampling of injection wells.

To ensure the effectiveness of the PRB and provide protection to the downgradient private water supply wells as intended, critical design parameters had to be confirmed. Design Verification Testing (DVT), REGENESIS' approach to optimize the design and application, was performed by the team.

Typically, DVT is specified and conducted ahead of mobilizing to the site to complete the remediation. However, since the site was already beyond the Remedial Investigation (RI) phase and well into the Remedial Action (RA) phase for an approved *in situ* bioremediation approach, EA Engineering and REGENESIS had to adapt and the DVT work had to be conducted either during or following the initial remediation phase. DVT involved a coordinated effort between REGENESIS and EA Engineering to adjust the remediation injection design and application as new information was received during the project.



Cross section depicting contaminant impacts across the Initial Phase PRB section, ranging from 82 to 100 feet bgs, based on sample analysis from the initial injection wells.

DVT Summary

DVT Components Completed By EA Engineering

Geophysical Logging	Confirmed vertical position of the sandstone units
Lateral and Vertical Profile Sampling and Analysis *Field Deployment and Sample Collection*	Defined contaminant distribution to determine product allocation and dosing
Performance Monitoring Well Installation and Further Plume Delineation	Tracked performance and demonstrates progress toward remedial goals. Information from these wells was also used for further characterization of the contaminant plume
Passive Flux Sampling	Completed during a later phase of the project, passive flux samplers were used to confirm contaminant flux across the PRB, necessary for engineering its effective longevity

DVT Components Completed By REGENESIS

Lateral and Vertical Profile Sampling and Analysis *Analysis and Mapping*	Defined contaminant distribution to determine product allocation and dosing
Piezometer Injection Test	Confirmed design volumes to secure full lateral distribution of injected products. Assessed optimal product injection rates and remedial injection timeframe.

The following were key findings from the ongoing DVT effort, describing how these findings were used to optimize the PRB construction.

- Before injection, downhole geophysical logging, completed at every fourth injection well (6 total), confirmed the vertical target interval, ranging from 82 to 100 feet below ground surface (bgs).

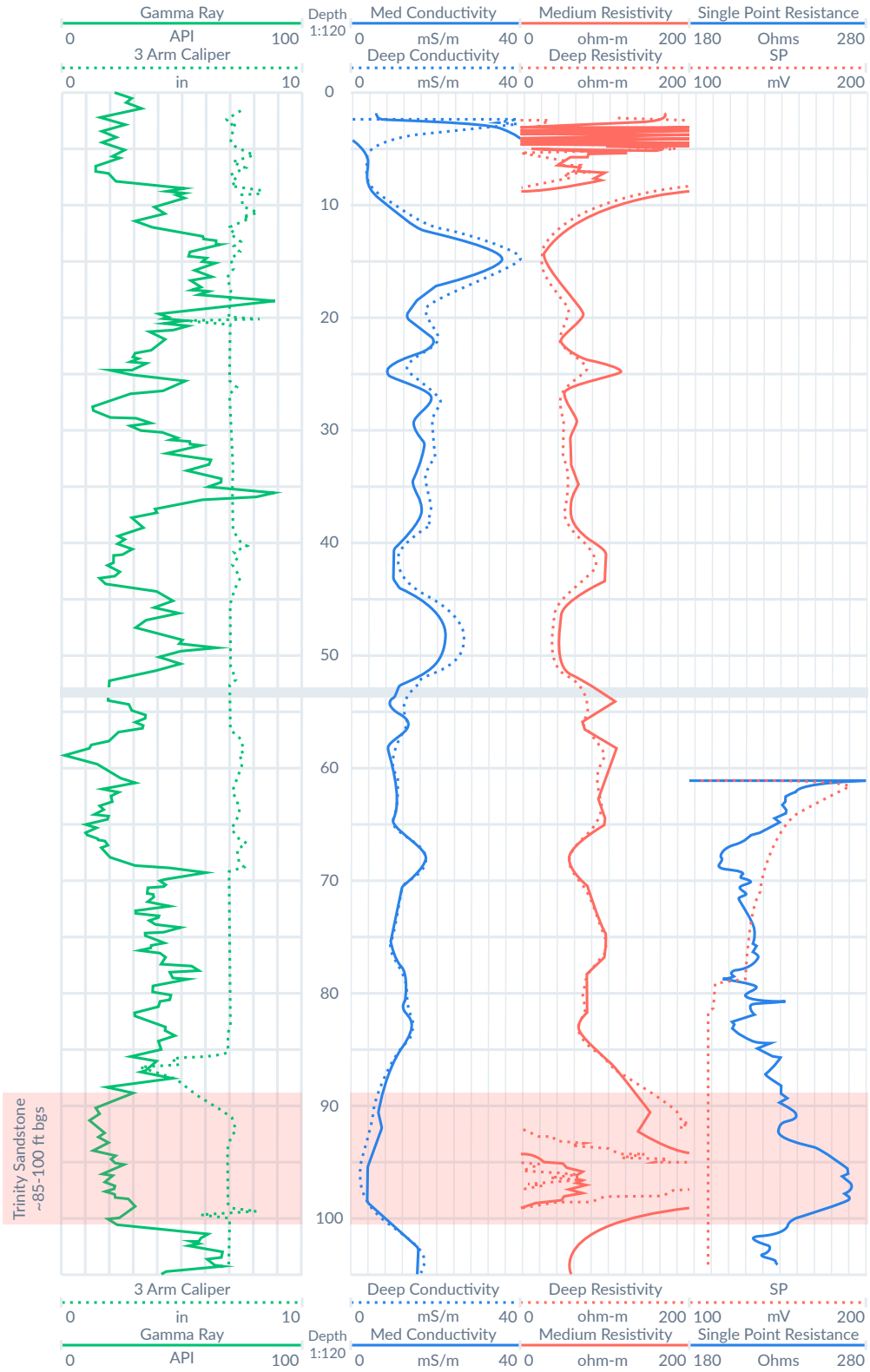
- Groundwater samples collected from the injection wells before the initial phase injection indicated that the contaminants were not evenly distributed across the PRB, with a prominent gap identified in the PRB's northern section. REGENESIS adjusted the initial phase design by varying the dosing applied across the PRB.

- An additional narrow plume lobe (or finger) was delineated to the north of the proposed PRB. The PRB was extended to address this lobe during the second application phase.

- Passive flux sampling data collected after the initial application confirmed higher contaminant flux rates than initially modeled. In response, additional PlumeStop was applied during the third application phase to increase the dose and maintain the design longevity of the PRB.

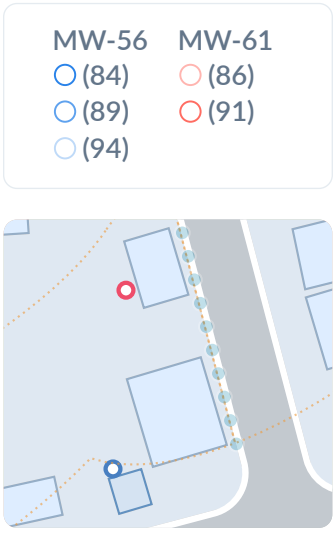
Additionally, injection pressure variability was observed in sections of the PRB during the application. This variability was thought to be related to the degree of caliche cementation, whereas the less permeable zones were likely correlated to more prominently cemented zones. RRS adjusted the application and modified the injection volumes in response to these localized differences.

Geophysical log depicting Trinity Sandstone Unit (red shaded area) between approximately 85 and 100 feet bgs in the borehole.

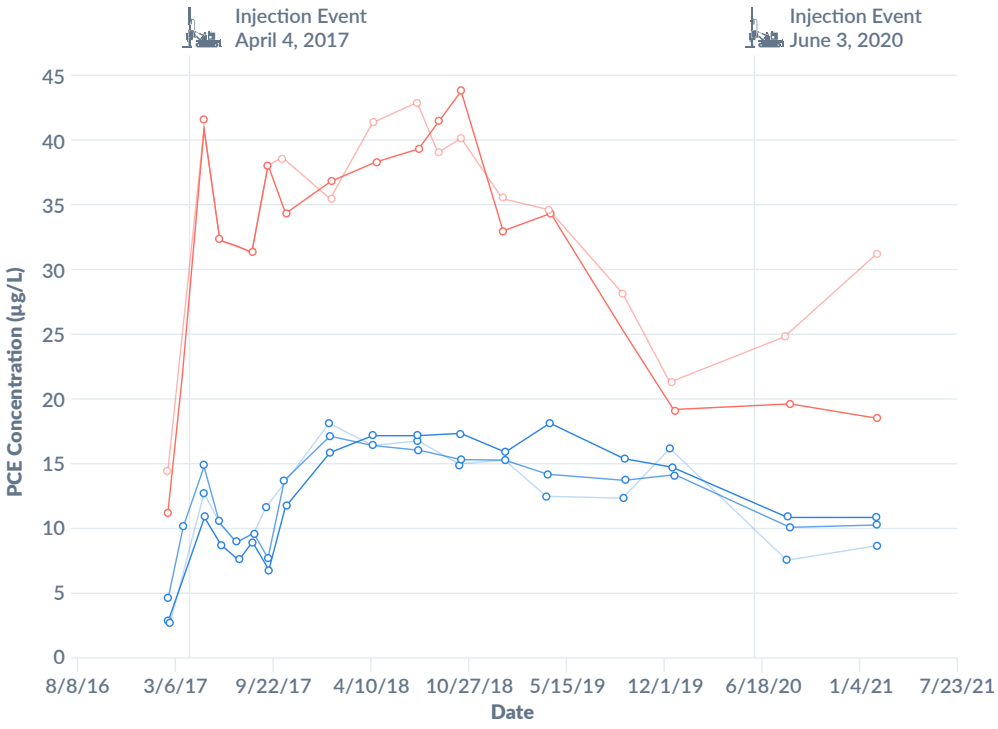


Performance Results
PlumeStop PRB Meets Objectives

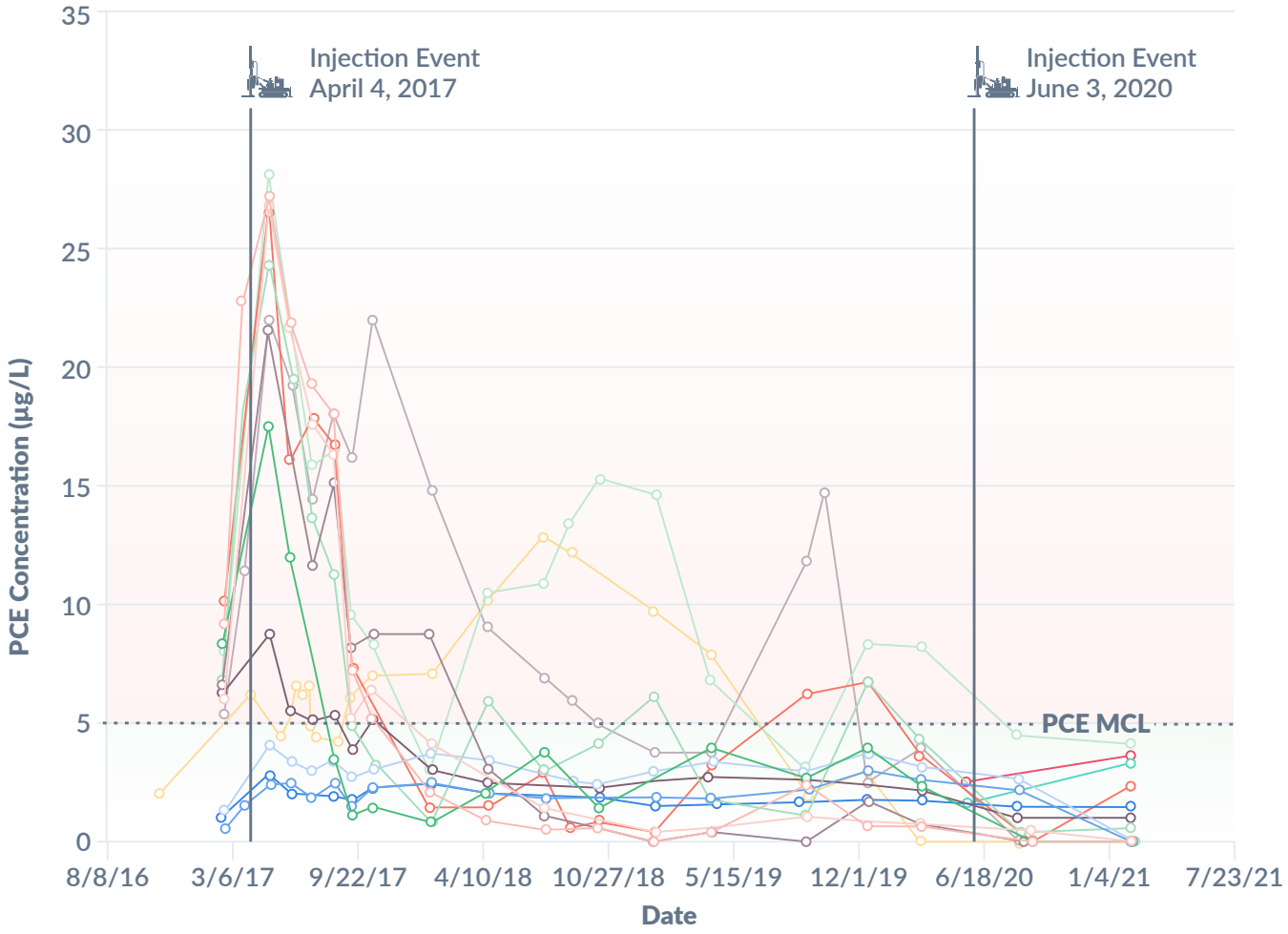
The PlumeStop PRB meets the project objective, cutting off PCE and chlorinated solvent daughter products and preventing further movement downgradient toward the identified sensitive receptors (i.e., private water supply wells). A robust network of performance monitoring wells has demonstrated PCE and daughter product reductions below drinking water MCLs downgradient of the PRB.



PCE Concentrations *Upgradient* of PlumeStop PRB (MW-56 and MW-61)



Observed PCE Concentrations in *Downgradient* Monitoring Wells

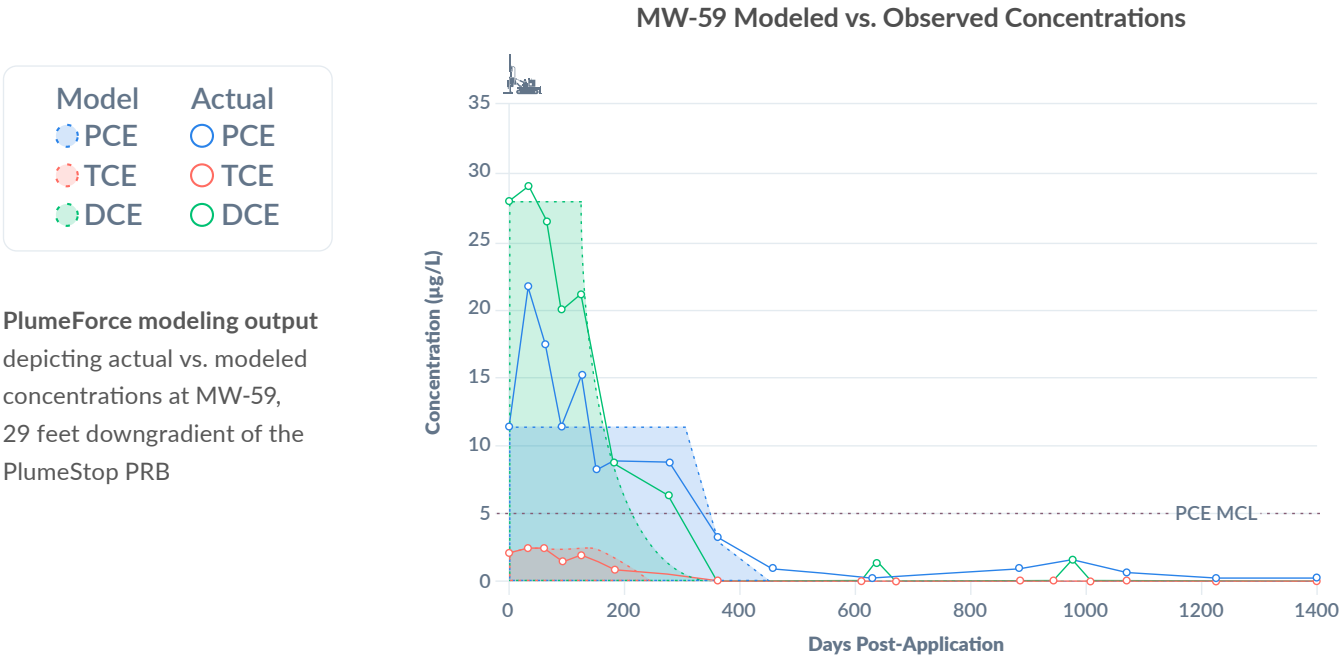


- MW-57 (88)
- MW-57 (93)
- MW-57 (98)
- MW-58 (88)
- MW-58 (93)
- MW-58 (98)
- MW-59 (87)
- MW-59 (91)
- MW-59 (95)
- MW-60 (85)
- MW-60 (90)
- MW-60 (95)
- MW-72 (92)
- MW-72 (95)
- MW-72 (98)
- GW-207

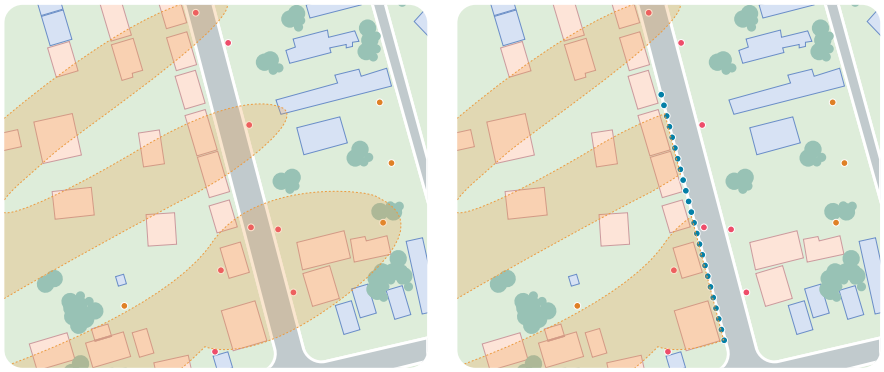
PlumeForce™ Modeling Tool

REGENESIS completed predictive modeling to assess performance and estimate the contaminant concentrations downgradient of the PRB over time. PlumeForce,™ a proprietary modeling tool developed by REGENESIS that accounts for the competitive sorption of multiple contaminants, potential back-diffusion of contaminants from fine-grained zones to permeable transport zones and predicts breakthrough for contaminants modeled was used to predict performance. Following this effort, actual contaminant concentrations in the downgradient wells were observed to be well correlated to the modeled predictions, giving confidence to the project stakeholders that the PRB is functioning as intended.

In summary, the PlumeStop PRB is performing as designed and is expected to maintain PCE concentrations below the MCLs for the 15-year design life expectancy of the barrier.



PlumeForce modeling output depicting actual vs. modeled concentrations at MW-59, 29 feet downgradient of the PlumeStop PRB



Areal map depicting the change in plume extent before (left) and after (right)PlumeStop application.

About The Consultant

EA Engineering, Science, and Technology, Inc., PBC

EA Engineering, Science, and Technology, Inc., PBC

EA Engineering, Science, and Technology, Inc., PBC provides a broad range of environmental science and engineering solutions to a diverse customer base including the federal and state governments, municipalities, private industry, and non-profit organizations.

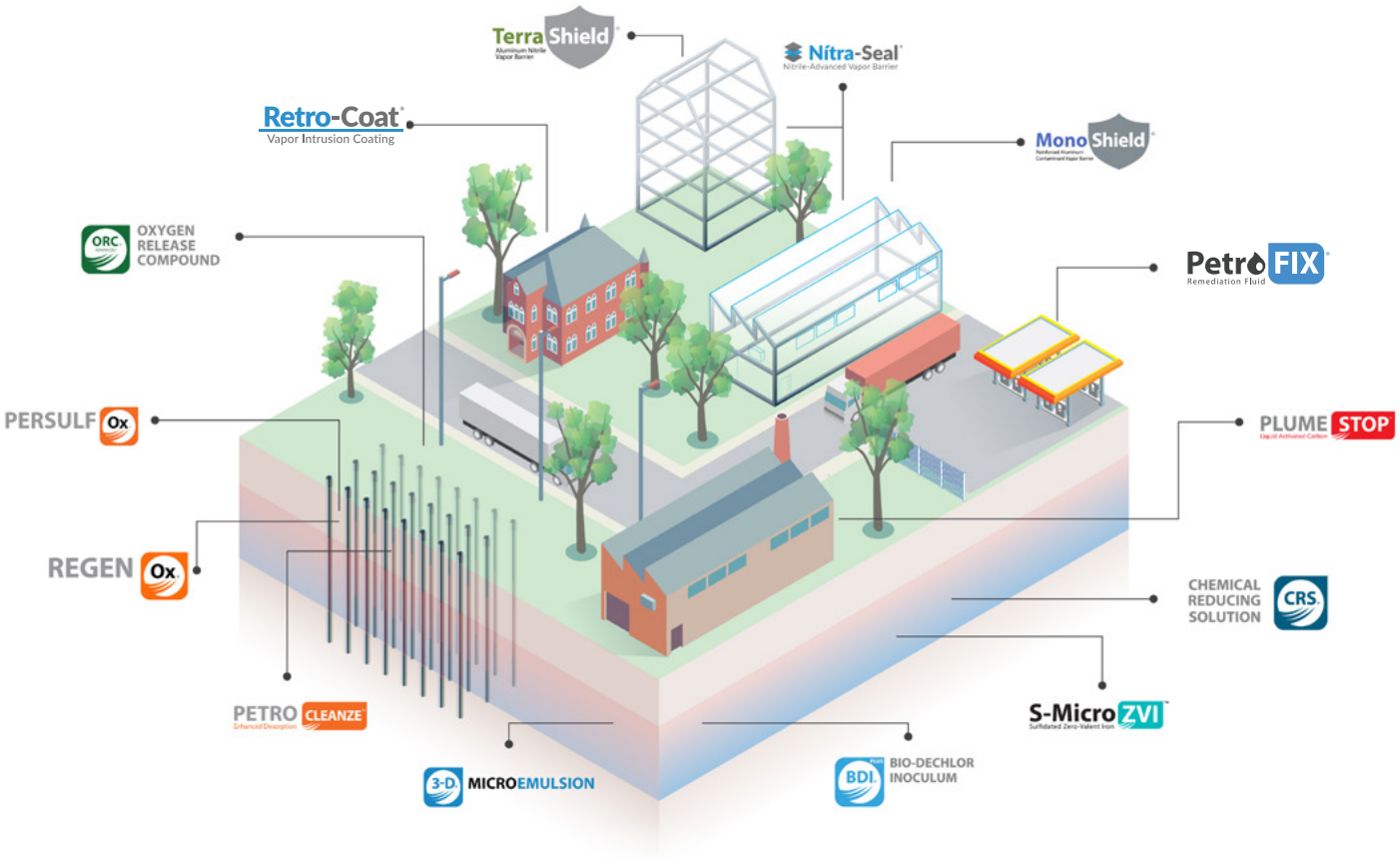
EA Engineering has completed more than 100,000 environmental projects and performed more than $1 billion of services worldwide. Engineering News Record consistently ranks EA among America's Top 200 Environmental Firms, a testament to the business earned from its clients as a result of the quality, cost-effectiveness, timeliness, and responsiveness of our service.

Technologies Used

PlumeStop Colloidal Activated Carbon

PLUME STOP® Liquid Activated Carbon

PlumeStop® Colloidal Activated Carbon is a fast-acting groundwater remediation reagent which captures and biodegrades a range of contaminants, thus accelerating the successful treatment of impacted sites and leading to their permanent closure. As a science-based, *in situ* treatment technology, REGENESIS' PlumeStop rapidly removes contaminants from groundwater and stimulates their permanent degradation.



About REGENESIS

At REGENESIS we value innovation, technology, expertise and people which together form the unique framework we operate in as an organization. We see innovation and technology as inseparably linked with one being born out of the other.

Inherently, innovation imparts new and better ways of thinking and doing. For us this means delivering expert environmental solutions in the form of the most advanced and effective technologies and services available today.

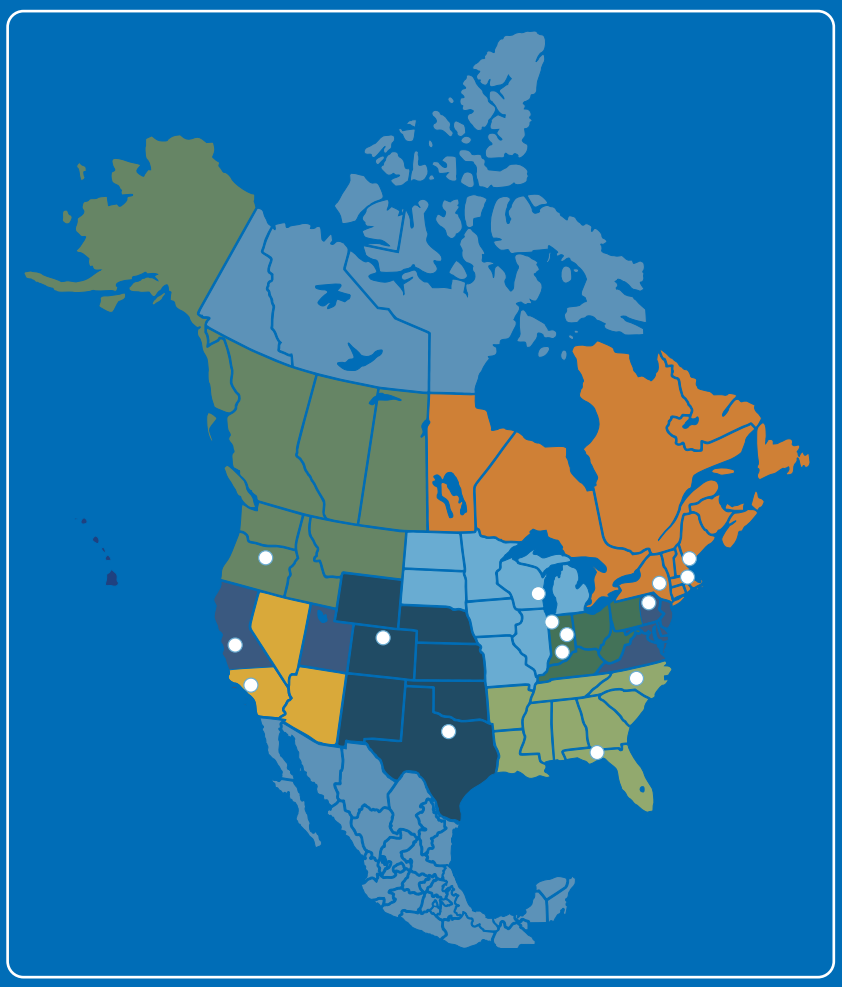
We value expertise, both our customers' and our own. We find that when our experienced staff collaborates directly with customers on complex problems there is a high potential for success including savings in time, resources and cost.

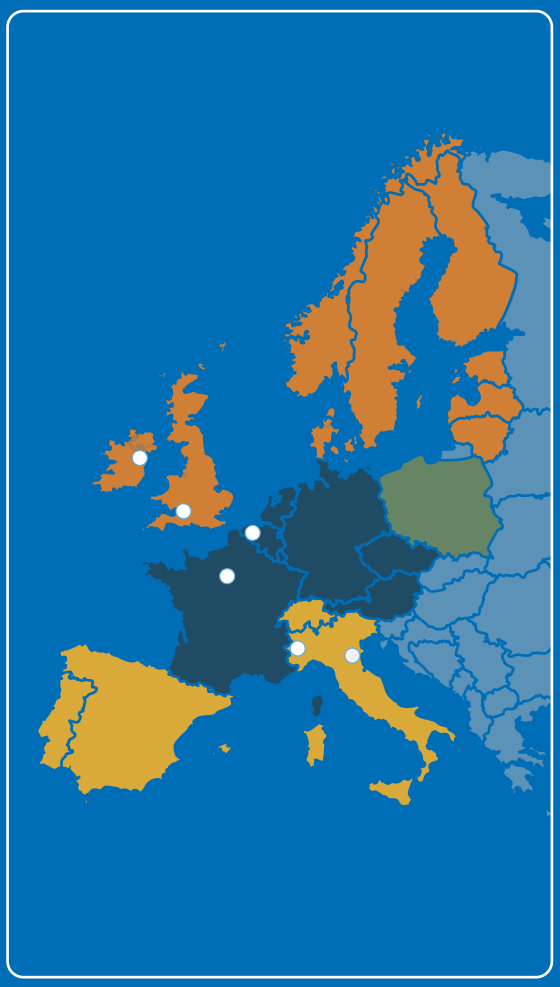
At REGENESIS we are driven by a strong sense of responsibility to the people charged with managing the complex environmental problems we encounter and to the people involved in developing and implementing our technology-based solutions. We are committed to investing in lasting relationships by taking time to understand the people we work with and their circumstances. We believe this is a key factor in achieving successful project outcomes.

We believe that by acting under this set of values, we can work with our customers to achieve a cleaner, healthier, and more prosperous world.

REGENESIS®

We're Ready to Help You Find the Right Solution For Your Site





Global Headquarters

1011 Calle Sombra
San Clemente, CA 92673 USA

Ph: (949) 366-8000
Fax: (949) 366-8090

Europe

Bath, United Kingdom
Ph: +44 (0) 1225 61 81 61

Dublin, Ireland
Ph: +353 (0) 9059 663

Torino, Italia
Ph: +39 338 8717925

Ieper, België
Ph: +32 (0) 57 35 97 28

Visit www.REGENESIS.com to learn more.

REGENESIS®

www.REGENESIS.com