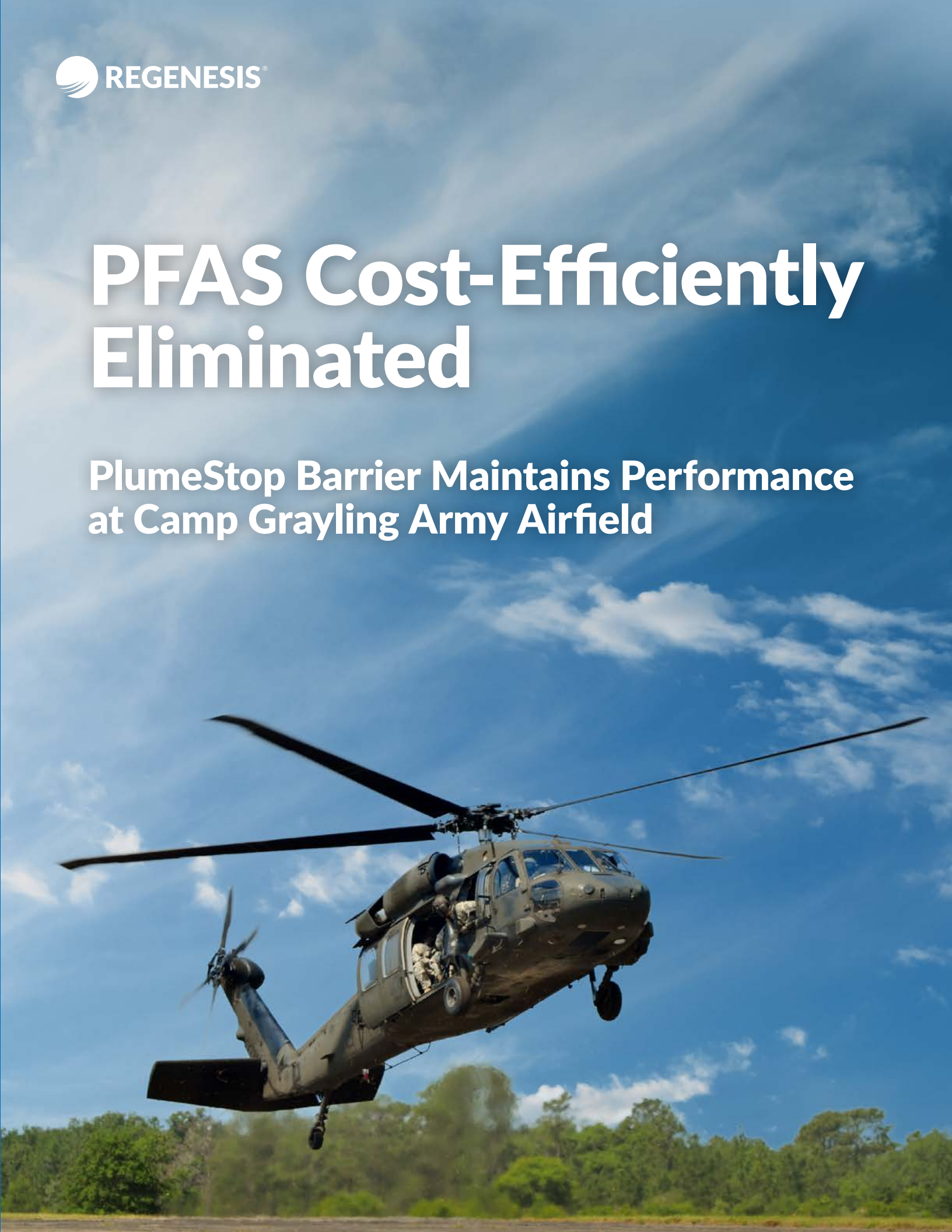
REGENESIS®

PFAS Cost-Efficiently Eliminated

PlumeStop Barrier Maintains Performance at Camp Grayling Army Airfield



Background

PFAS is Discovered in Groundwater at a Michigan Army National Guard Base

Innovative approach using colloidal activated carbon barrier to eliminate PFAS exposure pathway and protect the community.

Highly collaborative effort amongst interdepartmental groups.

Economical and effective pilot study design.

Camp Grayling in Crawford County, Michigan, is a year-round training center for the Michigan Army National Guard (MIARNG). As the largest National Guard training installation in the U.S., Camp Grayling provides year-round training support for the MIARNG along with military commanders and civilian leaders to meet their readiness requirements. Camp Grayling has a proud history dating back to the first World War and has been instrumental in training U.S. multi-reserve troops and Michigan National Guards corpsmen and women for every major war over the last 100 years. Camp Grayling is recognized internationally for hosting the event, Northern Strike, a joint training exercise involving all U.S. armed forces and armed forces from 12 other countries. The area surrounding Grayling is home to recreational activities that include hunting, boating, and fishing. It is known for its beauty, abundant wildlife, and many lakes and waterways.



Site Remediation History and Recent Discovery of PFAS

Since the late 1980s, the Michigan Department of Military and Veteran Affairs (DMVA) has been remediating groundwater impacted by chlorinated solvents historically used at the facility. In 2016, the DMVA became aware of the potential contamination of PFAS from past operations such as on-site firefighting training. In response, they began testing groundwater at the Grayling Army Airfield (GAAF). The testing revealed PFAS (per- and polyfluoroalkyl substances), commingled with chlorinated solvents, migrating towards the property boundary.



Firefighting training activities were conducted onsite previously, leading the DMVA to suspect PFAS contamination.



Groundwater sampling and laboratory analysis confirmed PFAS was present in groundwater.

70 Parts Per Trillion EPA

The U.S. EPA regulatory guidelines for two PFAS compounds, PFOS and PFOA, are set at 70 parts-per-trillion, equivalent to a single drop in three Olympic-size swimming pools. This concentration is 70 times lower than the U.S. EPA drinking water maximum contaminant level for benzene.

PFAS - Problematic for Remediation

PFAS are a large group of human-made chemical compounds that have been in use since the 1940s. The remediation of PFAS is particularly challenging since these compounds were designed to be very stable, making them highly persistent in the environment. They are mobile in groundwater and are very slow to biodegrade naturally. In addition, their reported toxicity has led to the establishment of exceedingly low cleanup goals by the Michigan Department of Environment, Great Lakes & Energy (EGLE), and other regulatory agencies, most often in the part-per-trillion range. PFAS have been used in consumer products for decades, and their ubiquity in the environment is a dawning realization for the environmental industry. As a result of these factors, few *in situ* treatments are available for PFAS, and fewer still have demonstrated effectiveness.

Michigan's PFAS Response

Michigan government leaders have been proactive in addressing PFAS as emerging contaminants of concern in groundwater. In 2017, the Governor of Michigan launched an interagency group called the Michigan PFAS Action Response Team (MPART) tasked with investigating sources and locations of PFAS and protecting drinking water and public health. This group, of which the Michigan DMVA is a member, frequently meets to address PFAS contamination and collaborate on proactive solutions.

"We have great partners with Wood, my staff, and REGENESIS to come up with a good strategy for an effective pilot study..."

Jonathan Edgerly
Environmental Manager,
Michigan National Guard

REGENESIS®

Remedial Technology Evaluation

PlumeStop, an *In Situ* PFAS Treatment Technology, Emerges as the Solution to Test

Remedial Technology Evaluation

The DMVA completed a remedial technology evaluation, ultimately deciding to pilot test a PlumeStop colloidal activated carbon PRB in the field. Expected performance and cost were the driving factors for the DMVA's decision.

What is a PlumeStop PRB?

A PlumeStop PRB is constructed of an injection point array with its orientation perpendicular to the principal groundwater flow direction. Soon after injection, PlumeStop binds to the aquifer soil, leaving the soil grains coated with carbon and creating a reactive sorption zone.

DMVA's Remedial Technology Evaluation and Decision

The DMVA's environmental task force evaluated possible groundwater remedial technologies to address PFAS, including classical mechanical approaches such as pump-and-treat. During the evaluation, the task force became aware of a new method to eliminate risk through *in situ* treatment, using REGENESIS' PlumeStop®, a form of colloidal activated carbon. This innovative technology has demonstrated effectiveness at other PFAS-impacted groundwater sites, quickly removing these contaminants from the dissolved phase and eliminating downgradient exposure risk. PlumeStop's effectiveness at PFAS removal from groundwater is expected to last for decades at these sites based on internal and third-party modeling simulations.

After reviewing potential remedial options to pilot-test in the field, including pump-and-treat, the DMVA ultimately decided to pilot test PlumeStop in a permeable reactive barrier (PRB). The primary reason DMVA chose PlumeStop for the pilot test was its demonstrated potential to remove PFAS from the dissolved phase quickly combined with long-term treatment promise. Additionally, the project life-cycle cost was a consideration for the DMVA in their selection. The projected cost for installing a PlumeStop PRB was significantly lower than operating a mechanical system over a similar timeframe.



Pilot Test

REGENESIS Develops and Implements an Efficient Pilot Test Barrier Design, Documenting Consistent PlumeStop Distribution

Following the selection process, REGENESIS and the Michigan DMVA team moved quickly to develop a pilot test plan for the PlumeStop PRB. The goal of the pilot test was to demonstrate both immediate and long-term removal of PFAS and the commingled chlorinated solvents by the PlumeStop PRB. The pilot test's efficient scoping minimized the materials needed and cost to accomplish the goal.

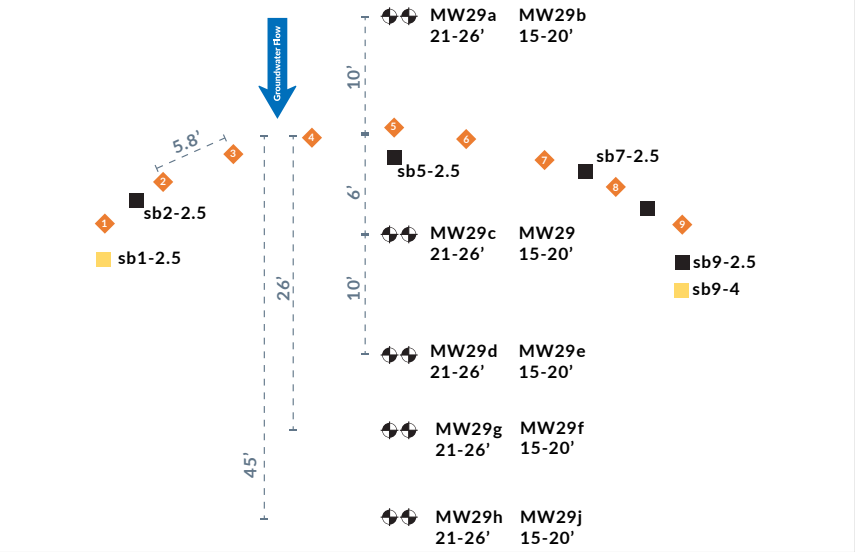
To determine the amount of PlumeStop needed for any PRB, REGENESIS utilizes a proprietary finite-difference model explicitly developed for PlumeStop. This model accounts for site-specific factors such as hydrogeology and contaminant flux and considers competitive sorption and biodegradation to determine the quantity of PlumeStop needed over a user-defined period.

How Does a PlumeStop PRB Work?

As groundwater passes through the treatment zone, the flow of PFAS and other contaminants are slowed (i.e., retarded) by orders of magnitude, effectively binding them, halting their movement, and eliminating exposure to down-gradient receptors. As the exposure to downgradient receptors is eliminated, so is the risk. In essence, a PlumeStop PRB functions as an *in situ* purifying filter for groundwater.

Legend:

- Monitoring Well
- Injection Point
- Searcher Core
- PlumeStop Present in Search Core



The application design consisted of a single row of nine direct push injection points positioned upgradient of a previously installed monitoring well, MW-29. The injection line was configured as an arc to account for temporal and spatial variability in the groundwater flow direction. Initially two downgradient well pairs (MW-29/29C and MW-29D/29E) were placed 6 feet and 16 feet downgradient of the barrier, respectively, to monitor the pilot test performance. Each well of a well pair was installed with a 5-feet screened section to monitor the upper and lower treatment interval sections.



Application Design Summary

Contaminants of Concern

PFAS	150 ng/L
PCE	6 µg/L
Seepage Velocity	200 ft/yr

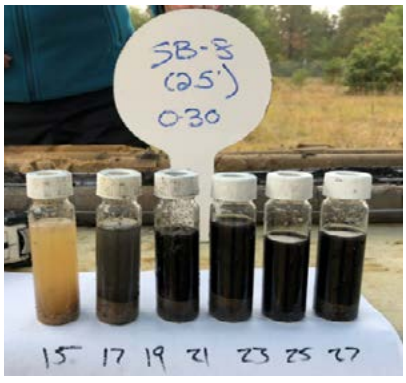
PRB Construction

Technologies Applied	PlumeStop
Injection Points	9
Injection Spacing	6 ft
Treatment Interval	15-27 ft bgs
Application Volume	8,500 gal

The vertical injection interval was specified from 15 to 27 feet below the ground surface (bgs) to match the PFAS flux zone and accommodate seasonal water table fluctuations. In the pilot test area, this PFAS flux zone was predominantly comprised of sand and gravel overlying a clay layer. Before injection, REGENESIS Remediation Services (RRS) verified this target interval by collecting soil cores, observing the soil grain size, and noting the degree of saturation.

RRS commenced the PlumeStop barrier application in October 2018. RRS performed optimization testing at the outset, methodically adjusting injection variables, including flow rate, screen size, injection volume, and injection point positioning. The purpose of the optimization testing is to ensure even placement of PlumeStop horizontally and vertically. RRS documented PlumeStop distribution by collecting soil cores and groundwater samples from temporary piezometers placed between injection points. The soil cores revealed consistent PlumeStop distribution over the target interval, while the groundwater samples collected from the piezometers indicated robust PlumeStop presence in groundwater.





Core samples and settling tubes taken from SB8-2.5 depicting consistent PlumeStop saturation from 15-27 feet bgs.

Results

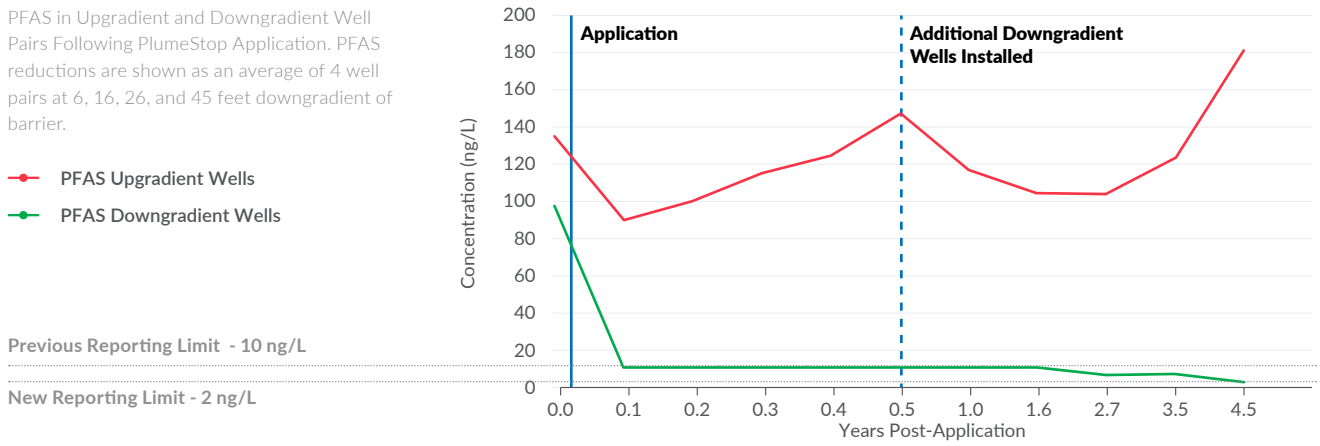
PlumeStop Removes PFAS and Chlorinated Solvents Immediately, with Reductions Maintained for 4.5 Years, Thus Far...

PFAS Levels Reach Non-Detect 1 Month Post Application and Remain Reduced in Downgradient Performance Monitoring Wells

By the first sampling event, approximately one month after injection, the PlumeStop PRB reduced PFAS to concentrations below the standard method detection limit of 10 nanograms per liter (ng/L) in downgradient wells. Initial reductions were also observed in upgradient well-pair (MW-29A/B), indicating potential injection influence. However, by the second event, approximately two months after injection, concentrations in these upgradient wells had begun to rebound while the downgradient wells remained at non-detect. Since then, the PlumeStop PRB has maintained PFAS reductions below 10 ng/L in the downgradient wells for 4.5 years thus far.

PFAS Performance Data

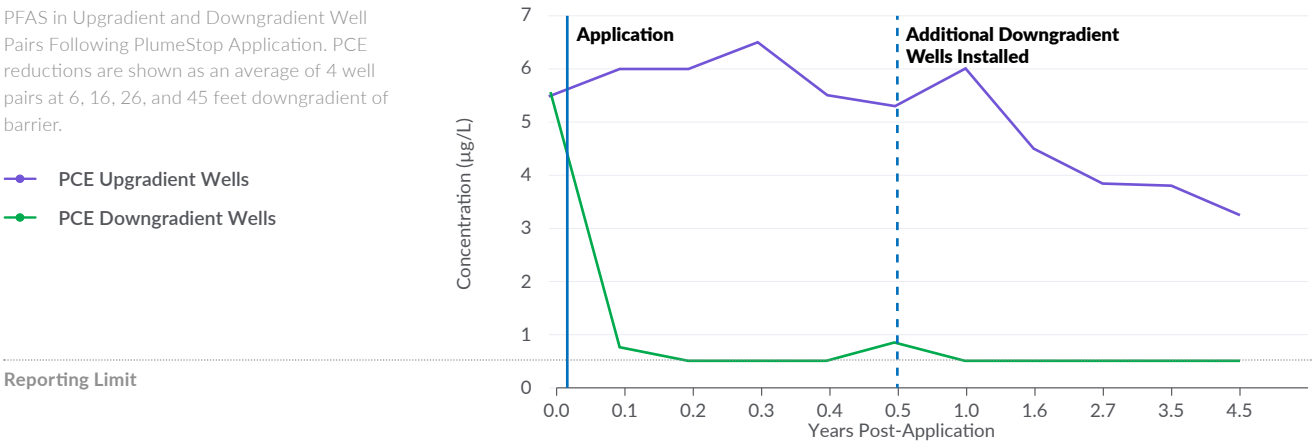
PFAS in Upgradient and Downgradient Well Pairs Following PlumeStop Application. PFAS reductions are shown as an average of 4 well pairs at 6, 16, 26, and 45 feet downgradient of barrier.



PCE concentrations followed a similar pattern as PFAS: reduction to non-detect (1 microgram per liter) by the first month, followed by sustained non-detect levels.

PCE Performance Data

PFAS in Upgradient and Downgradient Well Pairs Following PlumeStop Application. PCE reductions are shown as an average of 4 well pairs at 6, 16, 26, and 45 feet downgradient of barrier.



PlumeStop has achieved the remedial objectives for the pilot test, while modeling predictions suggest that the PlumeStop PRB installed for the pilot test will continue to remove PFAS for decades. Based on these performance results, the Michigan DMVA considers expansion of the treatment at this and other PFAS impacted sites.



Technology Used

PlumeStop Colloidal Activated Carbon

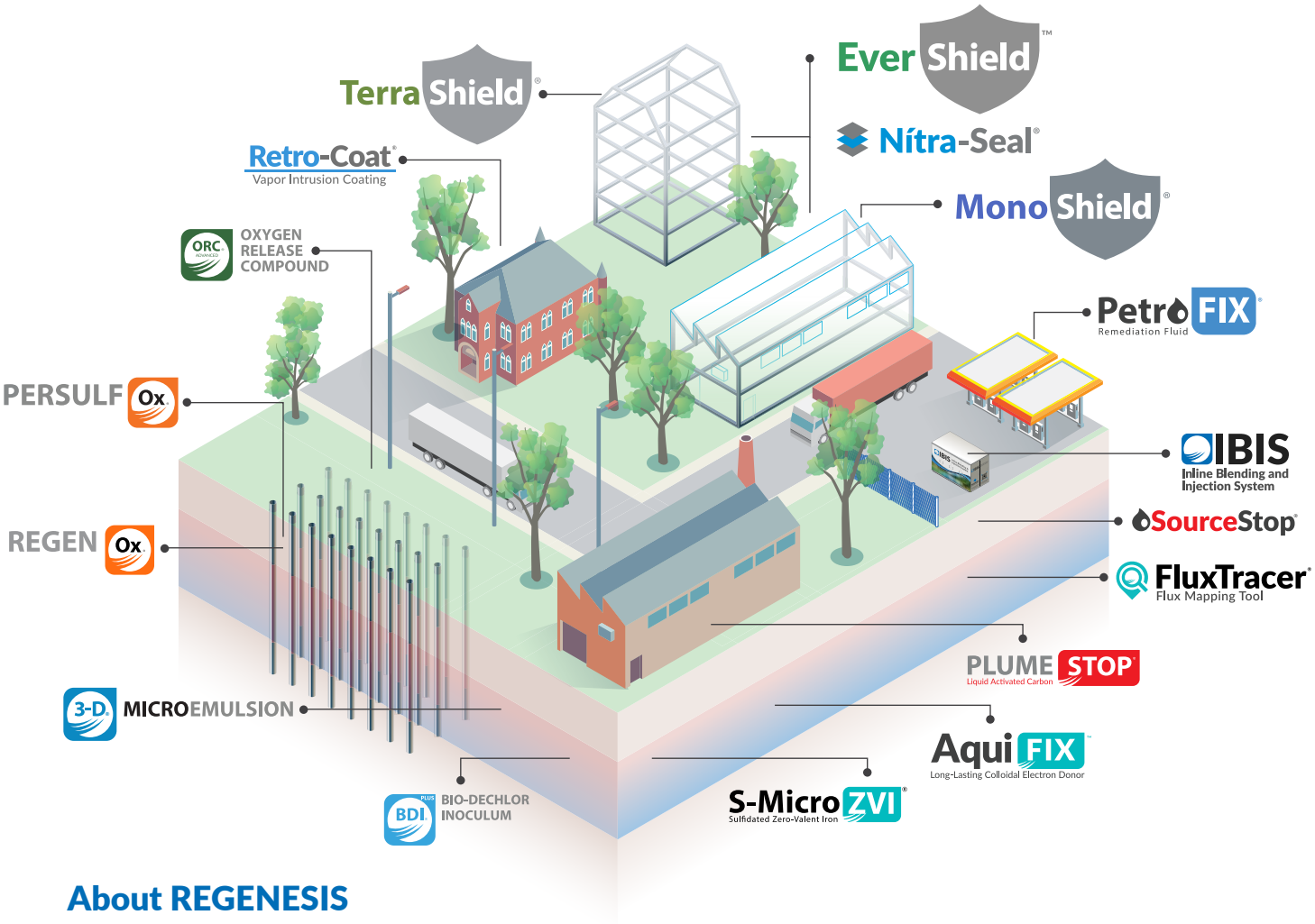
PlumeStop Colloidal Activated Carbon is an innovative groundwater remediation technology designed to address the challenges of excessive time and end-point uncertainty in the *in situ* remediation of groundwater contaminants. PlumeStop is composed of very fine particles of activated carbon (1-2µm) suspended in water through the use of unique organic polymer dispersion chemistry. Once in the subsurface, the material binds to the aquifer matrix, rapidly removing contaminants from groundwater, and expediting permanent contaminant biodegradation.

About MPART

Michigan PFAS Action Response Team

Launched in 2017, the Michigan PFAS Action Response Team (MPART) is the first multi-agency action team of its kind in the nation. Agencies representing heath, environment and other branches of state government have joined together to investigate sources and locations of PFAS contamination in the state, to take action to protect people's drinking water, and to keep the public informed as we learn more about this emerging contaminant. The state of Michigan is taking action to address this issue in a proactive and innovative way. Ten state departments, in coordination with local and federal officials across Michigan, are working together to ensure that the public health and safety of residents is protected while ensuring our environmental heritage is secure.

Additional information regarding the State of Michigan's response to PFAS can be found at:
https://www.michigan.gov/pfasresponse/



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.

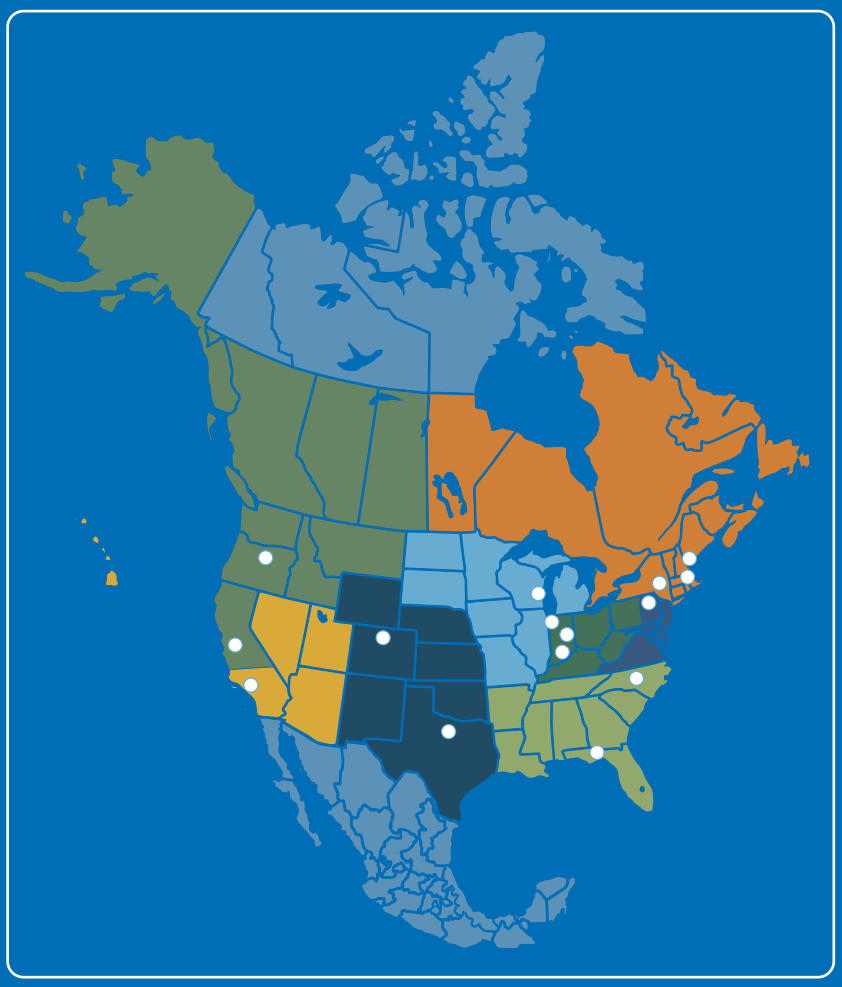
We value expertise, both our customers' and our own. We find that when our experienced staff collaborates directly with customers on complex problems, there is a high potential for success including savings in time, resources and cost.

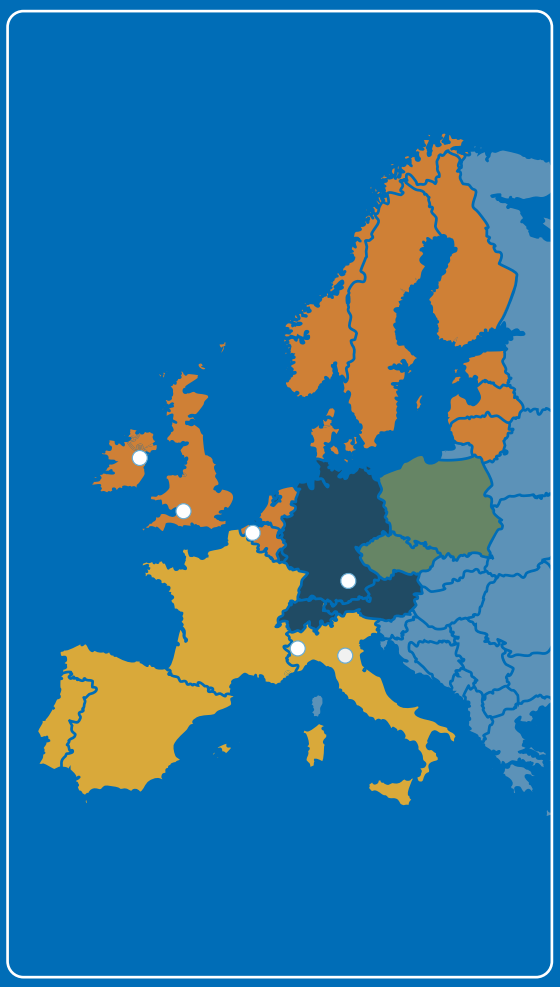
At REGENESIS we are driven by a strong sense of responsibility to the people charged with managing the complex environmental problems we encounter and to the people involved in developing and implementing our technology-based solutions. We are committed to investing in lasting relationships by taking 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





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