REGENESIS®

Challenging Fast-Moving, High Concentration Chlorinated Solvent Plume Effectively Treated

Permeable Reactive Barrier Installed Using Advanced Colloidal Technologies Demonstrates Pilot Test's Effectiveness

REGENESIS®

Summary

Site Type: Industrial

Contaminants: Chlorinated VOCs

Geology: Sand and Gravel

Treatment Approach: *In situ* biogeochemical reduction

Products Used: PlumeStop, Sulfidated MicroZVI, HRC-X, Dehalococcoides-containing bacterial culture

Results: Barrier reduces chlorinated VOC concentrations by >98% within a month, maintains >99% reductions for almost 3.5 years.

A permeable reactive barrier (PRB) incorporating PlumeStop® and S-MicroZVI® technologies was applied to a fast-moving, high-concentration chlorinated solvent plume in groundwater as part of an initial field-scale application to assess the approach's effectiveness. Within a month of the application, the highest concentrations were reduced by 98 percent. The single injection has maintained at least 99% reductions of chlorinated ethenes for 3.5 years in the barrier treatment wells.

Background

Extreme Contaminant Flux Environment Presents Remediation Challenges

The project site is a residential property and municipal right-of-way downgradient of an active chemical manufacturing and distribution facility in central Michigan. During past industrial activities, chemical solvents, including tetrachloroethene (PCE) and trichloroethene (TCE), leaked into the subsurface, creating a soil vapor and groundwater chlorinated volatile organic compound (CVOC) plume extending thousands of feet downgradient beneath a residential neighborhood.

EGLE

Environmental investigations began in the late 1990s. Subsequent remediation efforts led by the Michigan Department of Great Lakes and Energy (EGLE) have included source removal, vapor mitigation systems installed at residences above the plume, and periodic injections of dairy whey to biologically treat the CVOCs in groundwater at various risk/compliance points throughout a bifurcated plume.

>50,000 µg/L

Groundwater concentrations of CVOCs exceeded 50,000 µg/L near the target treatment zone

High concentrations of CVOCs, greater than 50,000 micrograms per liter (µg/L), were detected in groundwater near the target treatment zone. Petroleum hydrocarbon compounds (PHCs) were also spilled at the facility, forming light non-aqueous phase liquids (LNAPL) and creating a commingled plume beneath and near the facility. This commingling resulted in the formation of highly mobile daughter products, cis-1,2-dichloroethene (cis-DCE), and vinyl chloride (VC), extending from the source area to the pilot test area.

The hydrogeologic setting is controlled by a prominent esker, a linear shaped, glacially-deposited feature comprised of coarse sand, gravel, and cobbles. Groundwater velocities in the esker range from 1 to 10 feet (ft) per day. This combination of factors resulted in a persistent, high-contaminant-flux environment and bifurcation of the plume.

> *"[...] biological treatment alone was not capable of reaching the low concentration goals for achieving VI-related remedial objectives."*

This combination of the hydraulically-dominant Mason Esker, high parent CVOC concentrations, and high concentrations of mobile daughter products, (cis-1,2-DCE, and VC, caused by PHC commingling) resulted in an extreme transient plume condition that was very difficult to treat using traditional *in situ* treatment approaches. Further, the plume's location presented a vapor intrusion (VI) risk to the nearby residential neighborhood.

Although previous injections of dairy whey had reduced concentrations at other areas of the site, biological treatment alone was not capable of reaching the low concentration goals for achieving VI-related remedial objectives.

Remediation

A Novel Approach for Treating High Concentrations of Chlorinated Solvents in a High Flow Aquifer

Hamp, Mathews & Associates, Inc. (HMA), working on behalf of EGLE, collaborated with REGENESIS for developing a remedial approach to address the contaminant plume. Following data review and modeling, a sorption-ERD approach was selected for implementation in a field-scale test, using the following technologies applied in an *in situ* permeable reactive barrier (PRB).

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.

In this sorption-ERD approach, PlumeStop® slows the speed of contaminants (i.e., mass flux) entering a barrier, increasing the time available for the added amendments to fully reduce these contaminants into non-toxic end products such as ethene, ethane, carbon dioxide, and chloride before they leave the PRB. In combination, these remedial technologies create a highly reactive zone of biogeochemical reduction that can address plumes with high contaminant mass flux.

Remedial Design Development

Following approval by EGLE, REGENESIS and HMA moved quickly to develop a pilot test design for the PlumeStop PRB and coordinate its application. The goal of the pilot test was to demonstrate a sustained removal and degradation of the CVOCs, at a high rate of efficiency, as they passed through the PRB under natural flow conditions.

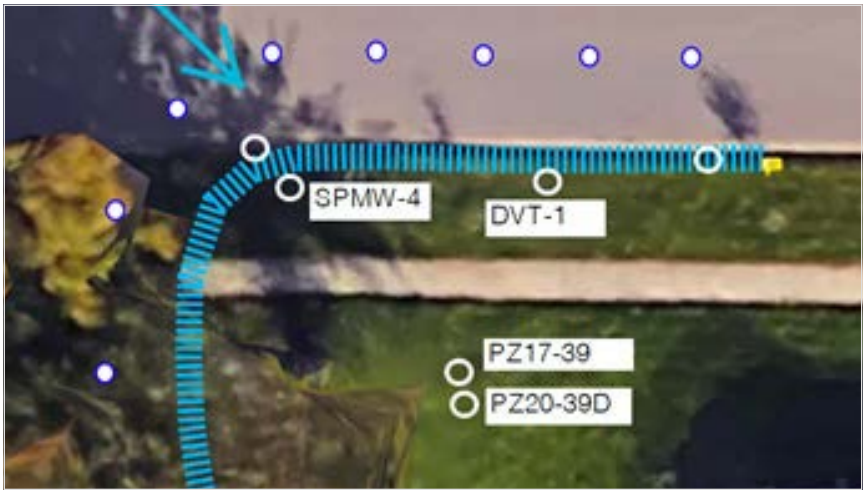
To determine the amount of PlumeStop needed for the PRB, REGENESIS utilized a proprietary finite-difference model explicitly developed for PlumeStop. This model accounts for site-specific factors such as hydrogeology and contaminant flux and considers competitive sorption and biodegradation to determine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

REGENESIS initially modeled contaminant flux over a 3-year PRB performance period for the pilot test based on an average input concentration of approximately 23 mg/L total CVOCs.

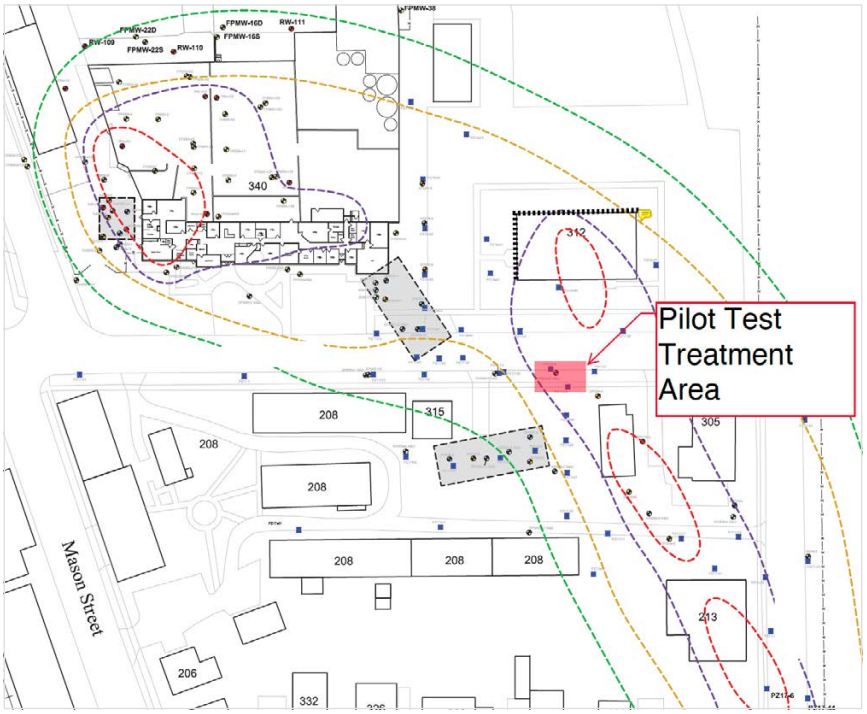
CVOC Concentrations (Avg.)	
TCE	2,000 µg/L
cis-DCE	19,500 µg/L
VC	1,600 µg/L
Seepage Velocity	170-660 ft/yr

PRB Construction	
PlumeStop and S-MicroZVI	18 Injection Points
HRC-X	8 Injection Points
Application Volume	5,600 gal

The application design consisted of a 70-ft long, single row of direct-push injection points with the center and highest flux zone of the PRB oriented nearly perpendicular to groundwater flow. The PRB's L-shape accounts for localized variabilities in groundwater gradient. The vertical interval targeted for application ranged from 15 to 28 ft bgs, corresponding to the upper section of the water column and vertically spanning the high-contaminant flux zone. REGENESIS specified 5,600 gallons of total fluid volume for all PRB reagents.



PlumeStop PRB treatment area and performance monitoring wells



Pilot test treatment area location within the 2017 TCE soil gas plume

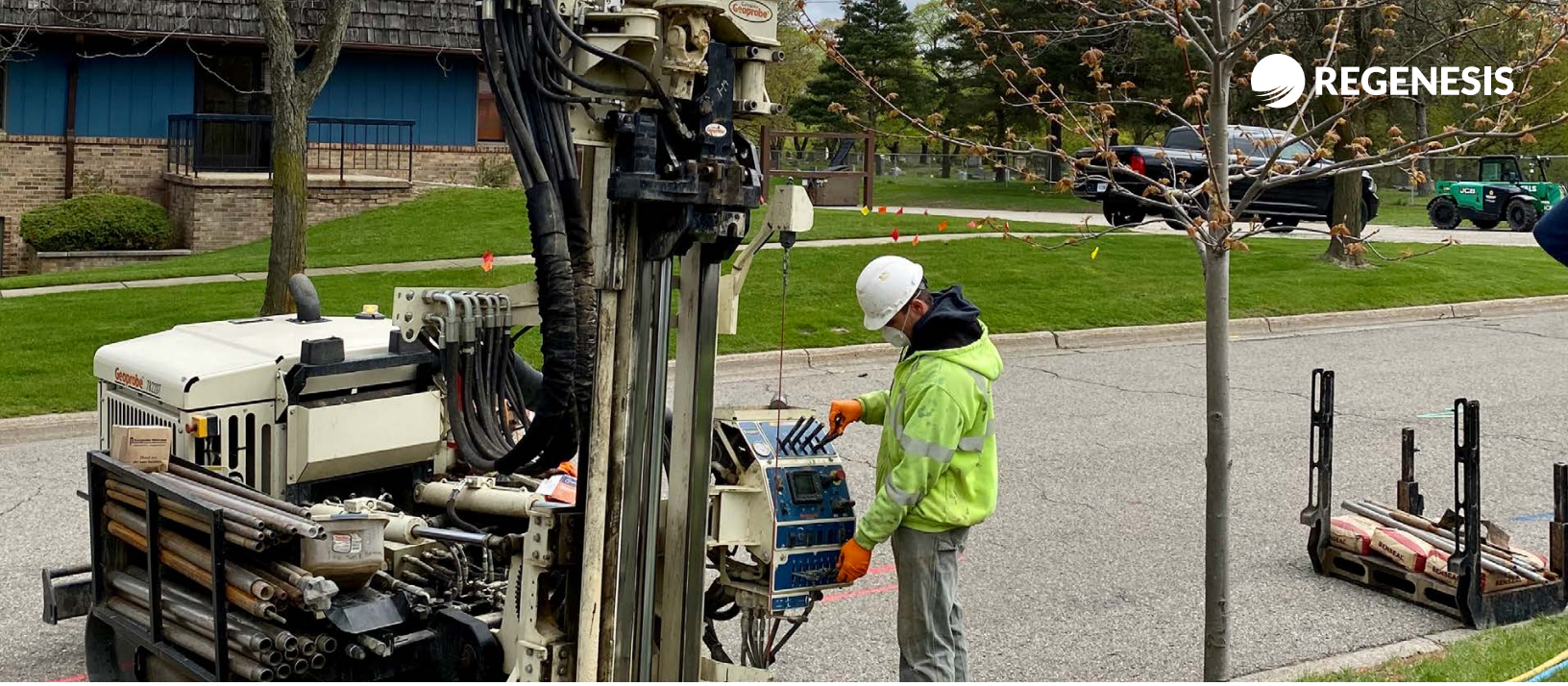
Design Verification Testing

REGENESIS and HMA teamed to develop a design verification testing (DVT) plan. The DVT plan's purpose was to verify design assumptions, concurrent with the pilot test program, that critically impact material quantities needed and barrier performance (i.e., the longevity for effective contaminant removal).

Soil cores collected as part of design verification testing

As part of the DVT, HMA collected soil cores, visually observed and logged the soil grain size, degree of saturation, and color. Additionally, soil samples were submitted for analysis of grain size and VOCs. The upper section of the target interval's soil grain size is approximately 90 percent fine to medium sand. Lower in the interval, between 23 and 24 ft bgs, the soil grain size coarsens abruptly, becoming predominantly gravel (i.e., greater than 75 percent), consistent with glacial esker deposits. The samples submitted for VOC analysis indicated up to two times higher CVOC concentrations in the gravel layer.

Contaminant mass flux is the most critical parameter for designing *in situ* PRBs as it directly relates to the rate of contaminant treatment that will needed. In many cases, there is high variability in contaminant flux within PRB, which must be accounted for. To better understand contaminant flux for this application, the DVT plan specified the use of passive flux samplers (PFS) in select monitoring wells.



Field Application

PlumeStop PRB Successfully Installed During the COVID-19 Pandemic

REGENESIS Remediation Services (RRS) commenced the PlumeStop PRB application in May, 2020. A hydraulic percussion rig was used to drive to depth, using 1.5-inch diameter drilling rods and attached retractable screens. The reagents were mixed and applied through the rod-screen assembly. Utilities were located and marked before the application.

RRS performed optimization testing at the outset of the application, methodically adjusting the injection flow rate to maximize volumetric delivery rates while maintaining injection pressures averaging less than 30 pounds per square inch. 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 and groundwater samples collected from the piezometers and in-barrier observation wells showed PlumeStop presence in groundwater.

RRS completed the application in less than four days while conforming to strict safety protocols, including special safety procedures to prevent the spread of the COVID-19 virus. The application was completed per the design without significant modifications.

Results

PlumeStop PRB Treats CVOCs for >3 Years in High-Mass-Flux Aquifer

The PlumeStop PRB reduced CVOC concentrations by more than 98% in less than two months. After more than three years, the barrier continues to remain highly effective, maintaining greater than 99% reduction, with baseline concentrations exceeding 10,000 µg/L and 50,000 µg/L in the two in-barrier performance wells, DVT-1 and SPMW-4S, respectively.

Figure 1 DVT-1 (Within PRB 15'-20')

In situ PRB performance at in-barrier performance well DVT-1

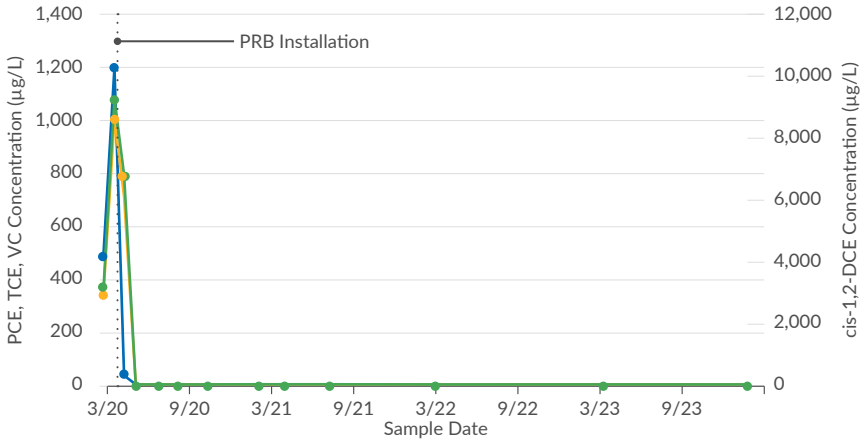
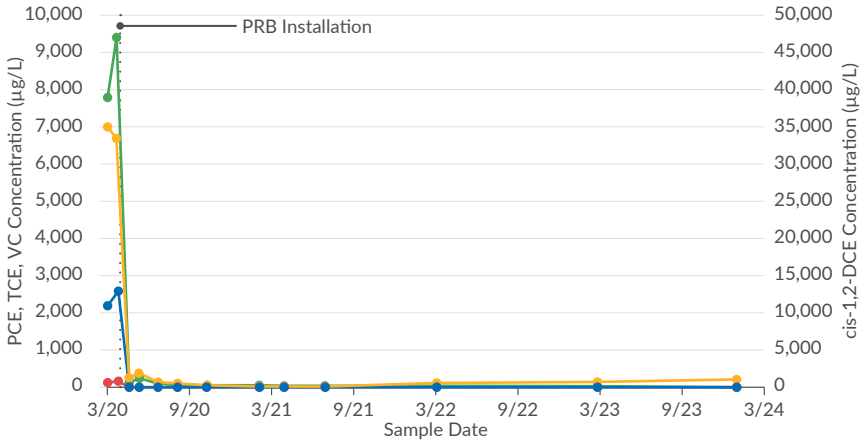


Figure 2 SPMW-4S (20'-25' Within PRB)

In situ PRB performance at in-barrier performance well SPMW-4S



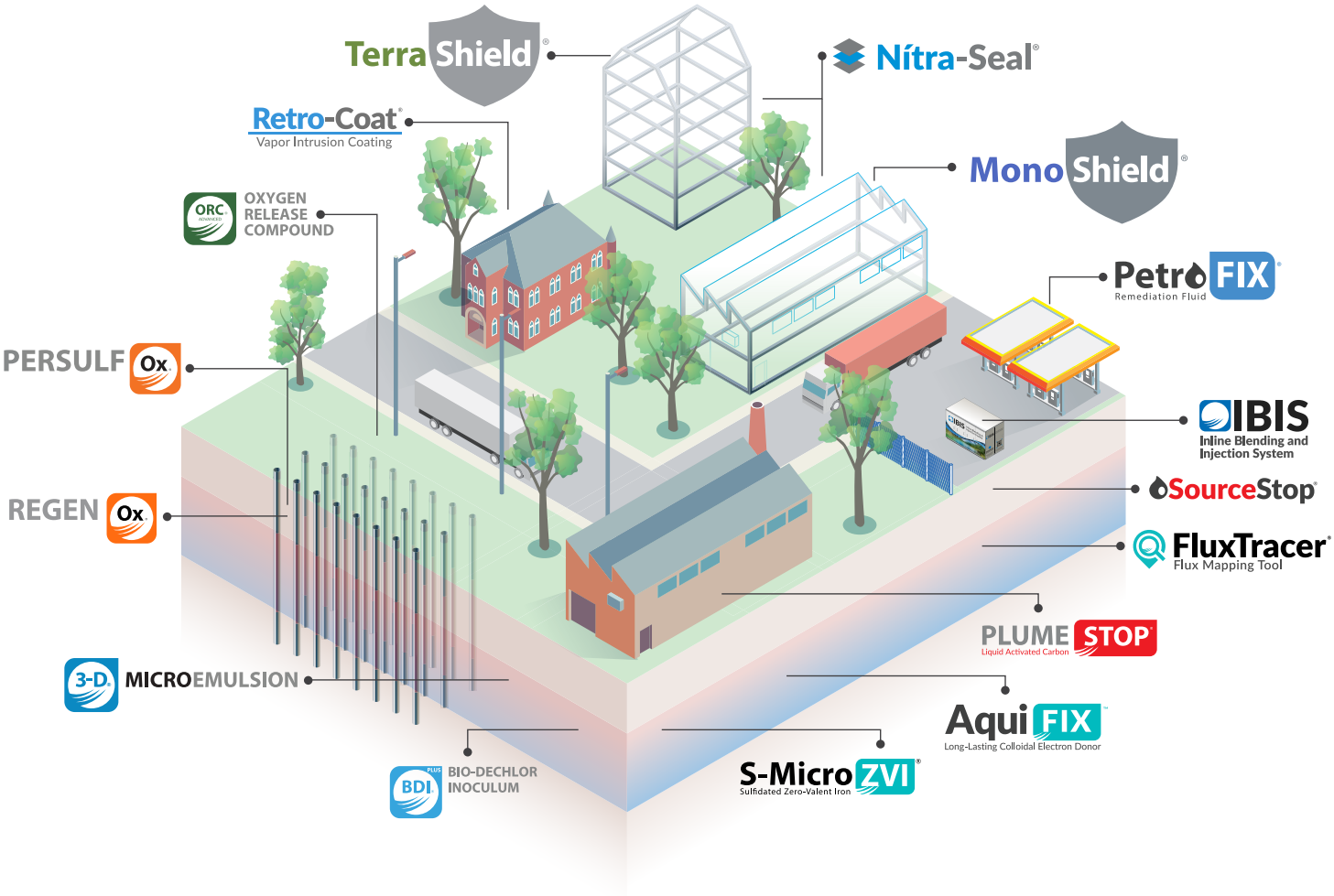
99%

CVOC concentrations reduced by 99% for more than 3 years post-application

The geochemical response at the in-barrier performance wells shows that the application created reduced conditions in the treatment area with dissolved oxygen sustained near zero parts per million and oxidation-reduction potential reduced significantly from baseline.

CVOC concentrations were initially reduced in the monitoring wells located further downgradient, however, significant CVOC mass in the soil beyond the barrier is back-diffusing into groundwater.

CVOCs have been reduced by 83% to 99.5%, based on samples collected in the PRB and downgradient, suggesting the PlumeStop-ERD approach can be effectively used to reduce the VI risk.



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.

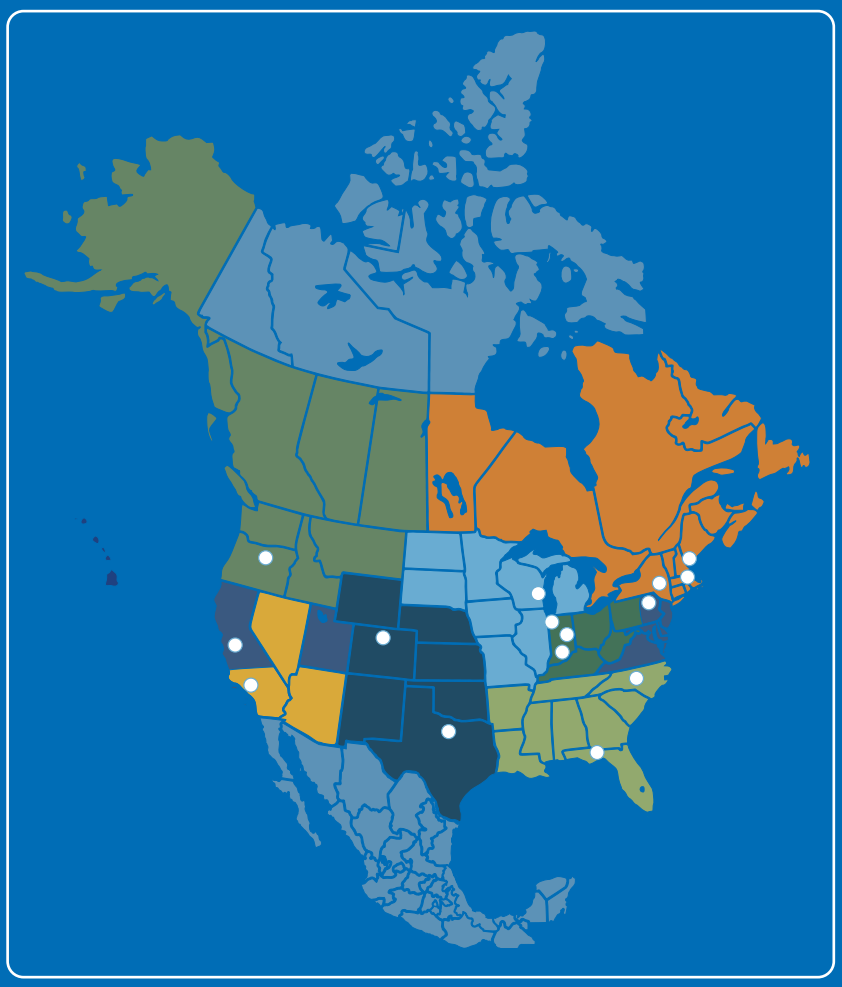
We value expertise, both our customers' and our own. We find that when our experienced staff collaborates directly with customers on complex problems, there is a high potential for success including savings in time, resources and cost.

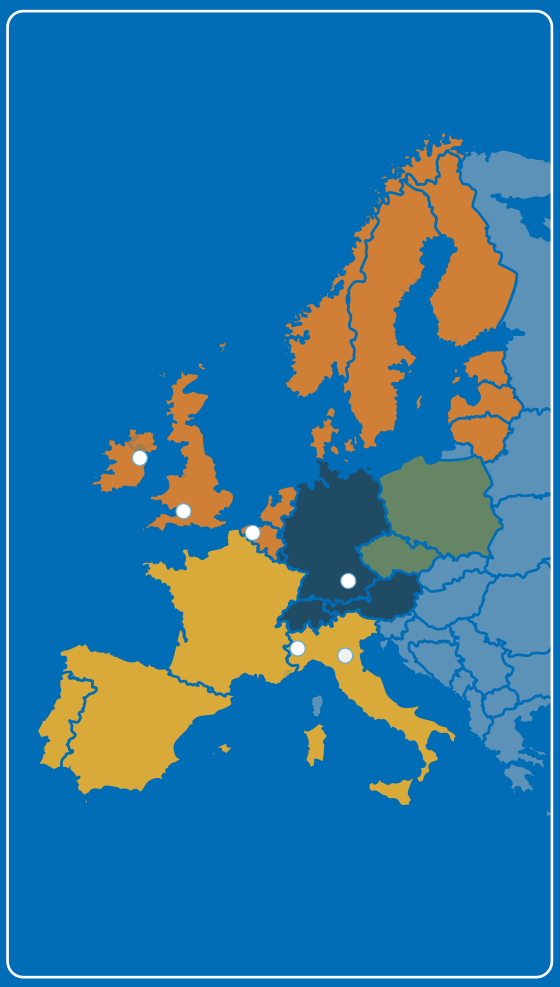
At REGENESIS we are driven by a strong sense of responsibility to the people charged with managing the complex environmental problems we encounter and to the people involved in developing and implementing our technology-based solutions. We are committed to investing in lasting relationships by taking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