REGENESIS®

# *In Situ* Treatment of Hexavalent Chromium Results in Site Closure

## S-MicroZVI and 3-D Microemulsion Rapidly Eliminate Cr(VI) Plume Resulting from Chrome Plating Operations

## Highlights

S-MicroZVI® and 3-D Microemulsion® distribute through clays underneath building

Cr(VI) reduced Below Treatment Goal

State Regulatory Authority Issues Closure for Decades-old Cr(VI) Release

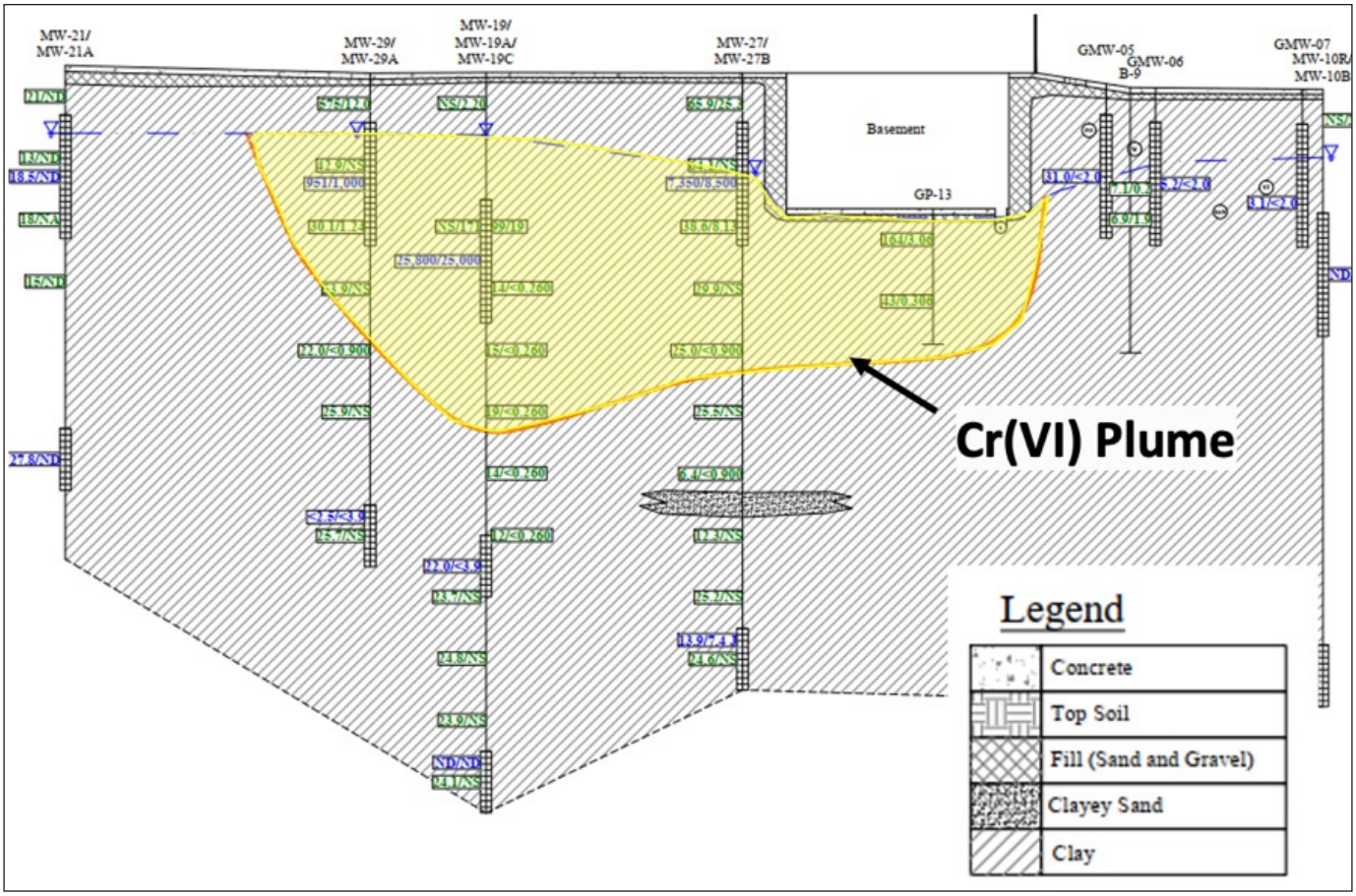
# Introduction

After decades of operation, hexavalent chromium, a.k.a. Cr(VI), was discovered in the shallow aquifer at a chrome plating facility in the Midwest, forming a contaminant plume in groundwater. In the late 1980s, a pump & treat (P&T) system was installed to control the Cr(VI) plume and prevent its migration toward an adjacent residential neighborhood. Decades of P&T operation had shown it to be ineffective at advancing the site towards a regulatory closure endpoint and a remedy was sought to rapidly and cost-effectively achieve this goal.


Approximate Cr(VI) aerial plume extent in groundwater before remediation.

The radial groundwater plume exhibited a range of Cr(VI) concentrations from hundreds of parts per billion to several hundred parts per million in the plume core. Much of the plume was contained in low-permeability soils and located beneath a manufacturing/warehouse facility, presenting challenges to the remedial effort.

Following successful bench scale testing, a field scale program was developed to assess the effectiveness of *in situ* chemical reduction, combined with *in situ* bioremediation (i.e., ISCR-BR) to facilitate Cr(VI) reduction. Enviroforensics, a leading Midwest environmental engineering, consulting, and remediation firm, directed the pilot test efforts.




X-sectional view of Cr(VI) plume in groundwater.

REGENESIS®

# Field Testing of *In Situ* Cr(VI) Treatment Amendments

The primary goals of the field-scale pilot test were to 1) determine the optimal remedial amendment formula to achieve rapid and effective Cr(VI) treatment via ISCR-BR and 2) demonstrate whether the aquifer could accommodate the amendment fluid volumes required for successful treatment.

3-D MICROEMULSION

CRS CHEMICAL REDUCING SOLUTION

Two areas were established for conducting the pilot test, both located within the existing facility. One area was treated using a viscous, zero-valent iron (ZVI)/organic mixture injected as a slurry. In another area, 3-D Microemulsion (i.e., an emulsified electron donor) and Chemical Reducing Solution® (i.e., CRS, a ferrous iron-containing amendment) were used to facilitate ISCR/ISB.

## Combining *In Situ* Chemical Reduction and *In Situ* Bioremediation (ISCR-BR) to Treat Hexavalent Chromium

Combining *in situ* chemical reduction with *in situ* bioremediation (i.e., ISCR-BR) is an effective, well-established practice for treating hexavalent chromium. The approach creates a reducing environment in the saturated zone by supplying electrons to reduce the highly mobile and toxic Cr(VI) to the non-toxic and immobile Cr(III). The approach adds electrons directly in the form of ZVI while using native subsurface bacteria to indirectly generate electrons via an injected electron donor such as 3-D Microemulsion. The process forms Cr(III) compounds like chromium hydroxide or chromium-iron-hydroxides, which are stable under most environmental conditions.

### Example ISCR-BR Treatment Chemistry:

$$CrO_4^{-2} + 1.5\ Fe^0 + 5H_3O^+ \rightarrow Cr(OH) + 1.5\ Fe^{+2} + 6H_2O$$

**Cr(VI) compound = Toxic, Mobile**

**Cr(III) compound = Non-Toxic, Immobile**


# Field Scale Study Findings

The commodity ZVI material reduced Cr(VI) from 19 milligrams per liter (mg/L) to less than 0.2 mg/L within three months. Over the same period, the 3-D Microemulsion/CRS mixture showed a greater than 100 mg/L Cr(VI) reduction from a baseline concentration of approximately 300 mg/L. Reductions were sustained through the nine-month field study at both locations.

These results showed that both the ISCR-BR approaches were effective at quickly reducing Cr(VI). The testing also revealed improvements that could be made in a full-scale remedy, based on the following observations:

1. In the ISBR test area, the 3-D Microemulsion/CRS solution was not sufficiently robust to fully address the highest Cr(VI) concentrations.

2. The commodity ZVI slurry, while a robust reductant, distributes via small seams caused by high-pressure-induced 'fracking' of the clay matrix and would likely lead to significant treatment gaps during full-scale implementation.

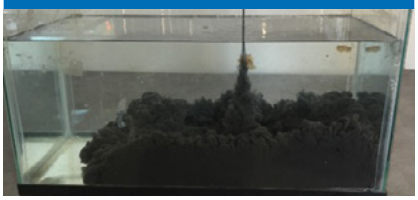
S-Micro ZVI®
Sulfidated Zero-Valent Iron

3-D MICROEMULSION

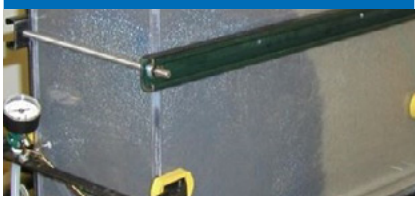
The project team reasoned that injecting a ZVI amendment with enhanced distribution characteristics could substantially improve the remedial performance. Accordingly, S-MicroZVI®, a colloidal, sulfidated ZVI amendment with superior distribution and reactivity compared to commodity ZVI slurries, was proposed for the full-scale application, along with 3-D Microemulsion. This enhanced ISCR-BR formula would facilitate rapid and sustained chemical and biological reduction processes for treating Cr(VI).

S-MicroZVI and 3-D Microemulsion are colloidal, liquid amendments that can be co-applied with low-pressure injection techniques to achieve excellent distribution in glacially deposited clays and other low-permeability soils. Their enhanced distribution properties were identified as a critical factor in achieving remediation success due to the access restrictions imposed by the building, utilities, and other infrastructure.

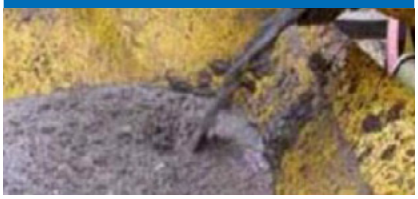
**Colloidal ZVI Suspension**



**Low Pressure Sandbox Demo**



**Commodity ZVI Slurry**



**Depiction of Subsurface Fractures**

Comparing physical appearance and distribution of S-MicroZVI colloidal amendment with commodity ZVI Material

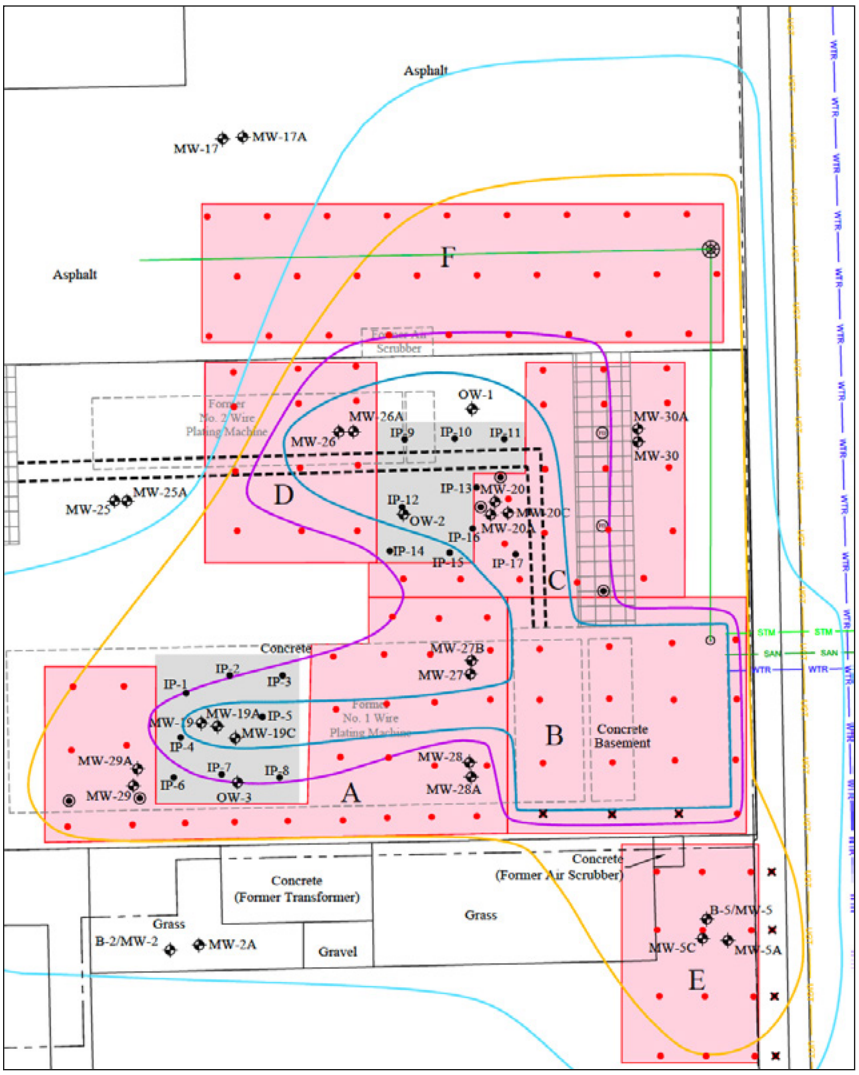
# Full-Scale Treatment

Enviroforensics implemented the full-scale groundwater remedy in 2019, with a treatment goal of reducing the Cr(VI) concentration in groundwater below 0.1 mg/L. Additional remedial activities completed by Enviroforensics included: soil blending of a powdered ZVI amendment in shallow, unsaturated soils to reduce Cr(VI) leaching at three defined soil source zones, removing of underground piping and drains, basement backfilling, and monitoring well sealing/abandonment.

## Application Details

Full-Scale Cr(VI) Treatment

| | |
|---|---|
| **Areal Extent** | ~10,000ft$^2$ |
| **Treatment Vertical Depth** | 5-25 ft bgs |
| **Injection Points** | 116 |
| **Total Volume Applied** | 16,900 gal |
| **Total S-MicroZVI/3DME Amendment Blend Applied** | 11,000 lbs |




Depiction of treatment areas and injection points for the Cr(VI) groundwater treatment. Red-shaded and gray-shaded areas show full-scale and pilot test treatments, respectively.

# Results

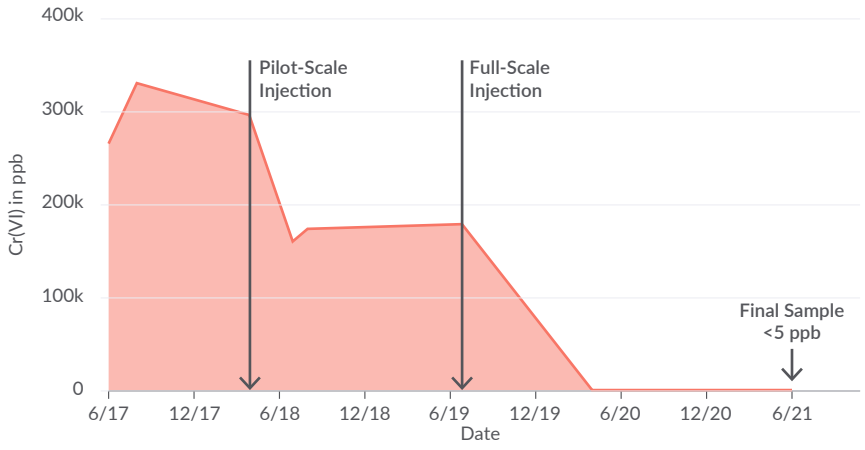
The results of the full-scale remediation of the Cr(VI) groundwater plume were highly successful, as demonstrated by the following:

- Cr(VI) concentrations were quickly reduced by 99% and maintained in all monitoring wells through 18 months.
- The treatment was effective across the entire Cr(VI) concentration spectrum, reducing concentrations below the 0.1 mg/L target, even in the most impacted wells.
- The treatment removal increased by approximately 150% compared to the pilot test.

Based on these results, the regulatory authority granted closure for the long-open Cr(VI) release case.

## Cr(VI) in MW-20/20R

Cr(VI) concentrations in the most impacted well, MW-20/20R, before and after S-MicroZVI and 3-D Microemulsion injections.

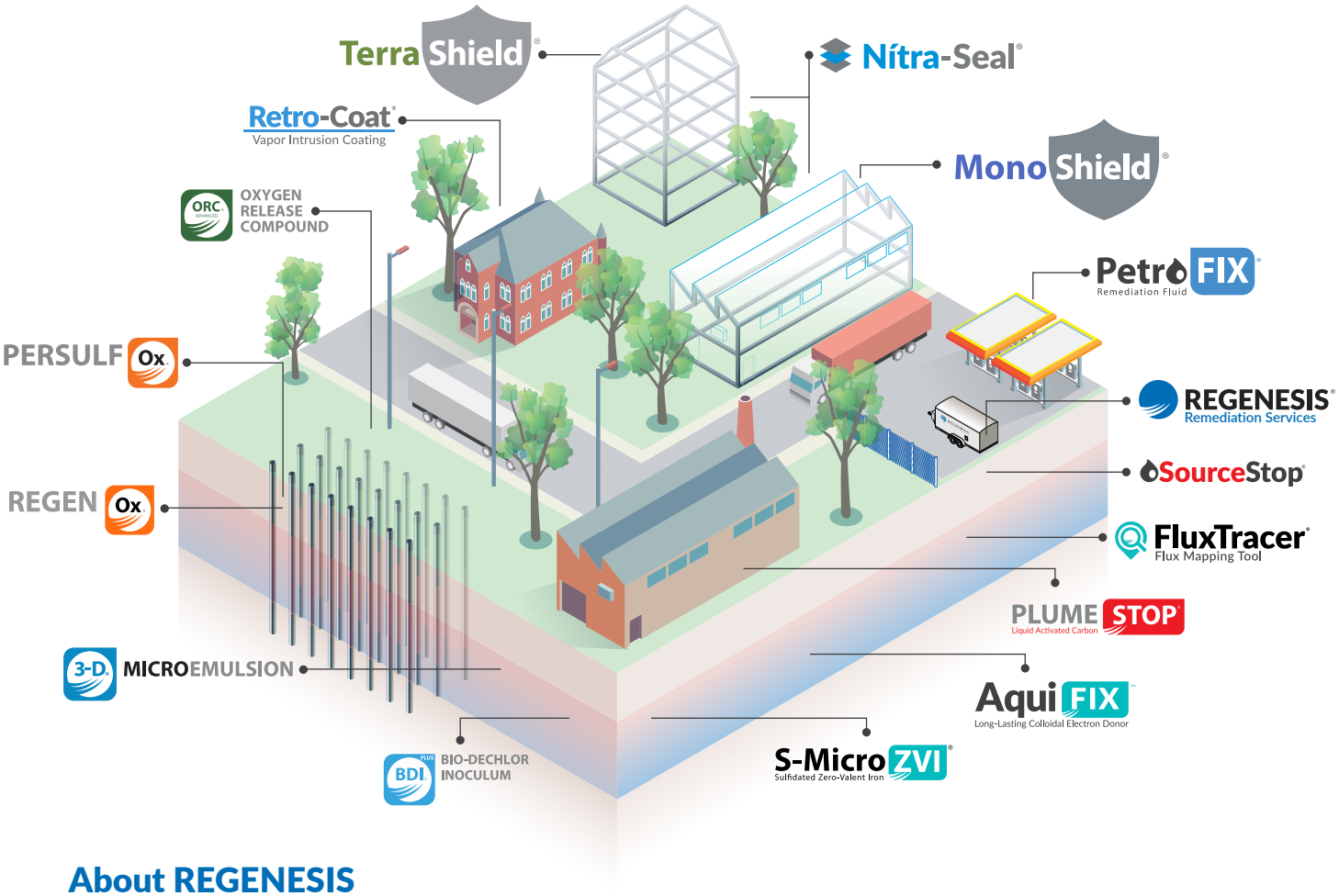


# Conclusions

This project demonstrates that *in situ* remediation of Cr(VI) using S-MicroZVI and 3-D Microemulsion to facilitate ISCR-BR is highly effective, offering a solution that is powerful, fast-acting, and permanent. The approach is ideal for almost all environments but provides superior benefits for existing facilities where minimal disruption is needed.

Additionally, these colloidal amendments are designed to move through the smallest soil pores, capable of achieving uniform distribution in clays and other fine-grained soils while requiring only low injection pressures for subsurface placement. It is not possible to achieve similar distribution with commodity ZVI slurries.

Combining S-MicroZVI and 3-D Microemulsion technologies is recommended to provide the maximum ISCR-BR treatment benefits. Beyond treating Cr(VI), these technologies are applied to remediate chlorinated solvents in groundwater and have demonstrated similar outstanding performance.




## 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.

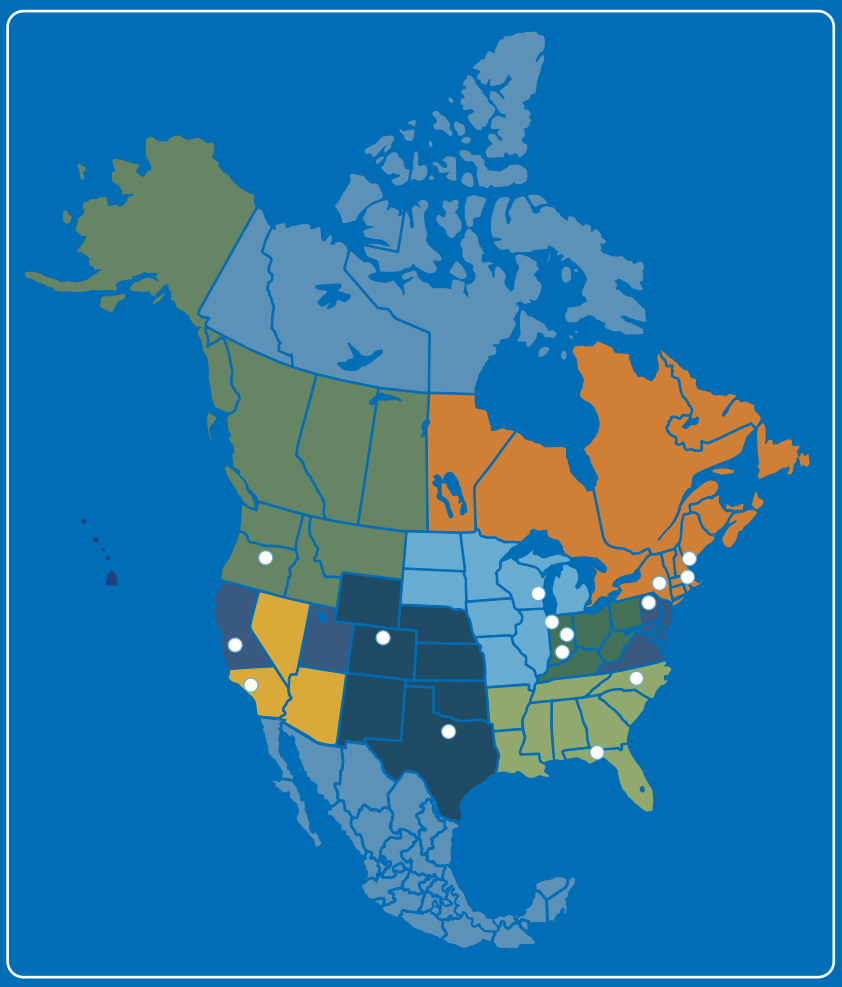
Inherently, innovation imparts new and better ways of thinking and doing. For us, this means delivering expert environmental solutions in the form of the most advanced and effective technologies and services available today.

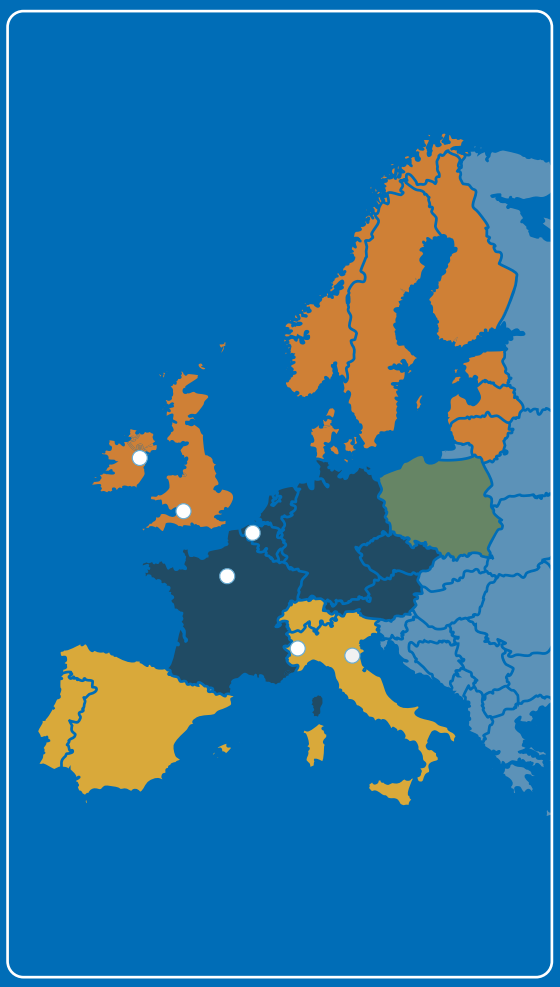
We value expertise, both our customers' and our own. We find that when our experienced staff collaborates directly with customers on complex problems, there is a high potential for success including savings in time, resources and cost.

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.

# 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