# **REMEDIATION OF DEEP TRICHLOROETHENE** PLUME USING ENHANCED IN SITU **BIOREMEDIATION TECHNOLOGY**

## INTRODUCTION

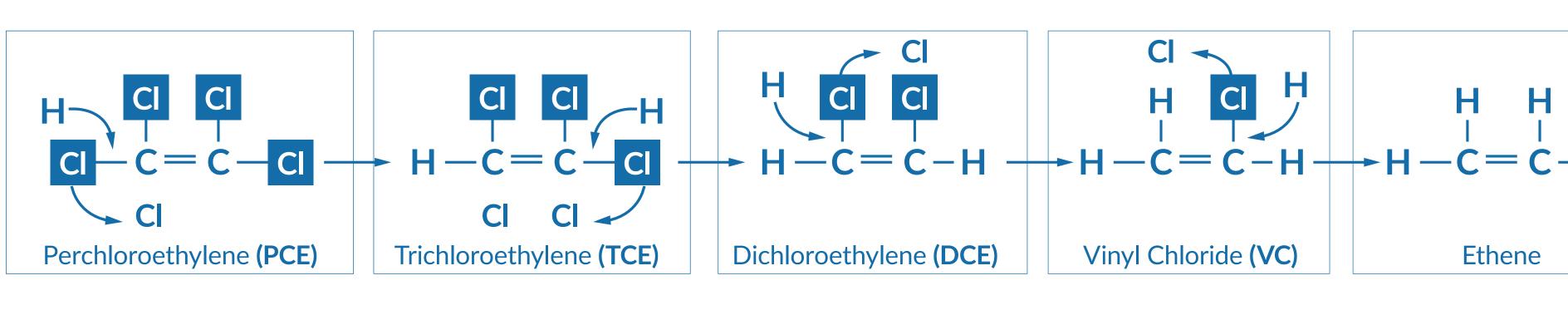
Between August 2013 and October 2017, Alta Environmental and REGENESIS were engaged in the Enhanced In situ Bioremediation (EISB) of a deep groundwater plume heav impacted by chlorinated volatile organic compounds (CVOCs), primarily trichloroethene (TCE). The EISB project was conducted at a confidential aerospace manufacturing facility located in Southern California. The depth to the impacted aquifer (Gage Aquifer) is approximately 90 feet below ground surface (bgs). The overall size of the TCE plume measures approximately  $\frac{1}{2}$  mile long (downgradient) by  $\frac{1}{4}$  wide (cross-gradient), the major of which extends offsite. Complications included significant offsite downgradient contribution of contaminants (including CVOCs) by other Responsible Parties.

## CHALLENGES

- Cost-effectively remediate onsite portion of migrating TCE plume.
- Install dual-nested injection wells safely in the Gage Aquifer (a deep, highly permeable) aquifer) consisting of "heaving sands".
- Alter aquifer conditions from aerobic to anaerobic.
- S Maintain pressure and delivery rates of injectable bio-amendments to maximize distribution both laterally and vertically.
- Example 2 Logistics of conducting field work in a safe manner without disruption to major active aerospace manufacturing facility personnel and operations.

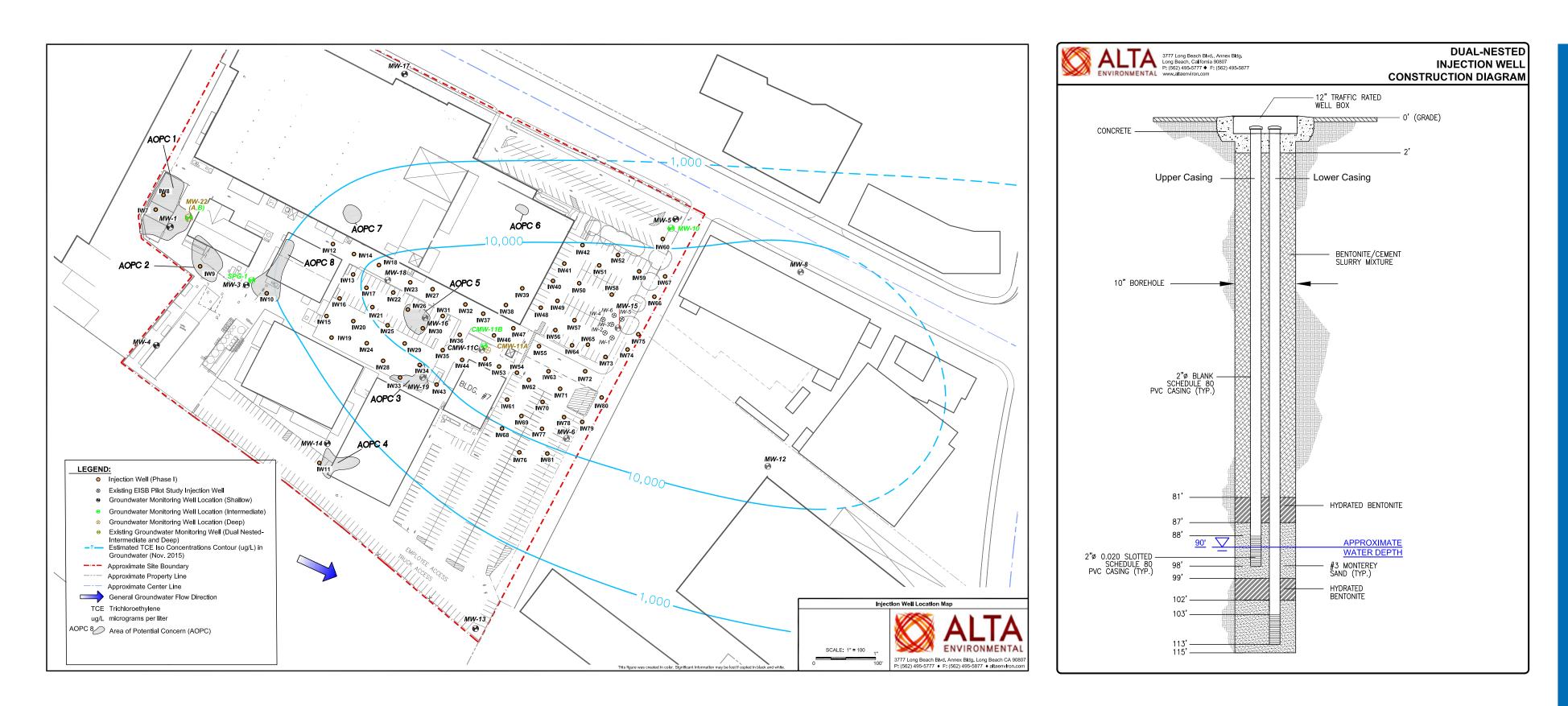
## EISB TECHNOLOGY DESCRIPTION

- EISB, or engineered bioremediation, is the acceleration of microbial activities using technology to enhance the degradation or detoxification of environmental pollutants an anaerobic environment.
- Ouring reductive dechlorination, anaerobic microbes substitute hydrogen (electron) donor) for chlorine on the chlorinated VOC molecule, thus converting the chlorinated VOC to a degradation product with one less chlorine atom.



www.regenesis.com 1011 Calle Sombra, San Clemente CA 92673 USA Steven Ridenour (steve.ridenour@altaenviron.com) (Alta Environmental, Long Beach, California, USA) Mike Cassidy (mike.cassidy@altaenviron.com) (Alta Environmental, Long Beach, California, USA) **Daniel Nunez and Craig Sandefur (Regenesis)** 

| 6      | 3-D MicroEmulsion <sup>®</sup> Factory Emulsified (3DMe): an injectable liquid  |
|--------|---|
|        | material which aids in the anaerobic biodegradation of CVOCs.   |
| Ð      | Chemical Reducing Solution <sup>®</sup> (CRS): an <i>in situ</i> chemical reduction agent<br>that combines bio-available carbon and soluble iron that facilitates the<br>biochemical reduction of CVOCs.  |
| Ð      | Bio-Dechlor Inoculum <sup>®</sup> Plus (BDI Plus): a natural microbial consortium<br>containing species of dehalococcoides (DHC). Chlorinated solvents,<br>such as TCE and/or another carbon source (such as 3DMe), are<br>consumed by DHC microbes which allows reductive dechlorination<br>processes to occur more rapidly. |
| 2      | OT TESTING  |
| Ð      | EISB pilot tests conducted in August 2013 and October 2015.   |
| Ð      | Six injection wells (IW1 through IW6) were installed at locations cross-gradient and up-gradient of well MW-15, located within the core of the TCE plume.   |
| •      | Marginal reductions of TCE, increases of DHC, increases of<br>degradation products cis-1,2-DCE and vinyl chloride (first appearance),<br>and decreases of DO/ORP levels were detected in observation well<br>MW-15 after the 3DMe/CRS/DHC injection.  |
| •      | Alta concluded that reductive dechlorination and bio-activity processes were being accelerated as a result of the 3DMe/CRS/DHC (in particular DHC) injection.   |
| )(     | DST PILOT TEST GROUNDWATER REMEDIATION  |
| b<br>b | Groundwater Remedial Action Plan (GWRAP) was prepared and<br>proved by the LARWQCB. In accordance with the GWRAP, and after<br>caining revised M&RP requirements from the LARWQCB, the following<br>rk was conducted:   |
| 9      | From November 8, 2016 to January 18, 2017, 75 dual-nested injection wells (screened 88-98 and 103-113 feet bgs) were installed within the core of the TCE plume.  |
| Ð      | Wells located in accessible areas were installed on a modified and staggered 30-foot by 60-foot grid pattern.   |



Injection Well Location Map

Well Construction Diagram

From January 31 through April 5, 2017, approximately 700,000 gallons of reagent solution was applied to the 75 dual-nested injection wells (150 casings) and previously-installed wells IW3 and IW5 as follows:

#### Treatment Area: >10,000 µg/l TCE (55 dual-nested wells, plus IW3 and IW5)

| Total Amount Applied |              | Approximate Average Applied Per Injection Point |             |
|----------------------|--------------|---|-------------|
| 3DMe                 | 215,980 lbs. | 3DMe  | 1,928 lbs.  |
| CRS                  | 86,109 lbs.  | CRS   | 769 lbs.    |
| BDI Plus             | 1,476 liters | BDI Plus  | 13.0 liters |

#### Treatment Area: <10,000 µg/l TCE (20 dual-nested wells)

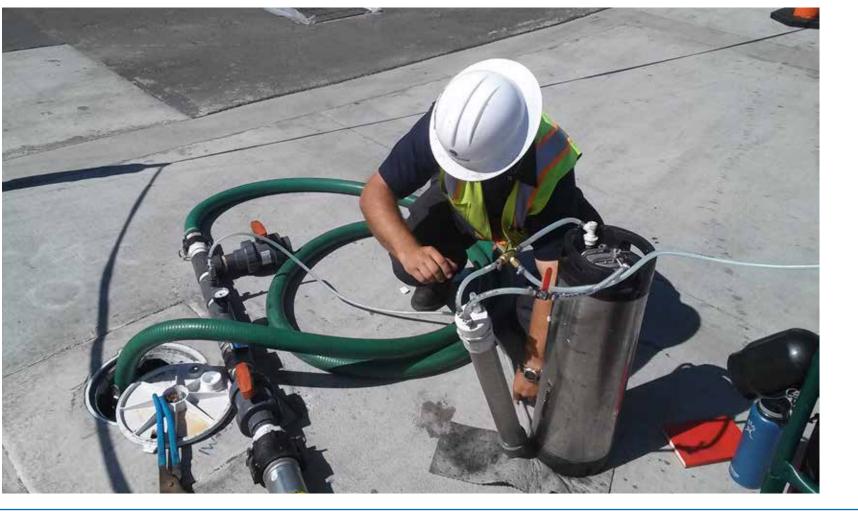
| Total Amount Applied |             | Approximate Average Applied Per Injection Point |             |
|----------------------|-------------|---|-------------|
| 3DMe                 | 71,214 lbs. | 3DMe  | 1,780 lbs.  |
| CRS                  | 28,309 lbs. | CRS   | 708 lbs.    |
| BDI Plus             | 488 liters  | BDI Plus  | 12.2 liters |







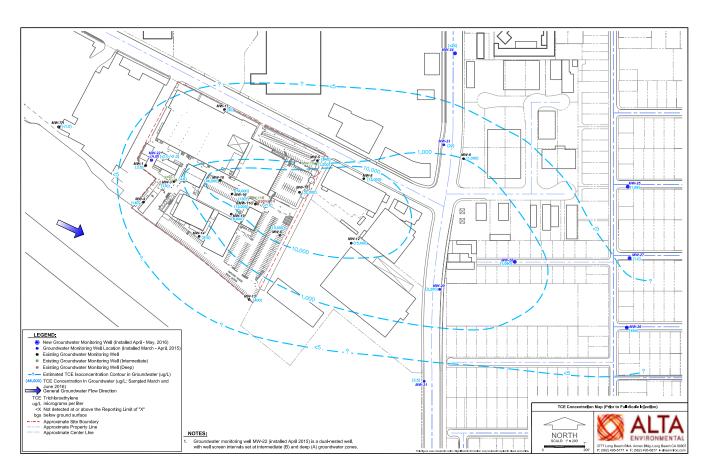
- The 3DMe was mixed and applied as a 5% solution. The CRS was applied at an approximately 2% solution. Two liters of BDI Plus (DHC) was applied in-line (4.5 to 7.1 times concentrated) into each injection well
- Injection flow rates typically ranged from 40 to 150 gallons per minute (gpm). Sustained injection pressures ranged from 0 to 30 psi.



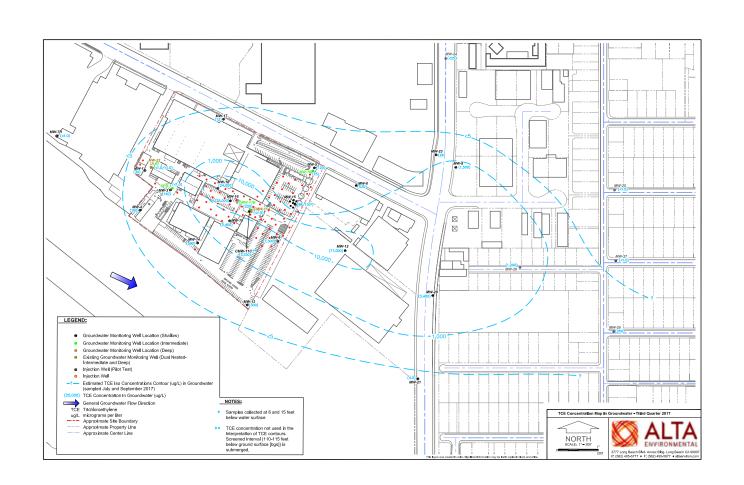


GROUNDWATER MONITORING AND SAMPLING

- Groundwater monitoring and sampling has been ongoing since the initial pilot tests, conducted quarterly since the fourth quarter 2015 reporting period.
- Wells MW-6, MW-7R, MW-8, MW-12, MW-15, MW-16, MW-18, MW-19, and CMW-11C were monitored for VOCs, DHC, DO and ORP, and other parameters required in the M&RP.
- Solution Notable reductions of TCE from prior to post pilot test injection (November 2016 or January 2017) to most recent (September 2017) event illustrated as follows:
  - 25,000 µg/l to 100 µg/l - MW-15:
  - MW-6: 16,000 µg/l to 7,300 µg/l
  - MW-8: 1,800 µg/l to 530 µg/l
  - 10,000 µg/l to 2,400 µg/l - MW-19:
  - CMW-11C: 9,300 μg/l to 3,100 μg/l
- PCE reduced during same time period in MW-15 from 570  $\mu$ g/l to 10  $\mu$ g/l, cis-1,2-DCE reduced from 7,300  $\mu$ g/l to 1,300  $\mu$ g/l.
- Ethene increased significantly in MW-15 from ND (before second pilot test) to as high as  $1,260 \mu g/l$  (post full-scale injection).
- DHC concentrations in MW-15 increased significantly from essentially ND to as high as 1,680,000 cells/ml.



TCE Plume Map Prior to Full-scale Injection



TCE Plume Map – Third Quarter 2017 (approximately 5 months after injection)