# Improved reagent delivery using hydraulic fracturing during enhanced reductive dechlorination

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**Abstract.** In-situ remedial strategies that involve the injection of a remedial fluid offer much promise for cost-effectively treating groundwater contaminants such as chlorinated solvent compounds, nitrated explosives, and perchlorate. The successful implementation of many in-situ remediation projects is dependant on the ability to develop an efficient and effective system for the delivery of the necessary reagents to the target treatment areas, especially in low permeable environments. Hydraulic fracturing (also known as hydrofracturing) is a technique that offers the potential to overcome low native permeability and enhance the effectiveness of amendment injection into systems that might otherwise be considered unsuitable for in-situ injection-based methods. The focus of this study includes an analysis of hydraulic fracturing of a sedimentary bedrock aquifer to accelerate remediation of a chlorinated solvent plume using In-situ Reactive Zone (IRZ) technology. For this application of IRZ, a molasses-based amendment solution was routinely injected into the aquifer to create a strongly reducing environment in-situ, facilitating Enhanced Reductive Dechlorination (ERD) of tetrachloroethene (PCE) and other chlorinated compounds.

The natural hydraulic conductivity of the aquifer at the site is relatively low ($3.2 \times 10^{-5}$ to $6.7 \times 10^{-4}$ cm/sec); therefore, hydraulic fracturing was used to increase the effective aquifer permeability at injection locations in order to improve molasses delivery rates and increase distribution. A network of 65 hydro-fractured injection wells were installed over 27 acres during a 6-month period. Fractures within each borehole were typically induced at three discrete intervals to enhance existing fracture networks below the water table as projected during system design and specifically identified during drilling. The enhanced permeability created by the hydraulic fracturing dramatically increased the efficiency of injections and injection well zone of influence. Periodic injections of a molasses solution into the groundwater have resulted in site-wide reductions of PCE concentrations in excess of 90% over 18 months. Ongoing monitoring of biodegradation daughter products trichloroethene (TCE), cis-1,2-dichloroethene (cis-DCE), and vinyl chloride (VC), and various other reductive dechlorination parameters clearly indicate accelerated degradation of PCE is ongoing on site.

The results of this project demonstrate the potential advantages of enhanced reagent delivery techniques, particularly when used in the context of an IRZ or other in-situ remedial strategies. In this case, the use of hydraulic fracturing accelerates the overall remediation by improving amendment solution delivery efficiency and access to contaminants within the low permeability aquifer.