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Changes in contaminant mass discharge from DNAPL source mass depletion: Evaluation at two field sites

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ABSTRACT

Changes in contaminant fluxes resulting from aggressive remediation of dense nonaqueous phase liquid (DNAPL) source zone were investigated at two sites, one at Hill Air Force Base (AFB), Utah, and the other at Ft. Lewis Military Reservation, Washington. Passive Flux Meters (PFM) and a variation of the Integral Pumping Test (IPT) were used to measure fluxes in ten wells installed along a transect down-gradient of the trichloroethylene (TCE) source zone, and perpendicular to the mean groundwater flow direction. At both sites, groundwater and contaminant fluxes were measured before and after the source-zone treatment. The measured contaminant fluxes (J; $ML^{-2}T^{-1}$) were integrated across the well transect to estimate contaminant mass discharge (M_D; MT^{-1}) from the source zone. Estimated M_D before source treatment, based on both PFM and IPT methods, were ~76 g/day for TCE at the Hill AFB site; and ~640 g/day for TCE, and ~206 g/day for *cis*-dichloroethylene (DCE) at the Ft. Lewis site. TCE flux measurements made 1 year after source treatment at the Hill AFB site decreased to ~5 g/day. On the other hand, increased fluxes of DCE, a degradation byproduct of TCE, in tests subsequent to remediation at the Hill AFB site suggest enhanced microbial degradation after surfactant flooding. At the Ft. Lewis site, TCE mass discharge rates subsequent to remediation decreased to ~3 g/day for TCE and ~3 g/day for DCE ~1.8 years after remediation. At both field sites, PFM and IPT approaches provided comparable results for contaminant mass discharge rates, and show significant reductions (>90%) in TCE mass discharge as a result of DNAPL mass depletion from the source zone.

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1. Introduction

Multiple modeling approaches have recently been used to evaluate whether significant reduction in contaminant mass discharge (M_D; MT^{-1}) will result from depletion of dense nonaqueous phase liquid (DNAPL) mass from source zones (Sale and McWhorter, 2001; Enfield et al., 2002; Rao et al., 2002; Rao and Jawitz, 2003; Lemke et al., 2004; Parker and Park, 2004; Soga et al., 2004; Zhu and Sykes, 2004; Enfield et al., 2005; Jawitz et al., 2005; Wood et al., 2005; Fure et al., 2006). Changes within the dissolved plume, resulting from decreased M_D as a result of source-zone treatment, have also been examined in recent modeling analyses (e.g., Falta et al., 2005a,b). Results from these models suggest that site-specific hydrogeological conditions and spatial distribution of DNAPL within the source zone control the relationship between source mass depletion and expected reduction in M_D. Results from laboratory studies (Fure et al., 2006; Suchomel and Pennell, 2006; Totten et al., 2007) and limited field measurements in hydraulically isolated test cells (Brooks et al., 2004; Childs et al.,

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2006) suggest that reductions in contaminant mass discharge occur after removal of DNAPL source mass. Analyses of data from several field studies also provide support for the prediction of M_D reductions due to source treatment, and suggest that a linear relationship might serve as a first-order approximation (McGuire et al., 2006; Falta et al., 2005a; Brusseau et al., 2007).

Here, we present measurements of groundwater and contaminant fluxes at two DNAPL sites, one located at Hill Air Force Base (AFB), near Layton, Utah, and the other at Ft. Lewis Military Reservation, located near Tacoma, Washington. Fluxes were measured before and after aggressive DNAPL source treatment (in-situ surfactant flushing at the Hill AFB site; resistive heating at the Ft. Lewis site) for depletion of source mass. Details of the source-zone treatment at the Hill AFB site were previously reported by URS and INTERA (2003), while details of the thermal treatment at the Ft. Lewis site are presented by Beyke and Fleming (2005), TRS (2005), and Powell et al. (2007). Our focus here is on performance assessment of the DNAPL source treatment, based on M_D estimated at a control plane just down-gradient of the source zone. Specifically, we compare M_D measurements collected at the source control plane before and after remediation to investigate changes in contaminant mass discharge resulting from DNAPL source remediation. Multiple methods were used to estimate M_D to minimize the uncertainty of any given single measurement, and while a comparison of results between methods is made, the comparison is secondary to the primary purpose of remedial performance assessment. At both sites, estimates of M_D were based on spatial integration of the contaminant fluxes measured in ten wells along a transect perpendicular to the mean groundwater flow direction; the wells were screened over the saturated zone of primary interest. Before and after source treatment, groundwater fluxes (q, LT^{-1}), and contaminant fluxes (J, $ML^{-2}T^{-1}$) were measured using two techniques: the Passive Flux Meter™ (PFM) approach (Hatfield et al., 2004; Annable et al., 2005; Basu et al., 2006), and a modified version of the Integral Pumping Test (IPT) approach, the origins for which lie in the IPT method as previously described (Bockelmann et al., 2001; Bockelmann

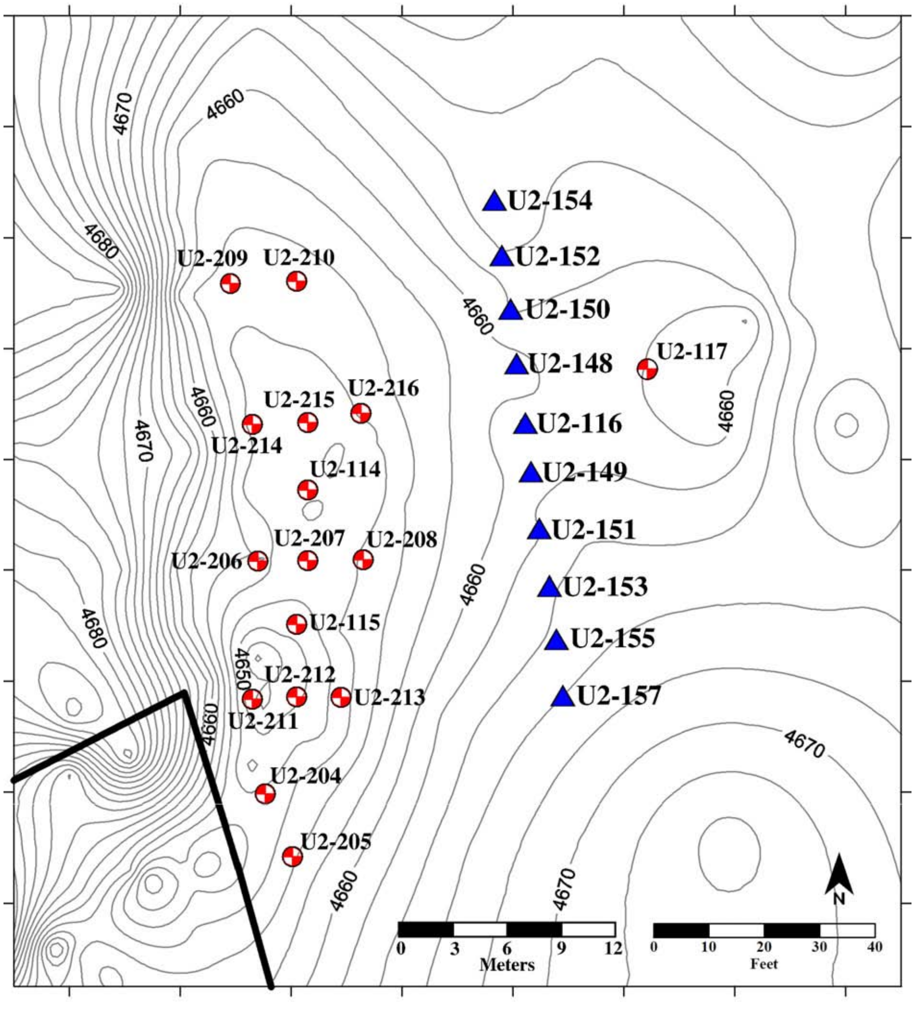

Fig. 1. Plan view of the Panel 5 area at Hill AFB. The thick black line in the lower left corner represents the containment wall installed around OU2. The triangular symbols represent wells used for mass flux measurements. The grey contour lines represent the surface of the clay unit (contours in feet) underlying the surficial aquifer.