Post-Closure Analysis Proves Success of Enhanced Hydrocarbon Bioremediation Using Twelve Horizontal Sparge Wells at Petroleum Products Bulk Terminal

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Introduction

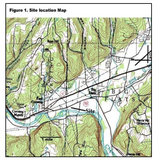
Griffith Terminal, a major oil storage facility (MOSF) in Big Flats, Chemung County, NY, was successfully remediated in the late 1990's using a horizontal well air sparge system. The site has required no remedial efforts since 2003.

- Non-aqueous phase liquids (NAPL) were discovered in the vicinity of a six-inch diameter petroleum product pipeline.
- 50,000 gallons of product were released between 1994 and 1995, including mixed oils, gasoline, No.2 fuel oil and kerosene.
- The objectives were to prevent exposure to sensitive receptors, control the 15 acre plume by preventing migration beyond the existing plume boundaries, and remediate the plume using a logical, phased implementation of the remediation program.
- The site was successfully remediated in the late 1990's using a horizontal well air sparge system. The site has required no remedial efforts since 2003.

Geographical Setting

- Surrounded by an area of low topographic relief with a shallow slope SE toward the Chemung River, which flows adjacent to the site along the S and SE property boundaries. Surrounding land use includes residential properties, light commercial properties and an industrial property (**Figure 1**).

Figure 1. Site location Map



Site Hydrogeology

- Storativity of 0.02 and hydraulic conductivity of 28.1 feet per day.
- Groundwater depth varies between 9 and 17 feet.
- Groundwater flow is predominantly southeast toward the Chemung River (**Figure 2**).
- Overburden soils consist of approximately 65 feet unconsolidated glacial and fluvial deposits.

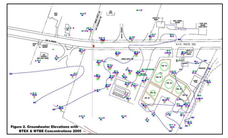


Figure 2. Groundwater Elevations with BTEX & MTBE Concentrations 2005

Conceptual Site Model

- The primary means of groundwater and contaminant mobility is through buried channels of transmissive sand and gravel. Boring logs show sand and gravel lenses interbedded with less permeable silty and clayey soils.
- A poorly cemented bed of gravel, sand and silt occurs at 10 to 15 feet bgs and appears to act as a barrier to vertical movement of soil vapor.
- Groundwater fluctuates about 4 feet, creating a substantial smear zone. Free product has collected in the smear zone. This makes the subsurface amenable to air sparging and soil vapor extraction.

Remedial Objectives

- Prevent impacts beyond known plume boundaries.
- Aggressively remediate the plume in the following step-wise phased approach:
  - Limit the migration of product and dissolved plume to the potential receptors including potable drinking water wells in the vicinity, the quarry to the east, and the Chemung River.
  - Remove free product.
  - Remediate soil and groundwater to established site-specific cleanup levels required by NYSDEC.

Remedial Strategy: Horizontal vs. Vertical Wells

- A total of 129 *vertical* wells coupled with 23 blowers would be required to remediate the entire affected area via bio-sparge technology. Only 12 horizontal bio-sparge wells coupled with 6 blowers would be required to remediate the same area.
- The vertical well system would only provide 272 feet of well screen. The horizontal well system would provide 2,650 feet of well screen. (The time and cost of a remedial project is approximately inversely proportional to the amount of well screen that can be placed in contact with contaminated media.)
- When assessing *total life cycle costs*, horizontal well systems are substantively less expensive than their vertical counterparts.
- Air sparge pilot testing of vertical wells indicated that dissolved oxygen (D.O.) increased significantly above ambient levels up to 44 feet away from the sparge wells. Pressure influence was detected up to 72 feet away.
- *The horizontal bio-sparge well option was selected on the basis of (1) large plume area, (2) expected rapid remediation versus vertical well configuration and (3) life cycle cost.*

Horizontal Air Sparge Well System

- Two networks of horizontal bio-sparge wells were installed during site remediation; the first in 1996 and the second in 1997. A perimeter network of six horizontal bio-sparge wells designed to protect the Chemung River and an adjoining quarry was installed in 1996.
- A second goal of installing the perimeter horizontal bio-sparge wells (**Figure 4**) was to determine the constructability and effectiveness of the horizontal remediation well technology in advance of designing and installing the "Core" plume area horizontal bio-sparge well network of 12 horizontal wells in 1997. The system operated from 1996 to 2003.

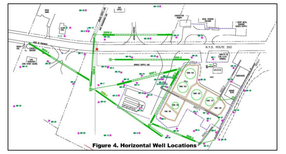


Figure 4. Horizontal Well Locations

Performance Evaluation and Conclusion

- NAPL decreased from a thickness of 2.3' in 1995 to essentially a sheen by 2003. Bio-sparging eliminated at least 30,000 gallons of NAPL. Soil samples collected circa 1996 uniformly and significantly exceeded regulatory criteria. Soil samples collected circa 2005 were either "non-detect" or below actionable clean-up criteria.
- The area with separate-phase hydrocarbons before the installation of the horizontal well system covered an area of 7 acres, shown in **Figure 5** with a dashed outline. After the horizontal well air sparge system was shut off, no separate-phase hydrocarbons remained.

Figure 5. Dissolved Hydrocarbon Plume 1995 & 2003

- The dissolved hydrocarbon plume experienced a dramatic size reduction from 1995 to 2003 (see **Figure 5**). Analysis of changes in concentrations of constituents of concern over time was used to assess the effectiveness of the remediation system, and to evaluate plume stability. Decreasing concentration trends of constituents of concern suggest that active remediation and natural attenuation is occurring.
- Groundwater contaminant concentration trend analysis demonstrated steady improvement from 2000-2005. The trend analysis reveals decreasing trends in most wells at the site, suggesting that active remediation and natural attenuation has reduced the source mass and decreased the footprint area of the dissolved plume (**Figure 6**).

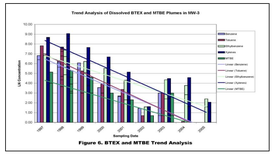


Figure 6. BTEX and MTBE Trend Analysis

A horizontal well system provide significantly greater source mass contact area and oxygen quantity compared to an equivalent system of vertical wells. Horizontal remediation well systems can be very effective and less expensive at remediating large expanse plumes than vertical well systems. In addition, this project demonstrates that horizontal sparge wells can be used as very effective barriers to plume migration.