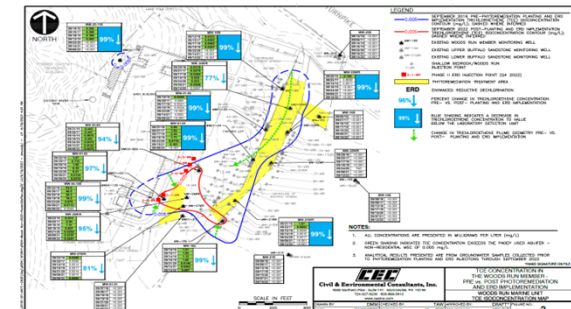
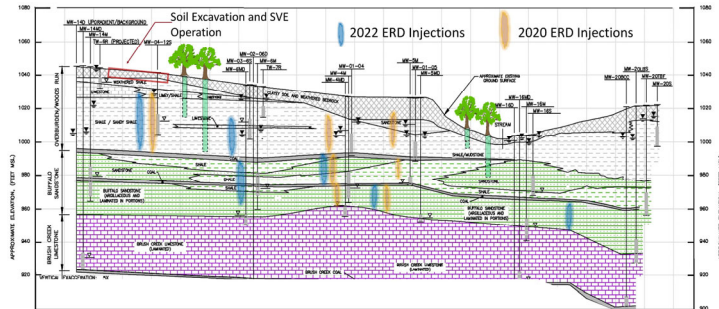
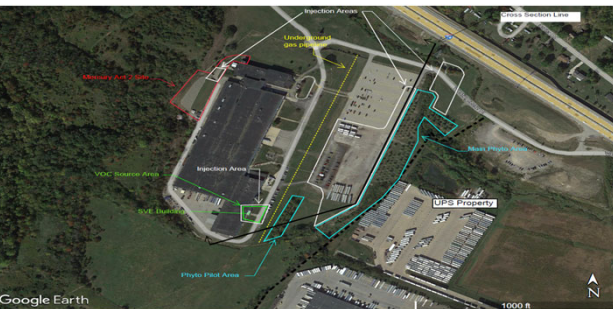




REMEDIATION OF A CVOC PLUME USING *TREEWELL*® PHYTOREMEDIATION TECHNOLOGIES AS PART OF A COMBINED REMEDIES APPROACH

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SITE CONDITIONS – SOUTHWESTERN PENNSYLVANIA: GROUNDWATER IMPACTS IN SHALLOW SURFACE SOIL AND UPPER PORTIONS OF FRACTURED BEDROCK AQUIFER



BACKGROUND/OBJECTIVES

- Site History**
- 1959-1960: Construction of the plant on green agricultural land.
 - 1960-2000: Production of thermostat controls for commercial and household appliances.
 - 2000: Identification of chlorinated VOCs including trichloroethene (TCE); cis-1,2-dichloroethene (DCE); chloroform; and 1,1,1-trichloroethane (TCA) in surface water and sediment near one of two outfalls leading from the plant wastewater treatment facility.
 - February 2001: Submitted Notice of Intent to Remediate – Pennsylvania Land Recycling Program.
 - March 2001-December 2010: Conducted a phased remedial investigation including 6 different water bearing zones: 1 at the soil bedrock interface and 5 within different water-bearing horizons in fractured cyclothem sequences of shales, sandstones, limestones, and coal.
 - 2007-2008: Pilot testing Accelerated Remediation Technologies, Inc.'s In-Well remediation system.
 - 2008-2010: Focused Feasibility Study with Bench-Scale Testing of Bioremediation and Chemical Oxidation.
 - 2010: Site is entered into the One Cleanup Program with U.S. EPA Region 3.
 - 2012: Develop Combined Remedies Approach including pilot testing of enhanced in-situ bioremediation (EISB) and EISB with in-situ chemical reduction (ISCR).

Remedial Objectives

- Reduce source area mass using SVE, ISCR, and EISB
- Hydraulic and Plume control of groundwater downgradient of the source area with *TreeWell* technology
- Mitigate off-site migration of VOC plume

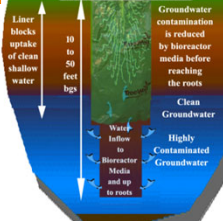
Remedial Strategy

- Combined remedies approach** – Source area shallow soil removal, soil vapor extraction, EISB, and ISCR in concert with plume/hydraulic control using *TreeWell* technology
- Shallow Soil Excavation** – 1,592 tons of soil removed from primary source area
- SVE**
 - 2007: Horizontal Wells installed beneath building in primary source area
 - 2022: 4 vertical extraction points added through building slab
 - Through 2022 – 1,461 lbs. of VOCs removed with SVE
- EISB** – Combination of 3DMe, BDI-Plus, and Chemical Reducing Solution (CRS) injected into 4 groundwater horizons including soil/bedrock interface and 3 bedrock horizons
 - Q2 2020 – 107 injection wells across 4 groundwater horizons to distribute:
 - 208,400 lbs. of 3DMe
 - 52,800 lbs. of CRS
 - 70 L of BDI Plus
 - Q4 2022 – 42 injection wells across 4 groundwater horizons to distribute:
 - 76,000 lbs. of 3DMe
 - 19,600 lbs. of CRS
 - 61.1 L of BDI Plus
- TreeWell Phytoremediation**
 - 2012-2013: 52-Unit Pilot *TreeWell* Unit Implementation
 - 2016-2017: 166-Unit Full-Scale *TreeWell* Unit Implementation

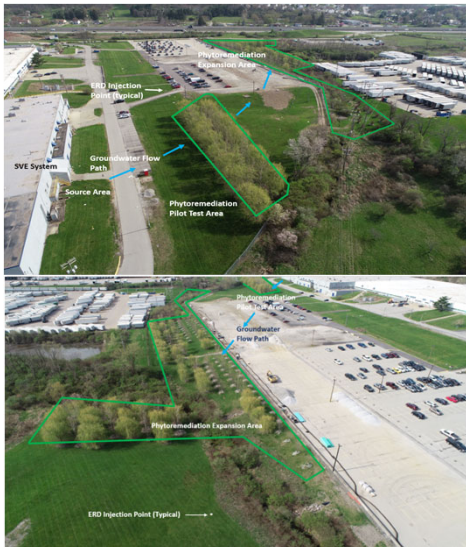
IMPLEMENTATION – *TREEWELL* PHYTOREMEDIATION

- Design – PHYTO-INTEGRATED™ Remediation System**
- Q4 2012 Pilot-Scale Installation: 52 *TreeWell* units installed downgradient of source area
 - 25 units installed in shallow soil (15 ft bgs)
 - 27 units installed in upper fractured bedrock (35 ft bgs)
 - Pilot conducted to evaluate efficacy of *TreeWell* technology to remove dissolved phased COCs, mitigate off-site migration, and evaluate tree species applicability
 - Utilized Hybrid Poplar and Willow
 - 2016-2017 Full-Scale Installation: 166 *TreeWell* units installed along downgradient property boundary
 - Targeted two upper fractured bedrock units with target depth ranging from ~4 to 47 ft bgs
 - 62 units in shallow soil
 - 104 units in upper fractured bedrock
 - Planted 5 species: Hybrid Poplar, Willow, Black Locust, London Plane, Red Twig Dogwood
 - 16 Red Twig Dogwood planted in units in area with low overhead utilities
 - Monitoring program developed to evaluate effectiveness of system included data logging pressure transducers to monitor groundwater drawdown within and near plantings, tree health assessments, tree growth, and groundwater monitoring.

Model of the *TreeWell* Unit



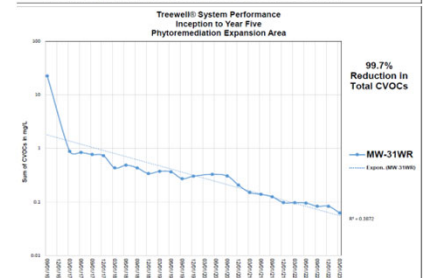
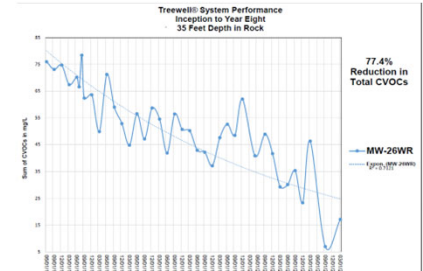
Root Development inside a *TreeWell* Unit



RESULTS TO DATE

Prior to Pilot Study – Source Area Total CVOCs: 262 mg/L 1,1,1-TCA and TCE principal contaminants

- No phyto-toxicity



Expansion Area Tree 150 – Willow growth over the first 5 years

