

New York State Department of Environmental Conservation

PRE-DESIGN INVESTIGATION REPORT

Former Cleanerama Site (Site #401056) Colonie, Albany County, New York

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Prepared for:

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1. INTRODUCTION

On behalf of the New York State Department of Environmental Conservation (NYSDEC) Division of Environmental Remediation, Arcadis implemented an remedial pilot study at the Former Cleanerama Site (#401056) at 253 Osborne Road, Colonie, Albany County, New York (the Site; **Figure 1**). The pilot study was designed to compare the effectiveness of EHC[®]-Liquid (EHC-L), a proprietary in-situ chemical reduction (ISCR) reagent with emulsified vegetable oil (EVO) which is used to biologically enhance reductive dichlorination, for the treatment of chlorinated (CVOCs) in the groundwater. EHC-L is composed of lecithin and iron gluconate (a soluble iron amendment), while EVO is a sparingly soluble organic substrate typically used to promote enhanced reductive dechlorination (ERD).

This Pre-Design Investigation Report (Report) documents injection activities, summarizes the performance of the EHC-L and EVO pilot studies, and provide recommendations for future site activities based on the results of the pilot study.

1.1 Site Background

1.1.1 Site Description and Location

The Site is an approximately 0.9-acre property located east of the intersection of Osborne Road and Albany-Shaker Road in Colonie, Albany County, New York. The Site contained a strip mall that was built in approximately 1955 and an office building that was built in 1962. The one-story strip mall of commercial properties included the Former Cleanerama dry cleaner, which operated at the Site from approximately 1960 to 1995. In 2003, the Site changed ownership and is currently owned by Walgreens. In August 2010, the strip mall was demolished, and the Site has remained vacant and undeveloped as of the time of this report. Commercial properties adjacent to the Site (e.g., restaurants, jeweler, floral shop, pharmacy) are currently operating. A summary of all previous investigations conducted at the Site is provided in the Final Feasibility Study Report (Shaw 2015). A map of the Site is provided as **Figure 2**.

1.1.2 Geology and Hydrogeology

The surface topography of the immediate Site slopes gently from the northeast to southwest, with steeper slopes southwest of Albany Shaker Road. According to soil borings collected at the Site and surrounding properties, the soil is generally composed of poorly graded sand and silt. Glacial till (silt, gravel, and clay) underlain by an approximately 1 foot thick layer of weathered bedrock (shale and siltstone) were found at the bottom of each soil boring. The depth to bedrock increases from 4.5 feet below ground surface (ft bgs) at the east end of the Site to 40 ft bgs at the west end of the Site. A geologic cross-section of the Site is provided on **Figure 3**.

Depth to groundwater follows the lay of bedrock in the subsurface and varies greatly (approximately 31 feet) from east to west across the Site. Depth to water at on the pilot study area ranges from 6 to 9 ft bgs

at the eastern side of the and increases to 29 ft bgs at the western edge of the Site. Groundwater flow direction is to the west-northwest at a gradient of 0.0769 ft/ft.

There are no water bodies or portable water wells identified near the Site. Sand Creek is the closest water body and is located approximately 500 feet west of the Site.

1.2 Pilot Test Rationale and Technology Description

Based on hydrological assumptions, which included a relatively high hydraulic conductivity and the presence of sand and weathered bedrock at the base impacted zone, Arcadis hypothesized that a transect based injection approach would be suitable for the Site. The pilot test injection wells and the downgradient dose response wells were used to test that hypothesis. This Pre-Design Investigation evaluates the performance of EHC-L and EVO to induce chemical reduction and/or enhance bioremediation of CVOCs in the groundwater via reductive dechlorination. The treatment mechanisms behind the ISCR and ERD technologies are described in the following sections.

1.2.1 In Situ Chemical Reduction

When iron-reducing conditions are achieved, dissolved-phase ferrous iron is liberated from the aquifer matrix. This geogenic iron may then stimulate the formation of reduced-iron minerals (e.g., trolite, mackinawite, pyrite, green rusts, and magnetite) within the aquifer matrix. These reduced iron minerals catalytically degrade tetrachloroethene (PCE) and its daughter products via reductive elimination reactions that take place on the mineral surface. Reduced iron minerals are not destroyed during the abiotic degradation pathway, and they will remain in the aquifer if they are stable in the aquifer's geochemical conditions.

Reaction intermediates from the abiotic pathway have short half-lives and are difficult to detect via analytical methods, Therefore, the most common sign that abiotic degradation is taking place in an in-situ reactive zone (IRZ) is a decrease in the concentration of CVOCs in the groundwater without a corresponding increase in daughter products.

1.2.2 Enhanced Reductive Dechlorination

Reductive dechlorination mechanisms can be limited by competing electron acceptors. Sulfate reduction and methane production indicate the strong reducing conditions required for ERD are present within an IRZ. Therefore, sufficient carbon (measured through total organic carbon (TOC)) must be introduced to exhaust the supply of electron acceptors such as dissolved oxygen (DO), nitrate, ferric iron, and sulfate before dechlorination may proceed. Once strongly reducing conditions have been established, reductive dechlorination of CVOCs can occur. When PCE (four chlorine atoms) degrades via reductive dechlorination, it is converted into the following daughter products: trichloroethene (TCE) (three chlorine atoms), cis-1,2-dichloroethene (cisDCE) (two chlorine atoms), and vinyl chloride (one chlorine atom).

Complete dechlorination has occurred when vinyl chloride is converted into non-chlorinated end products ethane and ethene.

1.3 Reagent Description

EHC-L is a proprietary ISCR reagent composed of a slightly soluble carbon substrate with an iron supplement. EHC-L is designed to promote both abiotic and biological degradation pathways, and is composed of a solid and liquid component that are mixed before injection. EHC-L liquid is a 25-percent (%) lecithin solution. EHC-L solid is composed of ferrous (iron II) gluconate and a proprietary blend of amino acids. Lecithin is an amphiphilic compound that readily forms micelles and liposomes (molecules that behave like surfactants) in water without the addition of a separate surfactant. The ferrous gluconate in EHC-L solid serves as a soluble source of iron. The charged nature of the lecithin molecule may enable the retention of EHC-L in the reactive zone as opposed to "wash out" with groundwater flow. The large molecule size of lecithin may also provide some longevity to the treatment in between injection events. At least one year of treatment represented by decrease in the CVOCs and accompanying reducing conditions could be anticipated after a full-scale injection event. Product specifications for EHC-L are provided in **Appendix A**.

TerraSystems' 60% SRS-SD EVO was used to test a slightly soluble carbon substrate without iron supplements. EVO is a sparingly soluble compound composed of emulsified vegetable oil, sodium lactate, and proprietary surfactants. This EVO does not contain supplemental iron. After EVO has been injected into an aquifer, the vegetable oil adheres to the aquifer matrix, providing a long-term source of TOC in an IRZ. Sodium lactate provides for a soluble carbon immediately available for microbial consumption and building up the reducing conditions. The vegetable oil serves as slow release carbon source. Based on Arcadis' experience, EVO is capable of sustaining TOC concentrations suitable for reductive dechlorination for one to two years depending on site conditions. Product specifications for EVO are provided in **Appendix A**

1.3 Objectives

The objectives of this report are listed below:

- 1. Document field data, including the values of real-time operating injection parameters, changes in groundwater levels, and other data/observations made by Arcadis field staff during the injection.
- 2. Document any pre-injection or post-injection measurements and activities conducted by Arcadis including quantity, mixing, and/or concentration of the injection solution, and document the appropriate demobilization and disposal of equipment/materials from the Site.
- 3. Summarize the performance of the injection and compare ERD and ISCR from a full-scale design perspective.
- 4. Summarize and recommend the design parameters developed from this Study.

2. PILOT STUDY IMPLEMENTATION

This section discusses injection well installation, injection system setup and operation, and subsequent performance monitoring.

2.1 Well Installation

In August 2017, Parratt-Wolff installed two injection wells using hollow-stem auger and split-spoon drilling methods. The locations of injection wells and previously installed monitoring wells are displayed on **Figure 2**. Injection well IW-1 is located upgradient of MW-8 in the parking lot adjacent to Albany Shaker Road. IW-2 is located upgradient of OS-1 on the northwest edge of the property that formerly contained the Cleanerama facility. Well construction details for injection wells IW-1 and IW-2 are included in **Table 1**. Well completion logs are provided in **Appendix B**. Lithologic logs are included in **Appendix C**.

2.2 Injection Volume Calculation

And injection volume of 2,585 gallons was calculated using the equation listed below.

$$V_{inj} = SF \times \pi \times r_{inj}^{2} \times h \times \theta_{n}$$

Where:

V_{inj} = volume of injection (cubic feet)

SF = straining factor (factor of 1.1 applied to sparingly soluble substrates to account for straining)

R_{inj} = radius of influence (10 ft)

h = height of well screen (10 ft)

 θ_m = mobile porosity (10%)

For both IW-1 and IW-2, a straining factor of 1.1 was applied to account for straining that can occur when injecting sparingly soluble substrates.

Carbon loading calculations were performed on EHC-L and EVO, and an equivalent carbon loading was calculated to allow for direct comparison between the performance of the reagents. A 3.1 percent by volume (% [v/v]) solution of EVO was injected at IW-1, and a 9.7 % (v/v) was injected at IW-2, as guided by Arcadis experience and vendor recommendation, respectively.

2.3 Injection Health and Safety

The following health and safety concerns were addressed upon arriving at the Site:

- · A traffic exclusion zone was established in the strip mall parking lot
- · High visibility traffic vests and hard hats were worn by Arcadis field staff
- A potential release of injection solution was managed using a 110% secondary containment
- Slips, trips, and falls associated with the injection conveyance and secondary containment were managed using good housekeeping and maintaining exclusion zones.
- Small spills within the secondary containment were addressed with absorbent pads.
- Given the potential freezing weather, heat trace was applied to the injection lines as needed to avoid any freezing and/or rupturing of the injection equipment.

2.4 EHC-L Injection (IW-1)

The EHC-L injection event began on December 8, 2016 with the injection of 9.7% EHC-L solution at IW-1. The EHC-L injection reached a completion on December 9, 2016 after injecting 2,697 gallons of EHC-L solution.

Injection using potable water from a Town of Colonie fire hydrant was initially intended. However, the hydrant was damaged and could not be used as a water source. Therefore, potable water was delivered to the Site by a local vendor and stored onsite in a 5,000-gallon tank.

EHC-L was delivered to the Site as separate liquid and solid components. EHC-L liquid was stored in secondary containment near IW-1. EHC-L solid was stored in a conex box located near IW-2. Before injection, the EHC-L liquid and EHC-L solid components were mixed. The EHC-L liquid was transferred to a 500-gallon polyethylene tank using a centrifugal pump. The EHC-L solid was then added to tank, and the EHC-L solution was mixed by recirculation with a centrifugal pump until the EHC-L solid was dissolved. EHC-L was mixed in a ratio of one drum of EHC-L liquid (50 gallons) to one bag of EHC-L solid (11 kilograms [kg]). The EHC-L solution was then mixed in-line to 9.7% (v/v) using a dosmatic pump.

A dosmatic pump was used to mix the solutions. Hydraulic head was applied to the water coming from the tank using a second centrifugal pump. The water then flowed to the dosmatic pump, which used the hydraulic head to mix a 9.7 % (v/v) solution of EHC-L. The diluted EHC-L solution then passed through a flow meter to document flow volume, and then passed through injection hosing to the wellhead at IW-1. The wellhead at IW-1 was equipped with a gate valve and pressure gauge to further regulate and document the injection pressure. The process and instrumentation diagram (P&ID) for the EHC-L injection is included as **Figure 4**.

During the injection event, four total iron samples were collected from the injection solution to determine the concentration of iron in the injection solution. Field parameters, specifically conductivity, were collected from each sample to provide a metric for gauging the arrival of injection solution in dose-response well MW-8.

Injection flow rate, injection pressure, and depth to water in MW-8 were checked routinely throughout the injection event. TOC samples and field parameters were collected from dose-response well MW-8 after every 250 gallons (i.e., approximately 10% of the total injection volume) had been injected in IW-1. TOC dose-response samples were held until the end of the injection event, when they were submitted to TestAmerica Laboratories in Buffalo, New York for analysis following the injection event.

Analytical reports for the dose-response samples are included in **Appendix D**. Injection field logs and dose-response monitoring results are included in **Appendix E**.

Following the EHC-L injection event, it was noted that only approximately 3 gallons of saturated EHC-L solid or iron precipitate were present at the bottom of the EHC-L tank, indicating that all the EHC-L solid was successfully delivered into the aquifer.

2.5 EVO Injection (IW-2)

The EVO injection event began on December 12, 2016 with injection of 3.1% EVO (TerraSystems 60% SRS-SD) solution at IW-2. On December 16, 2016 the EVO injection was terminated after injecting 1,930 gallons of 3.1% EVO in 98 hours of injection. The EVO injection event was terminated before reaching the target injection volume (i.e. 2585 gallons) due to the low injection rates.

The 5,000-gallon potable water tank was transferred to the IW-2 EVO Pilot Study Area after the completion of the EHC-L injection at IW-1. EVO injection initially used the same injection methodology as EHC-L except that the dosmatic pump was set to 3.1% (v/v), and no reagent mixing was required for the EVO (**Figure 4**).

After 50 gallons of injection, the injection solution began daylighting at IW-2. The flow rate was reduced to 0.5 gallon per minute (gpm) and daylighting subsided. Due to the low injection flow rate, the injection setup was converted to allow for gravity feeding overnight.

A 3.1% (v/v) EVO injection solution was mixed using the centrifugal pump and dosmatic pump and immediately transferred to the 500-gallon tank for storage. The injection solution then passed through the injection hose to a flow totalizer and then to the IW-2 injection well manifold. The P&ID for the gravity feed setup is included as **Figure 5**.

Due to the low flow rates in IW-2, EVO injection proceeded with continuous injection day and night. Due to freezing temperatures overnight, the injection line, injection manifold, tank fittings, and water tank valves were fitted with heat trace and insulation. A diesel generator was brought on site to power the heat trace.

Three injection solution samples were collected for total iron and TOC analysis. Due to a laboratory error, only one of the injection solution samples was analyzed for TOC.

The injection flow rate was too low to register a reading on the flow totalizer. Therefore, the injection flow rate was calculated using the graduated markings on the 500-gallon mixing tank. Injection pressure and depth to water in OS-1 were checked routinely throughout the injection event. TOC samples and field parameters were collected from OS-1 every 250-gallons of injected volume (i.e., approximately 10% of the proposed injection volume). IW-2 injections were conducted by gravity feeding overnight to help with the injection timeframe and field schedule. TOC dose response samples from OS-1 were held until the end of the injection event until they were submitted to TestAmerica Laboratories in Buffalo, New York for analysis.

A total of 1930 gallons of EVO was injected into IW-2. Analytical reports for the dose response samples are included in **Appendix D**. Transcribed injection field logs and dose-response monitoring results are included in **Appendix E**.

2.6 Performance Monitoring

A baseline sampling event was conducted in September 2016 before initiating the pilot study. Depth to water measurements were collected in 11 monitoring wells and two injection wells. Groundwater samples were collected from the injection wells IW-1 and IW-2 and dose-response wells MW-8 and OS-1 using low-flow sampling methods. Groundwater samples were also collected from nine other monitoring wells MW-1, MW-2, MW-5, MW-6, MW-8, MW-9R, OS-1, OS-4, OS-9, OS-10, and OS-12. Field parameters (pH, specific conductivity, oxidation reduction potential [ORP], dissolved oxygen [DO], temperature, and turbidity) were collected in addition to the following analytes: geochemical parameters (nitrate, total iron, total manganese, sulfate), alkalinity, chloride, TOC, light gases, and VOCs. The baseline sampling event serves as the benchmark for measuring remedial progress and changes in the groundwater geochemistry.

Performance monitoring events identical to the baseline monitoring event were performed in January 2017, March 2017, and June 2017 to evaluate remediation performance in both the EHC-L and EVO Pilot Test Areas.

Analytical samples from the baseline and performance monitoring events were submitted to TestAmerica Laboratories in Buffalo, New York for analysis. Laboratory analytical reports are included in **Appendix D**. Baseline and performance monitoring data are summarized in **Table 2**.

3. ENHANCED REDUCTIVE DECHLORINATION PILOT STUDY RESULTS

The injection system performance was assessed in both the EHC-L and EVO Pilot Test Areas. Performance monitoring results were assessed for evidence of abiotic and biological treatment in both the EHC-L and EVO Pilot Test Areas.

3.1 ISCR Pilot Study

EHC-L was injected in IW-1 located along Albany Shaker Road to evaluate to evaluate whether an in-situ remedy could prevent CVOCs from migrating off-site. Performance monitoring data were evaluated for evidence of abiotic and biological treatment.

3.1.1 IW-1 Injection Performance

Dose-response monitoring results, injection capacity, and groundwater elevation in MW-8 throughout the injection are plotted on **Figure 6**.

A total of 2,697 gallons were injected in approximately 9 total hours of injection. An average flow rate of 5 gpm was achieved throughout the whole injection event. The maximum pressure observed during the injection event was 1 pound per square inch (psi).

A final TOC concentration of 6,530 milligrams per liter (mg/L) was achieved in MW-8 after 2,700 gallons of injection solution was delivered into IW-1, and the groundwater elevation in MW-8 increased by approximately 2 ft during the injection event. This indicates that MW-8 was directly impacted by the EHC-L injection.

3.1.2 IW-1 Performance Monitoring Results

Baseline Conditions

Before the injection event, a baseline monitoring event was performed in September 2016. Baseline monitoring indicated that PCE was present at a concentration of 140 micrograms per liter (μ g/L) with limited conversion to TCE (5.9 μ g/L). Lesser chlorinated daughter products cisDCE and vinyl chloride were not detected during the baseline event, indicating that geochemical conditions were not sufficiently reducing to sustain reductive dechlorination.

Baseline biogeochemical conditions did not indicate the presence of reducing conditions required for the formation of reduced iron minerals for ISCR or biological reduction of PCE. Limited TOC (0.75 mg/L) was available to promote reducing conditions near IW-1. DO was present at a concentration of 4.74 mg/L, and

ORP was -45.7 millivolts (mV). These conditions indicate aerobic to slightly anoxic conditions during the baseline event. The background concentration of nitrate was low (1.1 mg/L). Total manganese (0.22 mg/L) and total iron (1.5 mg/L) were present at low concentrations, indicating that the metal-reducing conditions required for the formation of reduced iron minerals were not present near IW-1 during the baseline event. Sulfate was detected at a concentration of 59.6 mg/L, indicating that a substantial ambient sulfate was present in the aquifer. Upgradient of IW-1, the concentration of sulfate was similar in IW-2 (59.5 mg/L), indicating that sulfate is likely not reduced as groundwater moves from IW-2 to IW-1. Methane was not detected, indicating that the robust reducing conditions required for ERD were not present during the baseline event. ISCR and ERD end-product ethane and ethene were not detected during the baseline event.

Overall, constituent of concern (COC) and biogeochemical parameters indicate that the reducing conditions required for the formation of reduced iron minerals and reductive dechlorination were not present near IW-1 before the EHC-L injection event.

Performance Monitoring Results

In December 2016, 2,697 gallons of 9.7% (v/v) EHC-L were injected into IW-1, and a concentration of 6,530 mg/L of TOC was observed in dose-response well MW-8. Fifty-two days following the injection event, the concentration of TOC in IW-1 was 72.6 mg/L in January 2017. The concentration of TOC further dropped to 42.6 mg/L in March 2017 and 17.4 mg/L in June 2017. Though the concentration of TOC decreased quickly in IW-1, fairly reducing conditions were observed during the performance monitoring events.

DO concentrations generally decreased following the EHC-L injection event from the baseline value (4.74 mg/L) to 1.05 mg/L in January 2017, indicating that the TOC delivered during the injection event promoted the consumption of oxygen in the aquifer near IW-1. The concentration of DO was 4.73 mg/L in March 2017 and 1.80 mg/L in June 2017. The general decrease from the baseline event suggests that the delivered TOC resulted in more anaerobic conditions near IW-1.

ORP became more negative following the injection event. ORP was -45.7 mV in September 2016 in IW-1. Following the injection event, ORP ranged from -28 mV to -136 mV, indicating that the conditions in the aquifer became more reducing following the injection event.

Nitrate-reducing conditions were observed in IW-1 following the EHC-L injection event. The baseline nitrate concentration in IW-1 was 1.1 mg/L before the injection event in September 2016. Following the injection event, nitrate was not detected in IW-1 during the January or March 2017 events. In June 2017, the concentration of nitrate was 16.7 mg/L, which was an order of magnitude above the baseline event. Additional data would be required to verify whether this detection was anomalous or was a result of recharge of groundwater in the area.

Manganese-reducing conditions were observed in IW-1 following the EHC-L injection event. The baseline concentration of total manganese was 0.22 mg/L in September 2016. Following the injection event, the

total manganese concentration ranged from 3.7 mg/L to 6.2 mg/L. These results indicate that conditions were sufficient to liberate manganese from the aquifer matrix beginning in January 2017.

Iron-reducing conditions were likely observed in IW-1. The baseline concentration of total iron in IW-1 was 1.5 mg/L in September 2016. Following the EHC-L injection event, total iron increased to 28.4 mg/L in January 2017. Total iron remained stable in March 2017 (26.3 mg/L) and increased to 41.7 mg/L in June 2017. Because the EHC-L injection solution contained a total iron concentration of 269 mg/L (**Appendix E**), it is difficult to determine how much iron was liberated from the aquifer matrix. This increase in total iron is likely geogenic rather than from the injection solution given the increase in total manganese and rapid washout of TOC over a six-month period following the injection event.

Sulfate-reducing conditions were observed in IW-1 following the EHC-L injection event. The baseline concentration of sulfate was 59.6 mg/L in IW-1. Following the EHC-L injection event, sulfate was not detected during the January 2017, March 2017, and June 2017 performance monitoring events.

Robust methanogenesis was achieved in IW-1 following the EHC-L injection event. Methane was not detected during the baseline monitoring event in September 2016. Fifty-two days following the EHC-L injection event, methane was detected at a concentration of $3.5 \ \mu g/L$ in January 2017. The concentration of methane increased further increased to 1,400 $\mu g/L$ in March 2017 and 5,400 $\mu g/L$ in June 2017. The delay in the onset of strong reducing conditions following injection event may have been due to cold groundwater temperatures in January 2017.

Overall, the reducing conditions required for ISCR and ERD to occur were achieved near IW-1 following the EHC-L injection event.

CVOCs

The reducing conditions established by the EHC-L injection event facilitated the conversion from PCE to cisDCE near IW-1. During the baseline monitoring event, PCE was present at a concentration of 140 μ g/L, and limited concentrations of daughter products were observed. TCE was present at a concentration of 5.9 μ g/L, but lesser chlorinated daughter products were not detected in IW-1 during the baseline event.

Following the EHC-L injection, PCE fell from the baseline concentration of 140 μ g/L to 1.4 μ g/L in June 2017 (below the NYSDEC Standard of 5 μ g/L). The majority of PCE was converted into cisDCE. Minimal TCE was observed during the performance monitoring events, and TCE was not detected during the June 2017 monitoring event. Following the injection event, the concentration of cisDCE increased from the baseline value (non-detect) to 130 μ g/L in January 2017. Vinyl chloride and ISCR and ERD end products ethene and ethane were not observed during the baseline or performance monitoring events. This indicates that complete conversion of PCE was not achieved near IW-1 during the injection event.

The total molarity decreased from the baseline (0.99 micromoles per liter [µmol/L]) to 0.34 µmol/L in January 2017, likely due to dilution from the injection. Total molarity increased in March 2017 (1.50 µmol/L) and June 2017 (1.44 µmol/L) compared to the baseline value. Molar concentrations of contaminants of concern (COCs) are tabulated and plotted in **Appendix F**. The enhanced microbial

activity caused by the EHC-L injection event may have generated biosurfactants that mobilized sorbedphase PCE into groundwater, resulting in an increase in total molarity near IW-1. The generation of daughter products without a decrease in total molarity indicates that EHC-L promoted reductive dechlorination but did not stimulate abiotic degradation or ISCR near IW-1. Though biological conversion to cisDCE was achieved, the decreasing concentrations of TOC in IW-1 indicate that the reducing conditions achieved by the EHC-L conditions may start to decline after the six-month monitoring event.

3.1.3 MW-8 Performance Monitoring Results

Biogeochemical Parameters

In December 2016, a TOC concentration of 6,530 mg/L was achieved following the EHC-L injection event. The concentration dropped to 20.2 mg/L in January 2017, 13.2 mg/L in March 2017, and 5.1 mg/L in June 2017, indicating that TOC was approaching baseline conditions in June 2017. Biogeochemical conditions in MW-8 are reflective of this strong arrival of TOC during the injection event followed by rapid washout.

DO concentrations generally decreased following the EHC-L injection event. DO decreased from the baseline value (5.28 mg/L) to 0.53 mg/L in January 2017, indicating that the TOC delivered during the injection event promoted the consumption of oxygen in the aquifer near MW-8. The concentration of DO was 7.01 mg/L in March 2017 and 1.91 mg/L in June 2017. The general decrease from the baseline event suggests that the delivered TOC resulted in more anaerobic conditions near MW-8.

ORP became more reducing following the EHC-L injection event. Baseline ORP in MW-8 was 45.1 mV in September 2016. Following the injection event, ORP became more negative, ranging from -97 mV to - 106 mV.

Nitrate-reducing conditions were observed in MW-8 following the EHC-L injection event. The baseline nitrate concentration in MW-8 was 1.3 mg/L before the injection event in September 2016. Following the EHC-L injection, nitrate was not detected during the January 2017, March 2017, and June 2017 monitoring events, indicating that nitrate-reducing conditions were achieved and sustained upgradient of MW-8.

Manganese-reducing conditions were observed in MW-8 following the EHC-L injection event. The baseline concentration of total manganese in MW-8 was 0.15 mg/L in September 2016. Elevated concentrations of total manganese were observed in January 2017 (7.8 mg/L). Total manganese decreased to 4.8 mg/L in March 2017 and 1.8 mg/L in June 2017. This decreasing trend in manganese concentrations is likely correlated to the decreasing concentration of TOC in MW-8.

Iron-reducing conditions were likely observed in MW-1 following the EHC-L injection event. The baseline concentration of total iron in MW-8 in September 2016 was 1.3 mg/L. Following the injection event, the concentration of total iron in January 2017 increased to 24.4 mg/L and was sustained during the March 2017 (15 mg/L) and June 2017 (19.4 mg/L) monitoring events. Due to the increase in total manganese

following the injection event and fast washout of TOC, the increase in total iron is likely geogenic and indicative of iron-reducing conditions upgradient of MW-8.

Sulfate-reducing conditions were observed in MW-8 following the EHC-L injection event. Sulfate fell from the baseline concentration (52.5 mg/L) below the detection limit during January 2017 (7.0 mg/L) and March 2017 (3.5 mg/L) events. Sulfate was detected at a concentration of 10.5 mg/L during the June 2017 monitoring event. This increase in sulfate during the June 2017 event indicates that sulfate-reducing conditions became less prevalent upgradient of MW-8, likely resulting from the decrease in TOC observed in MW-8.

Moderate methane concentrations were observed in MW-8 following the EHC-L injection event. The baseline concentration for methane in MW-8 was 60 μ g/L in September 2016. The concentration of methane ranged from 300 to 940 μ g/L during the performance monitoring events. This indicates that methanogenesis was achieved upgradient of MW-8 but will likely not be sustained as TOC concentrations return to baseline conditions.

COCs

Evidence of reductive dechlorination was observed in MW-8 following the EHC-L injection event, but by the June 2017 monitoring event, reductive dechlorination became less strong as geochemical conditions became less reducing.

Before the EHC-L injection, little conversion of PCE to daughter products was observed. PCE was present at a concentration of 140 μ g/L, and TCE was present at a concentration of 6.2 μ g/L. Lesser chlorinated daughter products were not detected during the baseline monitoring event.

Fifty-two days following the injection event in January 2017, the concentrations of PCE and TCE increased slightly to 150 μ g/L and 11 μ g/L, respectively. CisDCE was detected at a concentration of 5.3 μ g/L, indicating that the EHC-L injection had resulted in some reductive dechlorination to cisDCE upgradient of MW-8. Vinyl chloride was not detected in January 2017.

During the March 2017 monitoring event, the concentration of PCE decreased by 90% to 14 μ g/L, TCE decreased to 2.4 μ g/L, and the concentration of cisDCE increased to 130 μ g/L. Vinyl chloride was not detected, indicating that reductive dechlorination halted at cisDCE.

During the June 2017 monitoring event, the concentration of PCE increased to 75 μ g/L, TCE increased to 5.5 μ g/L, and cisDCE decreased to 85 μ g/L. This indicates that reductive dechlorination became less active upgradient of MW-8 by the June 2017 as the concentration of TOC decreased.

Vinyl chloride and ISCR and ERD end products ethane and ethene were not observed during the baseline or performance monitoring program, indicating that complete conversion of PCE was not achieved upgradient of MW-8 following the EHC-L injection.

Total molarity remained stable following the baseline (1.00 μ mol/L) and January 2017 (1.06 μ mol/L) monitoring events. Total molarity increased in March 2017 (1.51 μ mol/L) and June 2017 (1.44 μ mol/L).

Molar concentrations are calculated and plotted in **Appendix F**. The enhanced microbial activity caused by the EVO injection event may have generated biosurfactants that mobilized sorbed-phase PCE into groundwater, resulting in an increase in total molarity in MW-8.

Overall, the performance monitoring results indicate that biological degradation of PCE to cisDCE was achieved but not sustained upgradient of MW-8 due to rapidly decreasing TOC concentrations. Evidence of ISCR (i.e., a decrease in total molarity without observation of daughter products) was not observed in MW-8 during the performance monitoring program.

3.2 ERD Pilot Study

EVO was injected at IW-2, which is located in the current area of highest CVOC groundwater concentrations. Performance monitoring data were evaluated for evidence of abiotic and biological treatment.

3.2.1 IW-2 Injection Performance

Dose-response monitoring results, injection capacity, and groundwater elevation in OS-1 throughout the EVO injection event are plotted on **Figure 7**.

A total of 1,930 gallons of EVO were injected into IW-2. Due to daylighting of injection fluid in IW-2, the majority of the injection event proceeded via gravity feed at an average flow rate of 0.3 gpm.

A final TOC concentration of 1,460 mg/L was observed in OS-1 after 1,930 gallons of injection. The groundwater elevation increased by approximately 0.2 ft in OS-1 during the injection event, and dose-response samples contained a turbid, milky white fluid, indicating that EVO had arrived in OS-1 during the injection event. The one injection solution sample analyzed for TOC contained 6720 mg/L TOC. Therefore, the relative strength of TOC delivered to OS-1 was approximately 22% that of the injection solution (1,460 mg/L).

3.2.2 IW-2 Performance Monitoring Results

Biogeochemical Parameters

In December 2016, 1,930 gallons of 3% (v/v) EVO were injected into IW-2, and a concentration of 1,460 mg/L was observed in dose response well OS-1. Forty days following the injection event, the concentration of TOC in IW-2 was 228 mg/L. The concentration of TOC in IW-2 increased to 333 mg/L in March 2017 and 389 mg/L in June 2017. This decrease in the concentration of TOC is expected, as the EVO falls out of the emulsion and adheres to the aquifer matrix.

The low DO baseline levels were generally maintained throughout the performance monitoring event. Baseline DO in IW-2 was 1.30 mg/L in September 2016. Following the injection event, DO was detected at low levels in January 2017 (1.48 mg/L) and June 2017 (2.33 mg/L). An abnormally high DO concentration was observed in March 2017 (9.84 mg/L). DO readings are measured using a groundwater quality probe, which can vary with field calibration, but the low DO levels observed in January 2017 and June 2017 generally indicate that partially anoxic conditions were observed in IW-1 during the baseline and performance monitoring events.

ORP became more negative following the EVO injection event. Baseline ORP in IW-2 was 144 mV in September 2016, indicating that oxidizing conditions were present in this well before the EVO injection event. Following the injection event, ORP ranged from -14 mV to -54 mV, indicating that aquifer conditions became more reducing following the injection event.

Nitrate-reducing conditions were observed in IW-2 following the EVO injection event. The baseline nitrate concentration in IW-2 was 0.12 mg/L. Nitrate was not detected in IW-2 during the January 2017, March 2017, and June 2017 monitoring events, indicating that nitrate-reducing conditions were achieved and sustained following the EVO injection event.

Manganese-reducing conditions were observed in IW-2 following the EVO injection event. The baseline concentration of total manganese in IW-2 was 4.0 mg/L in September 2016. After the EVO injection, the concentration of total manganese in IW-2 increased to 21.5 mg/L in January, 28.9 mg/L in March 2017, and 41.2 mg/L in June 2017. These results indicate that the EVO injection achieved and sustained robust manganese-reducing conditions, liberating a substantial amount of manganese from the aquifer matrix.

Iron-reducing conditions were achieved in IW-2 following the EVO injection event. The baseline concentration of total iron in IW-2 was 5.6 mg/L in September 2016. Following the EVO injection in December 2016, the concentration of total iron increased to 21.5 mg/L in January 2017, 65 mg/L in March 2017, and to 80.6 mg/L in June 2017. The maximum concentration of iron detected in the EVO injection solution was 3.3 mg/L (**Appendix E**). Therefore, the iron observed in IW-2 was geogenic in nature. Overall, these results indicate that the EVO injection achieved and sustained robust iron-reducing conditions, liberating a substantial amount of iron from the aquifer matrix.

Sulfate-reducing conditions were achieved in IW-2 following the EVO injection event. The baseline concentration of sulfate in IW-2 was 52.5 mg/L in September 2016. Following the December 2016 EVO injection, the concentration of sulfate dropped to 25.3 mg/L in January 2017. The concentration of sulfate further dropped below the 1.7 mg/L detection limit in March 2017 and the 3.5 mg/L detection limit in June 2017. These results indicate that sulfate-reducing conditions were achieved and sustained in IW-2 following the EVO injection event.

Methanogenesis was generally not observed in IW-2 following the EVO injection event, possibly due to the high concentration of iron and manganese in the aquifer matrix. The baseline concentration for methane in IW-2 was 2.1 μ g/L in September 2016. Following the injection event, methane was not detected above the 50 μ g/L detection limit. The concentration of methane was 2.1 μ g/L in March 2017 and 140 μ g/L in June 2017. Due to the sustained levels of TOC in IW-2, the low methanogenesis observed during the performance monitoring are likely not due to insufficient delivery of TOC, but may be due to high concentrations of ferric iron in the aquifer matrix. The high concentrations of total iron observed

during performance monitoring suggest that high levels of ferric iron are present in the aquifer matrix. The concentrations of ferric iron continued increasing throughout performance monitoring, suggesting that ferric iron has not been depleted as a terminal electron acceptor. Because the energy released via iron reduction is significantly higher than that with carbon dioxide reduction (i.e., methanogensis), bacteria will favor iron reduction over methanogenesis as an energy source until the supply of ferric iron is no longer available in the aquifer matrix.

CVOCs

Before the EVO injection, PCE was present at a concentration of 25 μ g/L, and limited conversion to TCE (0.88 μ g/L) and cisDCE (1.6 μ g/L) was observed. Vinyl chloride and non-chlorinated end products ethane and ethene were not detected during the baseline or performance monitoring events.

Following the injection event, the concentrations of PCE (23 μ g/L), TCE (0.63 μ g/L), and cisDCE (1.8 μ g/L) remained stable in January 2017. In March 2017, PCE dropped to 6.5 μ g/L and without an observed conversion to daughter products. During the June 2017 monitoring event, PCE further decreased to 4.4 μ g/L, and cisDCE was detected at a concentration of 4.9 μ g/L. TCE was not detected during the June 2017 monitoring event.

Molar concentrations are plotted and displayed in **Appendix F**. Total molarity in IW-2 decreased from 0.190 μ mol/L during the baseline event to 0.073 μ mol/L in March 2017; a 62% decrease from the baseline concentration. This decrease in total molarity was due to a decrease in the concentration of PCE without the generation of daughter products, which indicates that PCE likely degraded via the abiotic degradation pathway. CisDCE was observed in March 2017, indicating that the biological pathway is active as well. Overall, the EVO injection induced both abiotic and biological degradation pathways near IW-2 without the addition of supplemental iron to the injection substrate.

3.2.3 OS-1 Performance Monitoring Results

Biogeochemical Parameters

Limited TOC was observed in OS-1 throughout the performance monitoring program. The baseline concentration of TOC in OS-1 was 1.5 mg/L in September 2016. In December 2016, 1,930 gallons of 3.1% (v/v) EVO were injected at IW-2. The maximum concentration of TOC achieved in OS-1 during the injection event was 1,460 mg/L. Forty days following the injection event, the concentration of TOC in OS-1 was 2.6 mg/L. Limited TOC arrival was observed in OS-1 during the March 2017 (4.3 mg/L) and June 2017 (6.4 mg/L) monitoring events. These results indicate that sufficient EVO distribution was not achieved in OS-1 during the injection event.

The low DO baseline levels were generally maintained throughout the performance monitoring event. Baseline DO in OS-1 was 1.50 mg/L in September 2016. Following the EVO injection event, DO was detected at an abnormally high level in January 2017 (9.99 mg/L). Low DO levels were observed in March 2017 (1.91 mg/L) and June 2017 (2.69 mg/L). DO readings are measured using a groundwater quality probe, which can vary with field calibration, but the low DO levels observed in March 2017 and June 2017 generally indicate that DO levels remained near the baseline value throughout the performance monitoring program.

A decrease in ORP was observed in OS-1 following the EVO injection. The baseline ORP in OS-1 was 264.9 mV in September 2016, indicating that aerobic/oxidizing conditions were present before the EVO injection event. Following the injection event, ORP decreased to 5 mV in January 2017, -103 mV in March 2017, and -152 mV in June 2017. This indicates that the injection event resulted in more reducing conditions in OS-1.

Nitrate was not detected in OS-1 during the September 2016 baseline monitoring event or subsequent performance monitoring following the EVO injection.

Manganese-reducing conditions were observed near OS-1 following the EVO injection event. The baseline concentration of total manganese was 1.1 mg/L in September 2016. The concentration of total manganese in OS-1 increased to 12.9 mg/L in January 2017 but decreased to 6.4 mg/L in March 2017 and 7.4 mg/L in June 2017. These results indicate that EVO injection created reducing conditions, resulting in some manganese being liberated from the aquifer matrix near OS-1.

Weak iron-reducing conditions were observed in OS-1 following the EVO injection event. The baseline concentration of total iron in OS-1 was 0.057 mg/L in September 2016. Following the EVO injection in, the concentration of total iron increased to 0.28 mg/L in January 2017, 0.71 mg/L in March 2017, and 3.5 mg/L in June 2017. The maximum concentration of iron detected in the EVO injection solution was 3.3 mg/L (**Appendix E**). Therefore, it is difficult to determine how much of the increase in total iron was due to the injection event or reducing conditions liberating iron from the aquifer matrix. Given that manganese-reducing conditions were observed in OS-1, it is likely that iron-reducing conditions were present as well.

Mild sulfate-reducing conditions were observed in OS-1 following the EVO injection event. The baseline concentration of sulfate in OS-1 was 61 mg/L in September 2016. Following the EVO injection event, the concentration of sulfate decreased to 47.8 mg/L in January 2017, 45.3 mg/L in March 2017, and 43.4 mg/L in June 2017. Though a decrease in the concentration of sulfate was observed, the robust sulfate-reducing conditions required for reductive dechlorination were not observed in OS-1 following the December 2016 EVO injection.

The EVO injection event did not stimulate methanogenesis in OS-1. The baseline concentration for methane in OS-1 was 4.6 μ g/L in September 2016. Methane concentrations remained near the baseline concentration during the January 2017 (5.4 μ g/L), March 2017 (non-detect), and June 2017 monitoring events. This indicates that sufficient TOC was not delivered to OS-1 to induce the robust methanogenic conditions required for reductive dechlorination.

CVOCs

Baseline concentrations at OS-1 indicate that reductive dechlorination of PCE to TCE was limited. Before the EVO injection event, PCE was at a concentration of 150 μ g/L. Limited conversion to daughter products was observed. TCE was present at a concentration of 5.7 μ g/L. CisDCE, vinyl chloride, ethane, and ethene were not detected during the baseline event or during the performance monitoring program.

Following the injection event, the concentration of PCE increased to 240 μ g/L in January 2017 and 490 μ g/L in March 2017. The concentration remained stable in June 2017 (380 μ g/L). The concentration of TCE remained relatively stable at low levels in January 2017 (0.63 μ g/L), March 2017 (7.5 μ g/L), and June 2017 (9.4 μ g/L).

The increase in the concentration of PCE has two proposed explanations. First, the injection event may have pushed groundwater with higher concentrations of PCE toward OS-1. Second, the enhanced microbial activity caused by the EVO injection event may have generated biosurfactants that mobilized sorbed-phase PCE into groundwater.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 EHC-L Pilot

EHC-L resulted in biological treatment via reductive dechlorination rather than abiotic degradation. This is evidenced by the near complete conversion of PCE to cisDCE in IW-1 following the EHC-L injection without a net decrease in total molarity. Treatment of cisDCE was not achieved.

The TOC delivered in the EHC-L Pilot Test Area resulted in robust methanogenesis, sulfate reduction, and iron reduction in the subsurface. A fast washout rate of TOC was observed in the EHC-L Pilot Test Area. The strong reducing conditions induced by the EHC-L injection are not expected to be sustained for long since the concentration of TOC had fallen to 17.4 mg/L (IW-1) and 5.1 (MW-8) during the June 2017 monitoring event. This indicates that maintaining an IRZ along Albany Shaker Road would require frequent injections to sustain TOC levels for biological treatment.

The addition of an iron supplement did not promote abiotic degradation in IW-1 or MW-8. Both the iron generated in the aquifer and the iron injected may have formed reactive minerals downgradient of the IRZ. However, no evidence of abiotic degradation was observed in IW-1 or MW-8 following the EHC-L injection event.

EHC-L required an additional mixing step that did not provide an observed benefit in the performance monitoring data. EHC-L mixing lasted approximately 6 hours to prepare solution for one injection well and mixing and maintaining EHC-L in solution would be more difficult for full-scale implementation. Additional staff would be required just for mixing EHC-L, increasing the cost of the injection event.

4.2 EVO Pilot Study

EVO resulted in biological treatment via reductive dechlorination and there is evidence that abiotic degradation may have occurred in the EVO Pilot Test Area. EVO injection resulted in a decrease in total molarity of CVOCs without an increase in daughter products in March 2017. This indicates that abiotic degradation of PCE is likely taking place in the EVO IRZ. CisDCE was observed in June 2017 which indicates that biological treatment is occurring in the EVO IRZ as well.

Robust iron reducing conditions were observed in the EVO Pilot Test Area. Iron concentrations observed in the EVO Pilot Test Area (65 to 80.6 mg/L) were significantly higher than those observed in the EHC-L Pilot Test Area (26.3 to 41.7 mg/L). Moreover, evidence of abiotic treatment was observed in the EVO Pilot Test area, indicating that an iron supplement is not necessary to promote ISCR.

Concentrations of TOC were sustained between 228 and 389 mg/L in IW-2 throughout the performance monitoring program. This indicates that TOC concentrations can be sustained for a longer period of time in the EVO Pilot Test Area.

Limited methane generation was observed in the IW-2. The maximum concentration of 140 μ g/L was achieved in IW-2 during the June 2017 monitoring event. Methanogenesis is likely limited by high

concentrations of ferric iron in the aquifer matrix. Robust sulfate reducing conditions have been sustained in this well and cisDCE was generated, indicating that reductive dechlorination is occurring in this well. The sustained concentrations of TOC in IW-2 indicate that the microbial community responsible for methanogenesis will likely become more active once ferric iron becomes less available.

The EVO injection in IW-2 did not deliver sufficient TOC to OS-1 to promote a shift in biogeochemical parameters. OS-1 is not located directly downgradient from IW-2, which explains why terminal electron acceptors sulfate, reducing conditions. OS-1 is not located directly downgradient from IW-2, and therefore the shift in biogeochemical parameters induced by the EVO injection would not be expected to flow through OS-1.

Insufficient TOC was delivered to OS-1 to promote reducing conditions. A negligible decrease in the concentration of sulfate was observed, but the strong sulfate-reducing conditions and methanogenic conditions observed in IW-2 were not observed in OS-1. OS-1 is not located directly downgradient of IW-2, and therefore the reducing conditions and treated groundwater would not be expected to flow through OS-1.

The increase in the concentration of PCE in OS-1 following the injection event is likely due to a biosurfactant effect where sorbed was mobilized by enhanced microbial activity in the area. The injection in IW-2 may have also pushed groundwater with higher concentrations of PCE toward OS-1.

4.3 Recommendations

Overall, the two pilot studies indicated that a wide range of hydrogeologic conditions must be considered while developing a full-scale remediation design for the site. The south area (EHC-L Pilot Test Area) has 10-15 feet of overburden with a sand-dominated saturated zone which is underlain by weathered bedrock and the competent bedrock. The north area (EVO Pilot Test Area) has a much shallower overburden and thus a shorter injection target saturated injection zone. The variability in the injection flowrates can be directly attributed to the lithology in which the injection wells were screened. Similarly, the groundwater flow velocity and the subsequent washout of the injection solutions was faster in the south area (EHC-L Pilot Test).

The results of this pilot study indicate that an iron supplement is not required to achieve ISCR or abiotic treatment in an aquifer. EVO injection resulted in treatment via both abiotic and biological degradation pathways without iron amendment. Evidence of abiotic degradation was not observed in the EHC-L Pilot Test Area. Therefore, Arcadis recommends EVO, a sparingly soluble carbon substrate without iron amendment, for full scale remediation.

TABLES



Table 1 Well Construction Details Former Cleanarama (Site #401056) Loudonville, Albany County, New York



	EHC-L P	ilot Test	EVO Pil	ot Test
	IW-1	MW-8	IW-2	OS-1
Well Diameter (inches)	2	2	2	
Well Depth (ft bgs)	35	37.5	13	
Screen Material	Stainless Steel, Slotted	PVC Slotted	Stainless Steel, Slotted	
Screen Size (Inches)	0.5	0.01	0.5	
Screen Interval (ft bgs)	25 to 35	22.5 to 37.5	3 to 13	
Casing (ft bgs)	0 to 25	0 to 22.5	0 to 3	
Choker Sand (ft bgs)	21 to 23	17 to 20.5	1 to 2	
Filter Pack No. 2 Sand (ft bgs)	23 to 35	20.5 to 37.5	2 to 13	
Bentonite (ft bgs)		0 to 17		
Well Seal Type I/II Neat Cement (ft bgs)	0 to 21	0 to 17	0 to 1	
Surface Completion	Flush Mount	Flush Mount	Flush Mount	

Notes:

EVO = emulsified vegetable oiltion EHC-L = proprietary ISCR reagent ISCR = in-situ chemical reduction ft bgs = feet below ground surface PVC = polyvinyl chloride

		NYSDEC	IW-1	IW-1	IW-1	IW-1	DUP-1 ¹	DUP-1 ¹	DUP-1 ¹	DUP-1 ¹	IW-2	IW-2	IW-2	IW-2	MW-1	MW-1	MW-1	MW-1	MW-2	MW-2	MW-2	MW-2
Field Peremetere	Unito	GA	9/20/2016	1/30/2017	3/22/2017	6/9/2017	9/20/2016	1/25/2017	3/22/2017	6/9/2017	9/22/2016	1/25/2017	3/23/2017	6/7/2017	9/21/2016	1/26/2017	3/22/2017	6/8/2017	9/21/2016	1/26/2017	3/21/2017	6/7/2017
	Units	Standard	3/20/2010	40.54	42.44	45.00	9/20/2010	1/25/2011	5/22/2017	0/3/2017	3/22/2010	1/25/2017	0.74	45.74	3/21/2010	1/20/2017	40.74	40.04	3/21/2010	120/2017	40.70	40.00
	С СЦ	NA NA	7.02	6.22	13.41	13.90					6.09	7.01	0.71	13.71	19.70	6.92	6.91	6.02	10.30	7.02	6.77	7.04
pn Specific Conductivity	30 m£/om	NA NA	7.02	0.32	0.47	0.49					0.90	1.01	0.17	0.25	0.07	0.02	0.01	0.93	0.94	1.03	0.77	1.04
	m3/cm	N/A N/A	2.76	2.40	2.43	2.30					1.49	1.31	1.05	2.12	1.57	1.01	2.11	1.93	1.40	1.47	1.50	1.40
URP Dissolved Owegen	ma/l	NA NA	-45.7	-20	-130	-102					144	-14	-34	-49	14.0	239	100	09	0.20	0.21	100	1 40
Dissolved Oxygen	NTU	N/A N/A	4.74	1.05	4.73	1.00					1.30	9.64	1.40	2.33	0.66	1.70	4.44	2.75	0.20	0.31	1.39	1.49
Volotilo Organio Compoundo (USEBA 8260)	Unito	INA	32.0	24.5	< 0.3	< 0.5					23.0	279	-	< 0.5	10.6	< 0.5	< 0.5	< 0.3	30.4	₹ 0.5	< 0.3	< 0.5
2 Hovenono	ug/l	50	20.11	5011	20.11	20.11	20.11	5011	20.11	20.11	50.11	5011	50.11	21 1	5011	20 11	20.11	20.11	5011	5011	5011	5011
	µg/L	50	40 11	7.0 1	20 0	10 1	40 11	10 11	40 11	40 11	10 11	5.00	10 11	5.1 0	3.0 0	40 11	40 11	40 11	10 11	10 11	10 11	10 11
Benzene	µg/L	1	40 0	1.9 5	171	19 5	40 0	10.0	40 0	40 0	10 U	1011	10 0	1.0 11	1011	40 0	40 0	40 0	10 U	10.0	10.0	10 U
	µg/L		4.0 0	26	40.11	4.0 0	4.0 0	1.0 U	4.0 0	4.0 0	1.0 U	1.0 U	1.0 0	1.0 0	1.0 0	4.0 0	4.0 0	4.0 0	1.0 0	1.0 U	1.0 U	1.0 0
Chloroethane	µg/L	5	4.0 U	1011	4.0 U	4.0 U	4.0 U	1.0 0	4.0 U	4.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 0	4.0 U	4.0 U	4.0 U	1.0 0	1.0 U	1.0 U	1.0 U
Chloroform	µg/L	7	4.0 0	0.62	4.0 0	4.0 0	4.0 0	0.1	4.0 0	4.0 0	1.0 U	8.5	1.0 0	1.0 0	1.0 0	4.0 0	4.0 0	4.0 0	1.0 0	1.0 U	1.0 U	1.0 0
cis-1 2-Dichloroethene	µg/L	5	4.0 U	1.2	110	130	4.0 U	1.6	130	91.0	1.0 0	1.8	1.0 0	1.0 0	1.0 0	321	4.0 0	4.0 0	3.4	29	2.4	2.6
Methyl Ethyl Ketone	ug/L	50	40 U	12	40 U	40 U	40 U	25	40 U	40 U	10 U	1.0	1.6 0	28	5.3 J	40 U	40 U	40 U	10 U	10 U	10 U	10 U
Methylene Chloride	ua/L	5	4.0 U	0.81 JB	4.0 U	4.0 U	4.0 U	0.46 J	4.0 U	4.0 U	1.0 U	1.0 U	3.4	1.0 U	1.0 U	4.0 U	4.0 U	4.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Tert-butyl Ether	µg/L	10	4.0 U	1.0 U	4.0 U	4.0 U	4.0 U	1.0 U	4.0 U	4.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	4.0 U	4.0 U	4.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Tetrachloroethene	µg/L	5	140	46	38	1.4 J	150	15	13	88	25	23	6.5	4.4	11	80	180	140	12	14	13	20
Trichloroethene	µg/L	5	5.9	4.1	9.3	4.0 U	5.7	0.55 J	3.0 J	6.4	0.88 J	0.63 J	1.0 U	1.0 U	1.4	6.9	15	13	0.46 J	0.46 J	0.53 J	0.57 J
Vinyl Chloride	µg/L	2	4.0 U	1.0 U	4.0 U	4.0 U	4.0 U	1.0 U	4.0 U	4.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	4.0 U	4.0 U	4.0 U	1.8	1.4	1.4	1.3
Metals (USEPA 6010C)	Units																					
Iron	mg/L	300	1.5	28.4	26.3	41.7	1.8	21.9	17.6	18.9	5.6	27.7	65	80.6 B	192	0.34	0.12	0.23	0.96	0.10	0.14	0.12 B
Manganese	mg/L	300	0.22	4.2	6.2	3.7	0.24	22.2	5.1	1.8	4.0	21.5	28.9	41.2	9.4	3.3	1.1	0.92	0.63	0.88	1.1	1.2
Biogeochemical Parameters	Units				•						•	•						•				
Total Alkalinity (as CaCO ₃)	mg/L		223	235	275	327	223	281	308	243	333 B	294	534	733	294	336	321	321	325	326	295	308
Chloride	mg/L		676	617	586	542	685	191	554	751	227	190	243	289	259	304	366	387	264	254	273	284
Nitrate (as N)	mg/L		1.1	1.0 U	0.5 U	16.7 H	0.98	0.5 U	0.5 U	0.5 H	0.12	0.25 U	0.25 U	0.5 U	0.1 U	0.13	0.5 U	0.25 U	0.12	0.054	0.25 U	0.25 U
Sulfate	mg/L		59.6 B	40 U	20 U	20 U	58.8 B	23.3	20 U	10.8 J	59.5	25.3	10 U	20 U	60.8 B	55.9	53.8	59.5	55 B	53.8	53.1	45.7
Ethane	mg/L		0.75 J	75.0	42.0 75.11	380 11	0.81 J	7511	75.11	3.4 B	75.11	380 11	333 B	75 11	75 11	75 11	75.11	1.7 B	1.1	75 11	7.5 11	7.5 []
Ethene	ua/L		7.0 U	7.0 U	70 U	350 U	7.0 U	7.0 U	7.0 U	7.0 U	7.0 U	350 U	7.0 U	7.0 U	7.0 U	7.0 U	7.0 U	7.0 U	7.0 U	7.0 U	7.0 U	7.0 U
Methane	µg/L		4.0 U	3.5 J	1400	5400	4.0 U	4.0 U	390	1000	2.1 J	200 U	2.1 J	140	4.0 U	4.0 U	1.3 J	4.0 U	7.8	4.0 U	4.3	4.7
Imple - 7.0 U 7.0																						



		NYSDEC	MW-5	MW-5	MW-5	MW-5	MW-6	MW-6	MW-6	MW-6	MW-8	MW-8	MW-8	MW-8	MW-9R	MW-9R	MW-9R	MW-9R	OS-1	OS-1	OS-1	OS-1
Field Parameters	Units	GA Standard	9/20/2016	1/30/2017	3/22/2017	6/8/2017	9/21/2016	1/30/2017	3/23/2017	6/8/2017	9/20/2016	1/30/2017	3/22/2017	6/9/2017	9/22/2016	1/30/2017	3/23/2017	6/8/2017	9/22/2016	1/25/2017	3/23/2017	6/7/2017
Temperature	°C	NA	16.80	12.61	12.22	14.88	13.80	13.38	11.64	14.69	17.30	13.09	10.76	14.66	16.10	14.39	12.14	18.44	16.60	9.58	9.69	12.75
pH	SU	NA	7.06	7.01	6.9	6.72	6.98	7.02	6.9	6.86	6.92	6.96	7.07	7.25	7.03	6.98	7.03	6.55	7	7.02	6.91	7.23
Specific Conductivity	mS/cm	NA	3.76	3.45	3.68	3.63	3.96	3.41	3.32	3.66	2.66	2.58	2.34	2.79	3.75	3.13	3.69	4.57	1.39	1.53	1.38	1.21
ORP	mV	NA	-13.1	50	-27	-3	106.4	79	-1	30	45.1	-100	-97	-106	170	89	47	90	264.9	5	-103	-152
Dissolved Oxygen	mg/L	NA	0.31	0.31	4.75	1.72	0.72	0.44	1.81	2.76	5.28	0.53	7.01	1.91	3.88	2.04	3.33	4.59	1.50	9.99	1.91	2.69
Turbidity	NTU	NA	3.58	2.27	< 0.3	< 0.3	10.2	11.7	< 0.3	< 0.3	45.0	54.6	< 0.3	< 0.3	97.3	1000	-	-	3.61	103	-	< 0.3
Volatile Organic Compounds (USEPA 8260)	Units																					
2-Hexanone	µg/L	50	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	20 U	5.0 U	20 U	20 U	5.0 U	5.0 U	5.0 U	5.0 U	20 U	20 U	20 U	50 U
Acetone	µg/L	50	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	40 U	10 U	40 U	40 U	10 U	10 U	10 U	10 U	40 U	40 U	40 U	100 U
Benzene	µg/L	1	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	4.0 U	1.0 U	4.0 U	4.0 U	1.0 U	1.0 U	1.0 U	1.0 U	4.0 U	4.0 U	4.0 U	10.0 U
Carbon Disulfide	µg/L		1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	4.0 U	0.29 J	4.0 U	4.0 U	1.0 U	1.0 U	1.0 U	1.0 U	4.0 U	4.0 U	4.0 U	10.0 U
Chloroethane	µg/L	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	4.0 U	1.0 U	4.0 U	4.0 U	1.0 U	1.0 U	1.0 U	1.0 U	4.0 U	4.0 U	4.0 U	10.0 U
Chloroform	µg/L	7	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	4.0 U	1.0 U	4.0 U	4.0 U	1.0 U	1.0 U	1.0 U	1.0 U	4.0 U	4.0 U	4.0 U	10.0 U
cis-1,2-Dichloroethene	µg/L	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	4.0 U	5.3	130	85	1.0 U	1.0 U	1.0 U	1.0 U	4.0 U	4.0 U	4.0 U	10.0 U
Methyl Ethyl Ketone	µg/L	50	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	40 U	10 U	40 U	40 U	10 U	10 U	10 U	10 U	40 U	40 U	40 U	100 U
Methylene Chloride	µg/L	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.7 B	1.0 U	1.0 U	4.0 U	1.0 U	1.8 J	4.0 U	1.0 U	1.0 U	1.0 U	1.0 U	4.0 U	4.0 U	4.0 U	6.0 J
Tert-butyl Ether	µg/L	10	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	4.0 U	1.0 U	4.0 U	4.0 U	1.0 U	1.0 U	1.0 U	1.0 U	4.0 U	4.0 U	4.0 U	10.0 U
Tetrachloroethene	µg/L	5	1.0 U	1.0 U	1.0 U	1.0 U	4.1	0.68 J	1.0 U	11.0	140	150	14	75	16	18	20	21	150	240	490	380
Trichloroethene	µg/L	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	6.2	11	2.4 J	5.5	1.0 U	1.0 U	0.46 J	0.49 J	5.7	7.5	11	9.4 J
Vinyl Chloride	µg/L	2	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	4.0 U	1.0 U	4.0 U	4.0 U	1.0 U	1.0 U	1.0 U	1.0 U	4.0 U	4.0 U	4.0 U	10.0 U
Metals (USEPA 6010C)	Units						• •	• •	•									•				
Iron	mg/L	300	0.21	0.24	0.31	0.42	0.67	0.27	1.1	0.56	2.1	24.4	15	19.4	7.4	15	11.4	7.4	0.057	0.28	0.71	3.5 B
Manganese	mg/L	300	1	0.95	0.96	0.85	0.24	0.097	0.23	0.11	0.15	7.8	4.8	1.8	0.52	1	0.64	0.61	1.1	12.9	6.4	7.4
Biogeochemical Parameters	Units																					
Total Alkalinity (as CaCO ₃)	mg/L		277	295	293	287	259 B	287	277	278	216	273	307	237	287 B	292	289	287	283 B	306	300	314
Chloride	mg/L		980	953	1020	955	1050	961	922	984	646	681	556	744	1010	924 F1	1040	1280	200	252	207	178
Nitrate (as N)	mg/L		0.1 U	1.0 U	1.0 U	0.4 J	1.1	0.81 J	1.0 U	1.5	1.3	1.0 U	0.5 U	0.5 H	2.3	2.4 F1	2.0	2.5	0.1 U	0.5 U	0.25 U	0.25 U
Sulfate	mg/L		105 B	79.5	105	113	86.1 B	65.2	81	89.5	52.5 B	40 U	20 U	10.5 J	77.1	61.1 F1	80.4	85.4	61	47.8	45.3	43.4
Total Organic Carbon	mg/L		1.0 U	0.46 J	1.0 U	0.75 JB	1.0 U	1.0 U	0.48 J	0.87 JE	0.83 J	20.2	13.2	5.1 B	1.0 U	0.65 J	1.0 U	1.1 B	1.5	2.6	4.3	6.4
Ethane	µg/L		7.5 U	7.5 U	7.5 U	7.5 U	7.5 U	7.5 U	7.5 U	7.5 U	7.5 U	150 U	380 U	750 U	7.5 U	7.5 U	7.5 U	7.5 U	7.5 U	7.5 U	7.5 U	7.5 U
Ethene	µg/L		7.0 U	7.0 0	7.0 U	7.0 U	7.0 U	7.0 U	7.0 U	7.0 0	7.0 U	140 U	350 U	700 U	7.0 U	7.0 U	7.0 U	7.0 U	7.0 U	7.0 U	7.0 U	7.0 0
Wethane	µg/L		4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	98	3.0 J	4.0 0	00	940	300	700	4.0 U	4.0 U	4.0 U	4.0 U	4.0	5.4	4.0 U	5.3

 Notes:

 ORP = oxidation reduction potential

 °C = degrees Celsius

 SU = standard units

 mS/cm = milliSiemens per centimeter

 mV = milliVolts

 mg/L = milligrams per liter

 NTU = nephelometric turbidity units

 µg/L = micrograms per liter

 NYSDEC GA GW Standard = New York State Department of Environmental

 million

 = Concentration exceeds NYSDEC Class GA Standard.

 BOLD = Compound detected

 U = Compound detected at the indicated concentration.

 J = Compound detected below the reporting limit or reported concentration

 B = Compound was found in both the laboratory blank and the sample.

 H = Sample prepped or analyzed beyond the specified hold time.

 ¹ = duplicate sample collected from IW-1.



		NYSDEC	OS-4	OS-4	OS-4	OS-4	OS-9	OS-9	OS-9	OS-9	OS-10	OS-10	OS-10	OS-10	OS-12	OS-12	OS-12	OS-12
Field Parameters	Units	GA Standard	9/22/2016	1/25/2017	3/21/2017	6/7/2017	9/21/2016	1/26/2017	3/21/2017	6/8/2017	9/21/2016	1/26/2017	3/21/2017	6/7/2017	9/21/2016	1/30/2017	3/24/2017	6/8/2017
Temperature	°C	NA	15.90	9.34	12.00	12.91	15.50	13.59	17.12	16.14	17.60	9.25	11.03	15.35	16.00	9.40	13.14	19.42
pH	SU	NA	6.56	6.9	6.5	6.69	6.87	6.91	6.74	6.49	7.17	7.15	6.96	6.93	7.23	6.9	7.18	6.18
Specific Conductivity	mS/cm	NA	1.70	1.83	1.63	1.38	1.46	1.53	1.38	1.34	0.98	6.95	26.10	0.15	3.91	3.69	3.64	3.73
ORP	mV	NA	185.1	91	161	54	180.2	174	146	137	-175	179	-11	-4	69.2	-32	-58	-104
Dissolved Oxygen	mg/L	NA	0.63	9.41	1.71	1.99	0.67	0.56	1.10	2.20	0.21	9.36	1.61	1.79	4.27	6.00	5.68	2.91
Turbidity	NTU	NA	22.5	0.70	< 0.3	< 0.3	2.42	< 0.3	< 0.3	< 0.3	19.8	221	< 0.3	< 0.3	> 1000	> 1000		
Volatile Organic Compounds (USEPA 8260)	Units																	
2-Hexanone	µg/L	50	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U
Acetone	µg/L	50	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	4.9 J	6.0 J	6.6 J	10 U	10 U	10 U	10 U	10 U
Benzene	µg/L	1	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Carbon Disulfide	µg/L		1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	0.38 J	1.0 U	1.0 U	1.0 U
Chloroethane	µg/L	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Chloroform	µg/L	7	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
cis-1,2-Dichloroethene	µg/L	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	34	1.0 U	1.4	1.0	1.0 U	1.0 U	1.0 U	1.0 U
Methyl Ethyl Ketone	µg/L	50	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10.0 U	10.0 U	10 U	10 U	10 U
Methylene Chloride	µg/L	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	0.58 JB	1.0 U	1.0 U
Tert-butyl Ether	µg/L	10	1.1	1.2	0.31 J	0.42 J	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Tetrachloroethene	µg/L	5	0.65 J	0.88 J	1.0 U	0.65 J	1.0 U	1.0 U	1.6	1.0 U	11	3.4	12	10	23	1.9	3.2	14
Trichloroethene	µg/L	5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	5.2	0.7 J	2.5	1.6	0.48 J	1.0 U	1.0 U	1.0 U
Vinyl Chloride	µg/L	2	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Metals (USEPA 6010C)	Units																	
Iron	mg/L	300	8.6	0.66	0.16	0.099 B	0.21	0.063	0.048 J	0.023 J	14.2	3.0	0.91	1.6 B	106	40.1	23.3	55.1
Manganese	mg/L	300	5.6	1.4	0.69	0.041	1.5	0.28	0.6	0.27	0.6	0.086	0.3	0.16	5.2	1.8	1.4	3.4
Biogeochemical Parameters	Units																	
Total Alkalinity (as CaCO ₃)	mg/L		295 B	299	293	274	297	307	309	303	297	54.6	191	58.2	301	294	289	310
Chloride	mg/L		325	364	387	305	248	279	274	239	194	2930	11800	19.9	1060	1030	1050	1020
Nitrate (as N)	mg/L		0.11	0.5 U	0.25 H	0.25 U	0.35	0.26	0.25 U	0.28	0.1 U	2.1	5.0 H	0.049 J	0.9	0.68 J	1.0 H	0.93
Sulfate	mg/L		55.8	37.1	56.4	70.7	53.7 B	52.2	54.9	57.1	28.9 B	18.7	200 U	4.1	75.9 B	79.6	95.3	87.9
Total Organic Carbon	mg/L		2.0	2.3	1.7	2.4	0.86 JB	1.1	1.0	1.6 B	7.1 B	1.8	3.0	2.0	2.6 B	0.94 J	1.4	4.0 B
Ethane	µg/L		7.5 U	7.5 U	7.5 U	7.5 U	7.5 U	7.5 U	7.5 U	7.5 U	150 U	7.5 U	7.5 U	7.5 U	7.5 U	7.5 U	7.5 U	7.5 U
Ethene	µg/L		7.0 0	7.0 0	7.0 0	7.0 U	7.0 0	7.0 0	7.0 0	7.0 0	140 U 220	7.0 0	7.0 0	7.0 0	7.0 0	7.0 0	7.0 0	7.0 0
WEUIAIIE	_µy/∟		21	19	23	10	4.0 0	4.0 U	4.0 0	4.0 U	320	4.0 U	14	4.0 U	04	330	00	23

 Notes:

 ORP = oxidation reduction potential

 °C = degrees Celsius

 SU = standard units

 mS/cm = milliGrams per centimeter

 mV = milliGrams per liter

 NTU = nephelometric turbidity units

 µg/L = milligrams per liter

 NYSDEC GA GW Standard = New York State Department of Environmental

 Image: Subscript{SUBS}

 BOLD = Compound detected

 U = Compound detected below the reporting limit or reported concentration.

 J = Compound was not detected at the indicated plank and the sample.

 H = Sample prepped or analyzed beyond the specified hold time.

 1 = duplicate sample collected from IW-1.



FIGURES



Figure 1 Site and Vicinity



Former Cleanerama (Site # 401056) Remedial Design Loudonville, Albany County, New York



Figure 2 Site Plan and Injection Well Locations



Former Cleanerama (Site # 401056) Loudonville, Albany County, New York



ARCADIS Design & Consultancy for natural and built assets

Former Cleanarama (Site #401056) Loudonville, Albany County, New York







CITY: (Read) DIV/GROUP: (Read) DB: (Read) LD: (Opt) PIC: (Opt) PIC: (Opt) PM: (Read) LD: (Opt) LYR: (Opt) LYR: (Opt) ON=*, OFF=*REF* G: ENVCADITallahassee-FL\ACT\00266436\0000\00003\00266436-PID.dwg LAYOUT: 5 SAVED: 12/9/2016 12:05 PM ACADVER: 18.1S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: ARCADIS(SIZE A-B).CTB PLOTTED: 11/10/2017 4:03 PM BY: BERNDGEN, WENDY



CITY:(Reqd) DIV/GROUP:(Reqd) DB:(Reqd) DB:(Reqd) PIC:(Opt) PIC:(Opt) PIM:(Reqd) TM:(Opt) LYR:(Opt)ON=*;OFF=*REF* G:ENVCAD/Tallahassee-FL\ACT\00266436\0000\00003\00266436-PID.dwg LAYOUT: 6 SAVED: 12/9/2016 12:05 PM ACADVER: 18.1S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: ARCADIS(SIZE A-B).CTB PLOTTED: 11/10/2017 4:02 PM BY: BERNDGEN, WENDY XREFS: IMAGES: PROJECTNAME: ---A\$C0567561D.dib Rebrand_secondary_color-FULL DESCRIPTION.jpg 1/4" - SAMPLING PORT HOSE HOSE PVC PVC PVC PVC Ы DOSMATIC FT PUMP 1" HOSE 500 GALLON POLY TANK 2" WELL AHEAD ADAPTOR 5,000 GALLON FRAC TANK CENTRIFUGAL PUMP Х **INSTRUMENT LEGEND** 2" INJECTION WELL INSTRUMENT CONNECTED TO PROCESS LINE SECONDARY CONTAINMENT \bowtie BALL VALVE -1771-SAMPLE PORT ΡE PIPE DESIGNATION CHANGE FLEXIBLE HOSE **M** REDUCER EVO DRUM FT FLOW TOTALIZER PRESSURE INDICATOR PI FLOW TOTALIZER METER CENTRIFUGAL PUMP Former Cleanerama (Site # 401056) Remedial Design Loudonville, Albany County, New York PROCESS AND INSTRUMENTATION DIAGRAM FOR EVO INJECTION FIGURE ARCADIS International 5



Figure 6 IW-1 Injection Performance (EHC-L Pilot Test Area)

Former Cleanarama (Site #401056) Loudonville, Albany County, New York



Legend:

gpm - gallons per minute

psi – pounds per square inch

¹ – pressure at top of well screen calculated by adding 25 ft of head to gauge pressure

TOC - total organic carbon

mg/L - miligrams per liter

ft msl - feet above mean sea level

---- final reading collected on December 8, 2016


Figure 7 IW-2 Injection Performance (EVO Pilot Test Area)

Former Cleanarama (Site #401056) Loudonville, Albany County, New York



Legend:

gpm - gallons per minute

psi – pounds per square inch

¹ – pressure at top of well screen calculated by adding 3 ft of head to gauge pressure

TOC – total organic carbon

mg/L - miligrams per liter

ft msl - feet above mean sea level

---- - last data point before switching from pressurized to gravity feed injection

APPENDIX A

Reagent Specifications





A Dynamic Solution Promoting Abiotic and Biotic Processes

EHC[®] Liquid Reagent is an *in situ* chemical reduction (ISCR) product for the treatment of impacted groundwater. It is a cold-water soluble formulation that is specially designed for injection via existing wells or hydraulic injection networks for the treatment of a wide range of groundwater contaminants. EHC Liquid creates strong reducing conditions and promotes both biotic and abiotic dechlorination reactions. EHC Liquid is composed of two parts: EHC Liquid Reagent Mix, an organo-iron compound, and ELS[™] Microemulsion, which are easily combined and diluted for injection.

The benefits of EHC Liquid

- Stimulation of biotic reductive dechlorination through the generation of strong reducing conditions
- Structurally bound nutrients phosphorous and nitrogen released to bacteria via the fermentation of the lecithin molecule
- Direct chemical reduction from redox reaction of organoiron compound
- Surface dechlorination by magnetite and green rust precipitates from iron corrosion
- Replenished reactive iron surface provided by the cycling of iron from ferrous to ferric state in the presence of a carbon source - anticipated longevity of 2-3 yrs. depending on site conditions
- Easy to handle and cold water soluble

Contaminants treated

- Chlorinated solvents such as PCE, TCE, TCA, DCA, CCl₄, chloroform and methylene chloride
- Chlorobenzenes including di- and tri-chlorobenzene
- · Energetic compounds such as TNT, DNT, HMX, RDX, nitroglycerine and perchlorate
- Most pesticides including DDT, DDE, dieldrin, 2,4-D and 2,4,5-T
- Chlorofluorocarbons
- Nitrate compounds
- Chromium

The sound science of EHC Liquid

Organic carbon addition in the saturated zone is well-known to promote conventional enzymatic reductive dechlorination reactions. This happens because the carbon in the subsurface will support the growth of indigenous microbes in the groundwater environment. As bacteria feed on the soluble carbon, they consume dissolved oxygen and other electron acceptors, thereby reducing the redox potential in groundwater. As bacteria ferment the ELS microemulsion, they







Product Sheet

release a variety of volatile fatty acids (VFAs) such as lactic, propionic and butyric, which diffuse from the site of fermentation into the groundwater plume and serve as electron donors for other bacteria, including dehalogenators. The biogenolysis/hydrogenolysis reaction for the reduction of PCE is shown below.



Lecithin itself is composed primarily of phospholipids, which have both hydrophilic and hydrophobic regions in their molecular structure. As a result, ELS emulsions tend to be stable emulsions, expectedly more stable than with only hydrophobic compounds. Further, phospholipids support remediation by providing essential nutrients (carbon, nitrogen, phosphorus) to bacteria.

The soluble organo-iron compound is comprised of a ferrous iron (Fe^{+2}) that can form a variety of iron minerals (e.g. magnetite, pyrite) that are capable of reducing contaminants as they oxidize further to the ferric (Fe^{+3}) state via one electron transfer. The ferric ion can be "recycled" back to ferrous as long as other electrons from supplied carbon and indigenous carbon are available.

EHC Liquid is primarily recommended for plume treatment. It can be used as a source treatment depending on site conditions.

Application methods

- Direct push injection
- Gravity feed through existing wells
- Low pressure injections
- Recirculation systems

For more information and detailed case studies, please visit our website.





Introduction

EHC-Liquid[®] is a cold-water soluble formulation of EHC[®] that is specially designed to be emplaced via existing wells and/or hydraulic injection networks for the treatment of a wide range of groundwater contaminants. The base composition is a slow release carbon source (lecithin), an organo-iron compound and amino acids (all food-grade). EHC-Liquid is delivered as two components, which are mixed together in the field. The first component, a 25% liquid emulsion of lecithin, is provided in 55-USG drums containing 50 USG of emulsion. The second component (dry EHC-Liquid mix) which contains iron and amino acids is added to the liquid component during



injectate preparation in the field. The two components are proportioned so that 24.5 lbs of EHC-Liquid mix is required for each 50 USG of liquid product. This document provides standard operating procedures for preparation of diluted EHC-Liquid for injection.

Packaging

Part 1: Liquid emulsion delivered in 55-USG drums, filled with 50 USG / 420 lbs per drum.

Part 2: Water soluble powder with the organo-iron compound and other additives delivered in 24.5 lb bags.

EHC-L Injection Volumes and Dilutions

Depending on the application method, between 10% and 100% of the <u>effective</u> porosity is normally targeted during EHC-Liquid injection, with a higher percent pore fill normally



targeted during low-flow injections into wells and injection networks. This is in contrast to applications via direct push technology (DPT) where normally around 10 to 15% is targeted. To facilitate the desired injection volume, the EHC-L components will be diluted in the field. Table 1 shows examples of mixing recipes for a 55-USG drum of EHC-Liquid.

U					
	Dilution:	5-fold	10-fold	3-fold	
	Volume EHC-L emulsion per drum (USG)	50	50	50	
	Mass dry components (lbs)	24.5	24.5	24.5	
	% active components in EHC-L as delivered	25%	25%	25%	
	% active components in EHC-L after powder (mix) addition	29%	29%	29%	
	Dilution factor for EHC-L solution to inject	5	10	3	
	Volume water (USG)	200	450	100	
	Resulting total volume (USG)	250	500	150	
	Resulting EHC-L concentration	5.8%	2.9%	9.70%	

 Table 1:
 EHC-Liquid dilutions and corresponding concentration.

😢 PeroxyChem

General Mixing Procedures

Proportioning can be varied to accommodate mixing tank size. The general mixing procedure is:

- 1. Fill mixing tank with required amount of dilution water per the treatment design.
- Transfer EHC-Liquid Part 1 to mixing tank. Note that this material is preemulsified, has a viscosity of about 13 cPs and will require an appropriate pump for transfer from the drum. Alternatively, the concentrated emulsion may be transferred in pails by hand. A paddle mixer and/or recirculation pump is sufficient for mixing.
- 3. Add in EHC-Liquid dry mix Part 2 and continue mixing. Ensure no solids remain on bottom of tank.
- 4. If other additives are used (e.g., pH buffers), they may be added at this time.



5. Mixing time depends on equipment used (typically 10-15 min). Material is to be mixed until uniform.

Health and Safety

EHC-Liquid is completely non-hazardous and safe when handled properly in accordance with instructions for use, the advisory below and the MSDS. The EHC-Liquid MSDS is posted on our web site at:

Part 1:

http://www.peroxychem.com/markets/environment/soil-and-groundwater/products/ehc-liquid-amendment

When working with EHC-Liquid, the use of standard personal protective equipment, including safety glasses, steel toe boots, nitrile gloves, hearing protection (when Geoprobe is operated) and hard hat is recommended. Dust mask may be required when in close contact with the EHC-L powder component (Part 2) under certain conditions.



Field Implementation of a Novel Liquid Amendment Containing Lecithin and Ferrous Iron for Reductive Treatment of Chlorinated Hydrocarbons

Fayaz Lakhwala, Ph.D. Ravi Srirangam, Ph.D. Alan Seech, Ph.D., and Ian Ross, Ph.D.



AquaConSoil, April 15-19, 2013, Barcelona, Spain

Presentation Outline



- Reasons for developing a new liquid *in-situ* chemical reduction (ISCR) reagent
- Product composition
 - Soluble Carbon
 - Soluble Iron
- Laboratory evaluation
- Field applications
- Summary



Product Development



Objectives:

- 1) To create an ISCR product that is fully cold-water soluble and can be applied through well screens and in low permeability and deep formations.
- 2) To find a complex, relatively slow to ferment carbon source that also contains nutrients.
- To find a source of soluble iron that will remain in the ferrous state (Fe²⁺), not precipitate out during handling and injection
- 4) Promote formation of new/enhancement of existing reactive iron minerals





EHC-L Product Composition



- After evaluation of a number of soluble carbon and iron sources, a new liquid amendment composed of lecithin and ferrous iron was selected.
- EHC-L[®] = Liquid Emulsion + Powder Mix
- Liquid emulsion = 25% by wt. lecithin
- Powder Mix = Iron Salt + Amino Acids



EHC-L: The Carbon Component

Composition of Soy Lecithin (from Bailey's Guide 2005)

%		Lipophilic Hydrophilic					
20–22 21–23 18–20 4–8 –– 15 9–12		Fatty acid chains					
milar C:H:O ration	O:	Glycerol Polar ``backbone`` group					
e.g., E-a - Phosphalidylenoline ($C_{42}\Pi_{82}NO_8P$).							
	$ \frac{9}{20-22} \\ 21-23 \\ 18-20 \\ 4-8 \\ \\ 15 \\ 9-12 $ milar C:H:O ratione (C ₄₂ H ₈₂ NO ₈ P)	$\frac{\%}{20-22} \\ 21-23 \\ 18-20 \\ 4-8 \\ \\ 15 \\ 9-12$ milar C:H:O ratio: ne (C ₄₂ H ₈₂ NO ₈ P):					



EHC-L: The Carbon Component

Benefits of Lecithin



- High molecular weight results in slower consumption and extended life (2 to 3 years)
- Slower rate of consumption may also reduce incidences of high methane production.
- Charged nature of the molecule may enable retention of EHC-L in the reactive zone as opposed to "wash out" with groundwater flow.
- The two main components of lecithin (PE and PC) carry both positive and negative charges at the same time and can thus provide buffering of both acids and bases.
- Dissolved phosphorus, nitrogen and major nutrients are slowly released as the lecithin undergoes fermentation.



EHC-L: The Iron Component

- As dissolved iron moves down gradient it will be adsorbed on iron oxide mineral surfaces such as goethite:
 - adsorbed Fe⁺² is much more reactive than aqueous Fe⁺² (theories for how and why: Shoonen and Strongen, 2005; Weber, 2001)
 - Fe⁺² can convert (i.e., reduce) poorly reactive minerals to more highly reactive forms (e.g. ferrihydrite to green rust and magnetite; Usman et al., 2010) or hematite to magnetite (Matthews, 1976).
- These minerals can cycle between the ferrous and ferric forms, thereby serving as an iron redox cycle that works as long as other electrons from metabolizable carbon are available.
- A substantial reactive surface stimulating direct chemical abiotic dechlorination can be formed down gradient.



Environmental Solutions

EHC-L Column Data









EHC®-L: Applications



25% by wt. emulsion of Lecithin



Organic ferrous iron salt



Majority (90%) of droplets are <3 μ m, therefore are expected to easily pass through typical unconsolidated formations during injection (e.g., critical pore size for fine to coarse sand ranges from 12 to 120 μ m)



10X diluted in the field for injection



SITE #1: EHC[®]-L APPLICATION WITH BUFFER AND DHC IN UNCONSOLIDATED SOILS

• Objective of the pilot test was to accelerate the biotic and abiotic degradation of chlorinated volatile organic compounds (CVOC's) on a pilot scale.

• EHC-L ISCR amendment along with magnesium hydroxide buffer and DHC cultures were injected using Geoprobe.

• Nineteen (19) injection points targeted a vertical zone from 7-21' below grade (bgs).

• A total of 5,110 gallons of solution was injected containing 10,920 pounds of EHC-L (liquid component), 639 pounds of EHC-L (dry component), 3,670 pounds of magnesium hydroxide buffering agent and 24 liters of dehalococcoides (DHC) containing solution.





SITE #1: EHC®-L RESULTS





SITE #1: EHC[®]-L RESULTS- Contd..





Results and Future Scope of Work

- The injected amendments were successful at establishing reducing conditions conducive to chemical and biological reduction of cVOCs.
- 2) PCE and TCE concentrations were reduced to concentrations below the GWQS within 9 months following the pilot-scale treatment.
- 3) The quantity of magnesium hydroxide (alkaline buffer) injected during the pilot test resulted in high pH conditions restricting the proliferation of microbial community.
- 4) Byproducts of PCE and TCE dechlorination (VC and 1,2-DCE) remained above criteria.
- 5) Full-scale remedy will be designed to address shortcomings identified during the pilot test including:
 - proper pH dosing
 - sufficient inoculation of dechlorinating DHC microorganisms for VC and 1,2-DCE.

Environmental Solutions

SITE #2: INDUSTRIAL SITE EHC®-L APPLICATION WITHOUT BUFFER AND DHC IN UNCONSOLIDATED SOILS

- Pilot test objective was to demonstrate the efficacy of EHC-L to treat TCA and DCE contamination beneath the building and to reduce contaminant mass in the deeper saturated zone (20-25 ft bgs)
- The gravel-filled former source area excavation west of the building is used as a reservoir for ISCR amendments. Extraction wells installed east of the building are used to pull ISCR amendments under the building to promote treatment of TCA and DCE.
- Approximately 5,000 lbs of EHC[®] and 7,114 lbs of EHC-L[®] were injected into the gravel-backfilled former source area excavation along the west-side of the building.
- Ground water extraction was conducted at E-4, E-15, E-16, and TPW-2 wells following the injection of amendments.



SITE #2: EHC[®]-L APPLICATION WITHOUT BUFFER AND DHC IN UNCONSOLIDATED SOILS





SITE #2: EHC[®]-L RESULTS









Results and Future Scope of Work

- 1) The amendments and the delivery method successfully created anaerobic and reducing conditions downgradient of the injected area in wells along the west side of the building (D-16, E-16, DSW-27D, and DSW-59D).
- Data from six months of post-injection monitoring show greater than 50% reduction in concentrations of target CVOCs.
- 3) Sampling will continue on a quarterly basis till the end of 2013 followed by additional investigation/delineation of contamination under the building to identify multiple residual sources (if any).



EHC[®]-L Field Results



- To date, over 100 applications of EHC-L have been completed in Canada, the US and Europe.
- Reports from the field confirm the emulsion is easy to work with, completely cold water soluble with no precipitates forming, and negative redox is recorded in the mixing tank.
- Initial results look positive and we continue to collect data.



EHC®-L Summary



- EHC[®]-L is a liquid ISCR reagent composed of a slow-release carbon source (lecithin), a ferrous iron salt, and amino acids – all components are food-grade.
- The formulation is designed to enhance both microbially-mediated reductive dechlorination *and* abiotic dechlorination by formation of reactive reduced iron minerals.
- EHC[®]-L is easy to prepare for injection using equipment that is readily available and widely-used in the groundwater remediation industry.



Questions are Welcome!

For more information please contact:

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Tel: (908) 230-9567

Or visit our website: www.environmental.fmc.com







60% SRS[®]-SD Small Droplet Emulsified Vegetable Oil (EVO) Substrate for Maximum Radius of Influence United States Patent #RE40,448

The anaerobic bioremediation process uses native or introduced microorganisms (*Dehalococcoides*) to degrade chlorinated solvents such as tetrachloroethene (PCE) and trichloroethene (TCE) to innocuous end products including ethene and ethane. Terra Systems patented <u>SRS[®]-SD</u> Small Droplet Emulsified Vegetable Oil Substrate includes a <u>nonionic emulsifier</u> (does not have a charge), which does not readily stick to soil particles and is specifically designed when maximum radius of influence in the formation is key to making contact with the bacteria. It is is added to the groundwater to rapidly generate reducing conditions and provide the necessary carbon and hydrogen to support biodegradation of the chlorinated solvents.

Ingredient Percent **Description Benefit** Long lasting slow release source of carbon and Terra Systems operates Food Grade U.S. Grown hydrogen, consistent product quality, uniform 60% its own state-of-the-art droplet size, neutral pH, QA/QC lab on floor Soybean Oil manufacturing facility. to check product before shipment. Food Grade Sodium or Rapidly biodegradable Fast release source of carbon and hydrogen to 4% soluble substrate rapidly generate anaerobic conditions Potassium Lactate Proprietary organic and Nutrients have been demonstrated to support Proprietary Food Grade inorganic nutrients such <1% the growth of the anaerobic microbial Nutrients as yeast extract, nitrogen population. and phosphorus. Proprietary Food Grade Maximum radius of influence due to small Proprietary nonionic Emulsifiers and 7.5% droplet size and nonionic emulsifier in emulsifier Preservatives moderate to fine sand, silt and clay aquifers He et al. 2007 demonstrated Vitamin B_{12} to be At least 250 µg/L of an important micronutrient to enhance Vitamin B₁₂ <1% dechlorination activity with 25 µg/L providing Vitamin B_{12} maximum stimulation Maximum radius of influence due to small Median Oil Droplet Size NA 0.6 µm droplet size and nonionic emulsifier in (microns) moderate to fine sand, silt and clay aquifers 6.5 - 7 pН 6.5 - 7 Optimum microbial activity

Table I: SRS[®]-SD Small Droplet Emulsified Vegetable Oil Substrate Specifications

<u>Application</u>: Terra Systems **patented**, nutrient enriched, proven slow release SRS[®]-SD **small droplet** emulsified vegetable oil substrate with a **nonionic emulsifier** is used when a long lasting carbon substrate is desired that provides maximum radius of influence in moderate to fine sand, silt and clay aquifers, which increases the distance between injection points and reduces the frequency of reinjection. The groundwater flow-rate is typically less than 180 feet/year. SRS[®]-SD does not stick to soil particles and is specifically designed when radius of influence in the formation is key to making contact with the bacteria.

130 Hickman Road – Suite 1 – Claymont – Delaware – 19703 For More Information Call Michael Free at 302-798-9553 or Email: <u>mfree@terrasystems.net</u>



<u>Customers</u>: SRS[®]-SD is used extensively by consultants working with current and former drycleaners, semiconductor plants and private firms and the Air Force, DOD, Navy, and EPA to cost effectively remediate chlorinated solvent sites. SRS[®]-SD releases bio-available hydrogen over a period of 3 to 5 years thus enhancing the long-term anaerobic biodegradation of the chlorinated solvents and reducing the frequency of reinjection.

Manufactured vs. Field Emulsion

In the early days of in-situ bioremediation when Terra Systems first patented the technology, it was common to bring the water, emulsifiers, oil, and other ingredients to the site and using trash or other pumps to mix the ingredients together to form an emulsion. It soon became apparent that poor emulsion consistency and a broad range of droplet sizes resulted in inadequate and uneven distribution when injected. This resulted in higher long-term costs due to higher reinjection frequency and higher substrate volumes to adequately make contact with the COC.

Don't be "penny wise and pound foolish".

Consider:

- \checkmark The labor and equipment time and cost of mixing in the field.
- ✓ The need to mix the nutrients and Vitamin B_{12} longer to achieve consistency.
- ✓ The cost of inadequate distribution due to droplet size and emulsion inconsistency
- ✓ The inability to accurately determine if you have 100% emulsification.
- ✓ The lack of QA/QC in the field
- Terra Systems owns and operates a state of the art US based manufacturing plant with an in-house quality control laboratory for strict quality assurance of the emulsion, droplet size and pH.
- SRS[®]-SD arrives at the site "*injection ready*" with all the ingredients Vitamin B_{12} , proprietary nutrients, sodium or potassium lactate and anionic emulsifier(s) already blended together.
- At the PM's request Terra Systems will blend 2-8 g/L of sodium bicarbonate into the SRS[®]-SD during manufacturing to counter the acids produced during the fermentation process in the aquifer. This is especially beneficial for marginal pH aquifers of pH 5 6.



A Digital Microscope is connected to a laptop computer with proprietary *"Droplet Size Calculation Software"* which allows us to calculate the *"mean"* droplet size for each batch of SRS[®]-SD before transferring to a bucket, drum, tote or tanker for shipment to the customer

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- SRS[®]-SD optimizes the naturally occurring biodegradation system by supplying the rate limiting factor (in this case hydrogen) in the degradation of CVOC's, certain pesticides/herbicides, perchlorate, and immobilization of certain metals (hexavalent chromium, molybdenum, selenium, and some radionucleides).
- The small droplet size of $0.6 \mu m$ combined with the neutral surface charge on the droplets results in a higher radius of influence in the subsurface.
- Terra Systems holds United States Patent **#RE40,448** for the use of emulsified vegetable oil for remediation of chlorinated solvents.
- The soy bean oil is grown in the United States and provides a **slow release** biodegradable carbon source, which promotes long-term biological activity.
- SRS[®]-SD comes **standard** with **biostimulating vitamins** like Vitamin B_{12} , which He et al. 2007 demonstrated is an important micronutrient to enhance dechlorination activity.
- SRS[®]-SD contains proprietary organic and inorganic nutrients such as yeast extract, nitrogen and phosphorus, which have been demonstrated to support the growth of the anaerobic microbial population.
- SRS[®]-SD comes with **at least 4% sodium** or **potassium lactate** a quick release biodegradable substrate, which helps to "*jump start*" bacterial growth.
- SRS[®]-SD emulsified vegetable oil substrate has been validated by the Florida DEP, California Water Board and others.
- SRS[®]-SD contains only non-toxic food grade materials, which results in green, sustainable remediation.

<u>**Packaging</u>**: Terra Systems patented SRS[®]-SD can be shipped in 5-gallon buckets, 55-gallon drums, 275-gallon IBC totes, 275-gallon cardboard totes or bulk tankers.</u>



If the *Dehalococcoides* are not present or are in small numbers Terra Systems <u>**TSI DC**</u>[®] Bioaugmentation Culture can also be injected.



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APPENDIX B

Well Completion Logs



ARCADIS

Well Construction Log (Unconsolidated)

□ ↑ft	Project Former Cleanerama Well 1W-1
LAND SURFACE Sond	Town/City Loudonville
	County Albany State NY
inch diameter	Permit No.
drilled hole	Land-Surface Elevation and Datum:
	feet Surveyed
Well casing,	. Estimated
inch diameter,	Installation Date(s) 8/30/16
PYC	Drilling Method HSA/SS
Backfill	
Grout <u>Nega</u>	Drilling Contractor Paratt-Wolff
Cement	Drilling Fluid None
21 ft*	
	Development Technique(s) and Date(s)
Bentonito	
23 ft* pellets	Mini-monsoon (8/31/16)
	Bailing (s/3/11)
2.5_ft*	Fluid Loss During Drilling gallons
	Water Removed During Development gallons
	Static Depth to Waterfeet below M.P.
inch diameter	Pumping Depth to Waterfeet below M.P.
Steel	Pumping Duration hours
	Yield gpm Date
	Specific Capacity gpm/ft
	Jr
Formation Collaspse	Well Purpose injection wells
<u>35_</u> ft*	
35 ft*	Remarks
Measuring Point is	
Unless Otherwise Noted.	
* Depth Below Land Surface	
	Prepared by B: WUGGlier

~

ARCADIS

Well Construction Log

(Unconsolidated)	
(Unconsolidated)	Project Former Cleanerano Well $10-2$ Town/City Loudonville County Albany State NY Permit No. Land-Surface Elevation and Datum: feet Surveyed Estimated Installation Date(s) $8/31/16$ Drilling Method HSA/SS Drilling Contractor Parcatt-Wolffe
<u>I</u> ft* Since Sand Bentoniteslurry <u>2</u> ft*pellets <u>3</u> ft* Well Screen. wine wrapped <u>2</u> inch diameter <u>stainless</u> , <u>20</u> slot <u>steel</u>	Drilling Fluid NO NL Development Technique(s) and Date(s) Development Technique(s) and Date(s) Fluid Loss During Drilling gallons Water Removed During Development gallons Static Depth to Water Pumping Depth to Water feet below M.P. Pumping Duration Yield
Gravel Pack Gravel Pack Sand Pack Formation Collaspse (3_ft*)3_ft* Measuring Point is Top of Well Casing Unless Otherwise Noted. * Depth Below Land Surface	Specific Capacitygpm/ft Well Purpose injection well Remarks Prepared by B.QVaglieri

APPENDIX C

Lithologic Logs





Boring/Well	1w-1		Project/N	0.00266	438.0000 Page of 4			
Site				,	Drilling 1015 Drilling 1330			
Location	Form	rer C	leaner	rama (1	#401056 Started 8/30/16 Completed 8/30 116			
Total Depth I	Drilled	B	Feet	Hole Diamete	er <u>6</u> inches Coring Device <u>HSA Split Specon</u>			
Length and D of Coring De	Diameter vice	5'2	×6'		Sampling Interval feet			
Land-Surface	e Elev.		feet		Surveyed Estimated Datum			
Drilling Fluid	Used	Non	2		Drilling Method			
Drilling Contractor	Parro	H-wa	olff		Driller price Helper J. Ray Scher			
Prepared By	B.O.	aalie	eri		Hammer Hammer Weight Drop ins.			
Comple/Comp D		\mathcal{O}		Time // Ladam Via	그는 것 같아요. 이렇게 잘 잘 하는 것 같아요. 이렇게 하는 것 같아요. 이렇게 하는 것 같아요.			
(feet below land	d surface)	Core	PID	Pressure or				
		Recovery	Reading	Blows per 6				
From	To	(feet)	(ppm)	Inches	Sample/Core Description			
0	5	-	-	~	Asphalt + Gravelly Sand, hand cleared			
5	7'	0.1	0.0	-	Light brown medium to fine SAND, Sub-angular.			
"	Sh				Prv.			
7'	9'	08	0.0	-	7-7.6 Dark Brown medium to fire SAND.			
					Sub-angular, Dry,			
					7.6-8.6' Brown medium to fine SAND. Sub-angular Dry.			
					8.6-9.0' Light brown, medium to fine SAND.			
					Sub-angular. Moist.			
q,	11'	0.9	0.0	-	9-9.5' Brown medium SAND, Sub-angular,			
					Molst.			
					9.5-11 Light brown medium to fine SAND,			
					with some parting seams of red-brown sand.			
					Subanquiar. Dry.			
11,	13	1.6	0.0	-	11-11.7' Red-brown medium SAND. with			
					Some iron-precip. Sub-angular, Moist.			
					11.7-12.6' Brown coarse to medium SAND			
					Sub-angular, Moist.			
					12.6-13 Light Braun Course to medium			
	SAND. Subrangular. Moist.							
13'	15	1.6	0.0	-	13-142' - Light Brown medium to fine SAND.			

ARCADIS					
Sample	e/Core L	.og	(Cont.d)	

Boring/Well

Prepared by

Log (Cont.d) <u>IW-1</u> <u>B.Quaglieri</u>

Page <u>2</u> of <u>4</u>

Recovery Reading Blows per 6 From To (feet) (ppm) Inches Sample/Core Description	
13' 15' 16 0.0 - Sub-angular, Moist	
14,2-15 - Light Brown medium to find	
SAND with Some Parting Ison of	1
red-brown Sand, Sub-angular Ma	s1
15' 17' 1.7 0.0 - 15-15.4' Red-boom / light bour an	dium to
Fine SAND, trace pieces of	ulos
Sub-angular, Moist,	iu ue si
15:4-15:9' Light brown coarse to fi	20
SAND, Sub-angular, Maist,	2
15.9-16.3' Light Braun course SAN	D.
Sub-angular, Moist.	
16.3-16.7: Light brown coarse to me	dium
SAND. Sub-angular. Moist.	
16.7'-17' Brown course to fine SA	MD.
sub-angular, Moist,	
17' 19' 1.8 0.0 - 17-17.6' Brown coarse to Fire SAM	D.
Sub-angular, Moist,	
17.6-18.5' Light Brown course to	-
medium SAND. Sub-angular, Moist.	
18:5-19' Brown coarse to medium	
SAND. Sub-angular Moist.	
19' 21' 1.1 0.0 - 19-19.4' Light Gray coarse to mediu	n
SAND. Sub-angular. Moist.	
19.4-21' Light brown. Coarse to fin	re
SAND. Sub-angular. Moist.	
21' 23' 1.1 0.0 - 21-22.2' Braun coarse to fine SA	ND.
Sub-angular. Moist.	
22.2-23 Light brawn course to	fino


Boring/Well

Prepared by

B. Quadien

10-1

Page 3_ of 4

Frepared	by	B.QI	Jagne	0	
Sample/Cor (feet below	e Depth and surface)	Core Recovery	PID Reading	Time/Hydrauli Pressure or Blows per 6	
21'	22	(ieet)		Inches	Sample/Core Description
221	26	18	0.0		SAND Jub angular, Noist.
20	125	1.0	0.0		23-23.4 Light brown coarse to fine
and the second					SAND with Some Parting Seams in
					red-brown. Sub-angular, Moist.
					23.4-24.1 Brown coarse to fine SAND.
					with Sub-angular, Moist.
					24.1-24.3' Light brown medium to fine
					SAND, Sub-angular, Moist.
					24.3-25' Brown medium to fine SAND.
					Sub-angular, Maist,
25'	27'	1.2	0.0		25-25,3" Brown medium to fine SAND.
	<u> </u>				Subappular, Moist.
					25.3-26.6' Dark Brown Very Coarse to
					coarse SAND, Sub-anaular high schonicity
			1.1		Moist.
					26,6-27 Light Brawn Ven coarse to
					medium SAND Sub-angular Haish
27'	29'	1.4	0.0	-	27-27.2' Dad Brannyers (corse to
					COARSE SAND, SUB- analyce, Maist
					27.2-28.0-1 icht Brown 100-11 00000 to
					medium SAND, Subappulars Maish
					29 0 29 0 Bould Dark har is
					(mange to very fine SAND a inter
					Moich Moich
29'	31	1.2	0.0		29-29 2 ¹ Rol Rock and 1
			010		SAMA Subra la la la la
					Shive, Soprangular Moist.
					24.2-27.6 brown medium to fine

SA

ND Sub-angular, Very moist.

	ADIS	
Sample/Core	Log	(Cont.d)

Boring/Well

Prepared by

IW-1 B.Quaglieri

Page 4_ of 4_

.

Sample/Cor	e Depth	0		Time/Hydraulio	
(reet below i	and surface)	Core	PID	Pressure or	
From	То	(feet)	(ppm)	Inches	Sample/Core Description
29'	31'	1.2	0.0	-	29,6-30,4' Brown medium to fine
	_				SAND, Sub-angular, wet.
	_				30,4-31' Brown coarse to fine
					SAND with trace granules. Sub-
0					angular, wet.
31	33	1.0	0.0	-	31-332 Brown medium to fine SAND,
					sub-angular, wet,
					32-33' Light brain Coarse to medium
		6			SAND, Sub-angular, Wet.
33	35'	2.0	0.0		33-33.6' Brown redium to fine SAND,
					Sub-angular. Wet.
					33.6'-34.1' Braun coarse to fine
					SAND, Sub-anoplar, Wet,
					34.1-34.6' Dark Brown coarse to fine
					SAND, Sub-angular, Wet-
	+				34.1-34.9' Brown medium tofine SANP,
					Sub-angular, wet,
					34.9-35 Gray fine to very fine SAND
					with some weathered shale, sub-
					rounded. Wet.

Field Forms-Environmental.xls.xls Boring Log



Boring/Well 1U)-2	Project/N	No. 00266	0436.0000	1	Page of 2
Site		780.67			Drilling o	705 Drilling 0758
Location Lo	u donville	=, NY			Started	131116 Completed 8/31/16
Total Depth Drilled	13	Feet	Hole Diamete	er _ 6	inches	Type of Sample/ Coring Device HSA JSS
Length and Diame of Coring Device	ter <u>s</u> 'x	6"				Sampling Interval 2 feet
Land-Surface Elev		feet		Surveyed	Estimated	 Datum
Drilling Fluid Used	No	ne				Drilling Method HSA
Drilling Contractor	Parratt	-wol-	ff			J. PriceHelper J. Raucher
Prepared By	Quaglie	eni				Hammer Hammer Weight Drop ins.
Sample/Core Depth (feet below land surface	ce) Core Recovery (feet)	PID Reading	Time/Hydraulic Pressure or Blows per 6	Sample/Core Dec	intion	
0 5				Sample/Core Desc	mpuon	
				Hand cu	0160, 10	rowniked Braun SAIND
31 5	0.9	0.0		2-22' Q	anic ma	terial (wood, roots, etc).
				Subanaul	own m	edium to time stive.
				3.3-4.5	A W R	and madium to find SAMO
		1		Sibanaul	DOLL MON	et
				4.2-4.75	Brown	medium to fine SAND
				sub angula	v . Mai	St.
				4.7-5. B	rown f	ine to very fine SAND
				with som	e Silt.	Moist.
5'7	. 1.0	0.0	-	5-5.4'Br	own mee	live to very fine SAND
				with Some	silt.r	voi st.
				5.4-6.0 1	Brown	redium to fine SAND.
				Sub-ana	ular. M	ioîst.
				6.0-6.67	brown f	ine to very fine SAND
				with Son	re Sil.	t. Moi st.
				6.6-73	rown S	SILTY SAND traces it.
				Low pla	Sticity	Moist.
7' 4	1.7	0.0	-	7-7.3'Bro	un 5147	VSAND trace sand.
				Low pla	sticity.	Moist.



Boring/Well

en ig i to

10-2

Prepared by

B. Quaglieri

Sample/Core Depth			Time/Hydrauli	lic				
(feet below land surface)		Core	PID	Pressure or				
From	То	Recovery (feet)	Reading (ppm)	Blows per 6 Inches	Sample/Core Description			
ד'	9'	1.7	0.0		7.3-7.9 Brown medium to fine SAMO			
					Sub-angular. Moist.			
					7.9-8.2 park brown coarse to fine			
					SAND. Subrangular, Maist			
					8.2-8.8' Red Brown Coarse to			
					medium Sam SAND. Sub-angular.			
					Moist.			
					5.8'-9.0' Park Brown Black very			
					coarse-tomedium se SAND, Sub-angular			
01		+			Moist			
9.	11	1.0	0.0		9-9.4' Brown medium to fine SAND.			
					Sub-angular. Moist.			
					9,4-9.9' Light brown medium to fine			
					SAND, with trace weathered shale,			
					Sub angular. Moist.			
					9.9-11 Brown SILTY SAND trace			
					sand trace weathered shale. Low			
	101		0.0		plasticity, Wet.			
11	13	1.0	0.0		11-12.6 Brown medium to very fine			
					SAND with trace silt. trace weathered			
					shale. low pasticity, wet.			
					12.6-13 weathered shale.			
					Returnal at 13'.			

Page 2 of 2

APPENDIX D

Laboratory Analytical Reports



APPENDIX E

Injection Field Logs



Table E-1 EHC-L Pilot Test Area - IW-1 Injection Log Former Cleanarama (Site #401056) Loudonville, Albany County, New York



Date	Time	Wellhead Pressure/Vacuu m	Totalizer Volume (gallons)	Flowrate (gpm)	Cumulative Injection Volume	Notes:
		(psi)			(gallons)	
12/8/2016	10:15	1.5	70484.2	5.0	0.0	Start pressurized injection.
12/8/2016	11:42	0.5	70784.7	6.0	300.5	Start pressurized injection.
12/8/2016	12:45	0.5	71051.8	5.9	567.6	
12/8/2016	13:17	0.5	71242.1	5.8	757.9	
12/8/2016	14:02	0.5	71475.9	4.9	991.7	
12/8/2016	14:50	0.5	71739.9	4.0	1255.7	
12/8/2016	15:34	0.5	71958.2	5.3	1474.0	
12/8/2016	16:27		72285.6		1801.4	Stop pressurized injection.
12/9/2016	8:59	0.5	72404.4	6.0	1920.2	Begin pressurized injection.
12/9/2016	9:30	0	72598.6	7.1	2114.4	
12/9/2016	9:43	0	72673.1	6.0	2188.9	
12/9/2016	10:22	0	72889.0	5.0	2404.8	
12/9/2016	10:56	-1	72971.2		2487.0	
12/9/2016	11:07	-0.5	72989.8	4.5	2505.6	
12/9/2016	12:00	-0.25	73180.7	3.8	2696.5	End injection.

Notes:

psi = pounds per square inch gpm = gallons per minute

Table E-2 EHC-L Pilot Test Area - MW-8 Depth to Water Log Former Cleanarama (Site #401056) Loudonville, Albany County, New York



Dete	Time	Depth to Water (ft btoc)		
Date	Time	MW-8		
12/8/2016	7:45	29.75		
12/8/2016	11:42	29.26		
12/8/2016	12:45	29.77		
12/8/2016	13:17	29.02		
12/8/2016	14:02	28.92		
12/8/2016	14:50	28.85		
12/8/2016	15:34	28.80		
12/8/2016	16:27	28.80		
12/9/2016	7:15	29.60		
12/9/2016	9:43	28.87		
12/9/2016	10:22	28.61		
12/9/2016	10:56	28.30		
12/9/2016	12:00	27.86		

Notes:

ft btoc = feet below top of casing

Table E-3 EHC-L Pilot Test Area - MW-8 Dose Response Monitoring Log Former Cleanarama (Site #401056) Loudonville, Albany County, New York



Date	Time	Cumulative Injection Volume (gallons)	Temperature (°C)	pH (SU)	Specific Conductivity (mS/cm)	Turbidity (NTU)	TOC (mg/L)	Sample Name
12/8/2016	8:00	0	8.30	7.88	2.614	30.1		MW-8_20161208_0800
12/8/2016	11:12		12.50	7.52	2.454	3485		
12/8/2016	12:45	568	12.30	7.44	2.214	56.8	40.9	MW-8_20161208_1245
12/8/2016	13:17	758	12.10	7.32	1.850	1481	248	MW-8_20161208_1317
12/8/2016	14:02	992	11.80	7.06	1.642	OR	659	MW-8_20161208_1402
12/8/2016	14:50	1,256	10.80	6.30	17.310	OR		MW-8_20161208_1450
12/8/2016	15:34	1,474	10.20	5.96	1.734	OR	4230	MW-8_20161208_1534
12/8/2016	16:27	1,801	10.40	6.33	1.965	OR		MW-8_20161208_1627
12/9/2016	8:00	1,801	3.35	5.05	0.058	23.4	3300	MW-8_20161209_0800
12/9/2016	9:43	2,189	10.06	6.37	1.471	1150	2710	MW-8_20161209_0943
12/9/2016	10:22	2,405	9.69	6.44	1.590	1146.7	3980	MW-8_20161209_1022
12/9/2016	12:10	2,697	9.29	6.18	1.034	1142.8	6530	MW-8_20161209_1200

Notes:

* = injection volume calculated by interpolation

°C = degrees Celsius

mS/cm = milliSiemens per centimeter

NTU = Nephelometric Turbidity Units

OR = out of range

mg/L = milligrams per liter

SU = Standard Units

TOC = Total Organic Carbon

Table E-4EHC-L Pilot Test Area - Injection Solution Monitoring LogFormer Cleanarama (Site #401056)Loudonville, Albany County, New York



Date	Time	Cumulative Injection Volume (gallons)	Temperature (°C)	pH (SU)	Specific Conductivity (mS/cm)	Turbidity (NTU)	lron (mg/L)	Sample Name
12/8/2016	14:07	992	7.00	6.25	1.998	OR	268	EHC-L-IS-1
12/8/2016	14:50	1,256	6.80	6.84	1.107	OR	227	EHC-L-IS-2
12/8/2016	16:27	1,801	6.60	5.97	1.200	OR	273	EHC-L-IS-3
12/9/2016	7:30	1,801	1.33	5.43	3.188			
12/9/2016	10:22	2,405	5.86	5.87	1.052	1116.1	308	EHC-L-IS-4

Notes:

* = injection volume calculated by interpolation

°C = degrees Celsius

mS/cm = milliSiemens

NTU = Nephelometric Turbidity Units

OR = out of range

mg/L = milligrams per liter

SU = Standard Units

TOC = Total Organic Carbon

Table E-5 EVO Pilot Test Area - IW-2 Injection Field Log Former Cleanarama (Site #401056) Loudonville, Albany County, New York



Date	Time	Wellhead Pressure (psi)	Totalizer Volume (gallons)	Flowrate (gpm)	Cumulative Injection Volume (gallons)	Notes:
12/12/2016	12:40	0.5	73342.0	0.5	0	Begin pressurized injection
12/12/2016	13:40	0	73398.8	0.9	56.8	Injection solution daylighting from IW-2
12/12/2016	15:35	0	73446.0	0.5	104	Reduced pressure and daylighting stopped.
12/12/2016	16:10	0	73169.1	0.5	127.1	Stop pumping, begin gravity injection overnight.
12/13/2016	9:00	0		0.5	460	Overnight Volume: 330 gallons
12/13/2016	11:15	0		0.5	510	
12/13/2016	13:30	0		0.3	565	
12/13/2016	16:15	0		0.3	622	
12/14/2016	8:30	0		0.3	922	Overnight Volume: 300 gallons
12/14/2016	10:30	0		0.3	947	
12/14/2016	12:30	0		0.3	992	
12/14/2016	14:30	0		0.3	1020	
12/14/2016	16:00	0		0.3	1142	
12/15/2016	7:00	0		0.3	1442	
12/15/2016	9:10	0		0.3	1482	
12/15/2016	12:30	0		0.3	1530	
12/15/2016	13:40	0		0.3	1540	
12/15/2016	15:45	0		0.3	1580	
12/16/2016	6:30	0		0.3	1780	Overnight Volume: 200 gallons
12/16/2016	12:30	0		0.3	1880	
12/16/2016	15:00	0		0.3	1930	End injection.

Notes:

psi = pounds per square inch gpm = gallons per minute EVO = emulsified vegetable oil -- = not collected

Table E-6EVO Pilot Test Area - Depth to Water LogFormer Cleanarama (Site #401056)Loudonville, Albany County, New York



Dete	Time	Depth to Water (ft btoc)						
Date	Time	0S-1	0S-8	0S-10				
12/12/2016	12:20	9.58	5.81	9.26				
12/12/2016	16:47	9.47	5.76	9.79				
12/13/2016	7:30	9.42	5.82	9.95				
12/13/2016	16:00	9.37	5.81	9.99				
12/14/2016	7:30	9.40	5.84	9.93				
12/14/2016	9:30	9.39						
12/14/2016	11:30	9.38						
12/14/2016	13:30	9.39	5.85	9.94				
12/14/2016	15:30	9.39						
12/14/2016	16:30	9.38	5.85	9.95				
12/15/2016	8:00	9.39	5.83	9.95				
12/15/2016	10:00	9.39						
12/15/2016	13:30	9.38	5.84	9.94				
12/15/2016	15:30	9.38	5.84	9.94				
12/16/2016	8:00	9.38	5.84	9.95				
12/16/2016	12:00	9.39	5.84	9.95				
12/16/2016	15:00	9.39	5.85	9.94				

Notes:

ft btoc = feet below top of casing EVO = emulsified vegetable oil -- = not collected

Table E-7 EVO Pilot Test Area - MW-8 Dose Response Monitoring Log Former Cleanarama (Site #401056) Loudonville, Albany County, New York



(gallons) (indication)	
12/12/2016 12:15 0 11.28 6.27 1.209 75.4 3.6 OS-1_20161212_1	215
12/13/2016 7:30 440 9.22 6.74 1.227 550.2 203 OS-1_20161213_C)730
12/13/2016 13:00 560 6.38 7.07 0.673 1114.3	
12/13/2016 16:00 622 10.25 6.88 1.087 1153.8 792 OS-1-20161213_1/	600
12/14/2016 7:40 922 9.17 7.14 0.942 1119.4	
12/14/2016 15:30 1140 9.34 7.07 1.039 1741.9	
12/15/2016 8:20 1450 9.24 7.11 1.054 OR 568 OS-1_20161215_C)820
12/16/2016 7:30 1790 9.19 7.24 1.279 OR 85 OS-1_20161216_C)730
12/16/2016 12:00 1890 9.27 7.28 1.268 OR	
12/16/2016 15:20 1930 9.11 7.20 1.304 OR 1460 OS-1_20161216_1	510

Notes:

* = injection volume calculated by interpolation

°C = degrees Celsius

mS/cm = milliSiemens per centimeter

NTU = Nephelometric Turbidity Units

OR = out of range

mg/L = milligrams per liter

EVO = emulsified vegetable oil

SU = Standard Units

TOC = Total Organic Carbon

Table E-8 EVO Pilot Test Area - Injection Solution Monitoring Log Former Cleanarama (Site #401056) Loudonville, Albany County, New York



Date	Time	Cumulative Injection Volume (gallons)	Temperature (°C)	рН (SU)	Specific Conductivity (mS/cm)	Turbidity (NTU)	TOC (mg/L)	lron (mg/L)	Sample Name
12/13/2016	8:00	450	5.36	7.07	0.672	1111.1			
12/13/2016	9:00	460	5.59	7.06	0.672	1109.2		0.12	EVO-IS-1
12/14/2016	8:30	940*	4.24	7.21	0.753	1121.4		0.15	EVO-IS-2
12/15/2016	8:30	1450*	4.09	7.24	0.794	OR	6720	3.3	EVO-IS-3
12/16/2016	8:00	1800*	3.50	7.26	0.825	OR			

Notes:

* = injection volume calculated by interpolation

°C = degrees Celsius

mS/cm = milliSiemens per centimeter

NTU = Nephelometric Turbidity Units

mg/L = milligrams per liter

EVO = emulsified vegetable oil

SU = Standard Units

TOC = Total Organic Carbon

APPENDIX F

Molar Concentrations





Appendix F Molar Concentrations Former Cleanarama (Site #401056) Loudonville, Albany County, New York

Constituent	Units	IW-1	IW-1	IW-1	IW-1	MW-8	MW-8	MW-8	MW-8
Constituent		9/20/2016	1/30/2017	3/22/2017	6/9/2017	9/20/2016	1/30/2017	3/22/2017	6/9/2017
PCE		140	46	38	1.4	140	150	14	75
TCE		5.9	4.1	9.3	4.0 U	6.2	11	2.4	5.5
cisDCE	µg/∟	4.0 U	1.2	110.0	130.0	4.0 U	5.3	130.0	85.0
VC		4.0 U	1.0 U	4.0 U	4.0 U	4.0 U	1.0 U	4.0 U	4.0 U
PCE		0.8442	0.2774	0.2292	0.0084	0.8442	0.9045	0.0844	0.4523
TCE		0.0449	0.0312	0.0708	0.0304	0.0472	0.0837	0.0183	0.0419
cisDCE		0.0413	0.0124	1.1347	1.3411	0.0413	0.0547	1.3411	0.8768
VC		0.0640	0.0160	0.0640	0.0640	0.0640	0.0160	0.0640	0.0640
Total Molarity	µmol/L	0.9944	0.3370	1.4987	1.4439	0.9967	1.0589	1.5078	1.4350

Constituent	Units	IW-2	IW-2	IW-2	IW-2	OS-1	OS-1	OS-1	OS-1
Constituent		9/22/2016	1/25/2017	3/23/2017	6/7/2017	9/22/2016	1/25/2017	3/23/2017	6/7/2017
PCE		25	23	6.5	4.4	150	240	490	380
TCE		0.88	0.63	1.0 U	1.0 U	5.7	7.5	11	9.4
cisDCE	µg/∟	1.6	1.8	1.0 U	4.9	4.0 U	4.0 U	4.0 U	4.0 U
VC		1.0 U	1.0 U	1.0 U	1.0 U	4.0 U	4.0 U	4.0 U	4.0 U
PCE		0.1508	0.1387	0.0392	0.0265	0.9045	1.4473	2.9548	2.2915
TCE	umol/l	0.0067	0.0048	0.0076	0.0076	0.0434	0.0571	0.0837	0.0715
cisDCE	μποι/L	0.0165	0.0186	0.0103	0.0505	0.0413	0.0413	0.0413	0.0413
VC		0.0160	0.0160	0.0160	0.0160	0.0640	0.0640	0.0640	0.0640
Total Molarity	µmol/L	0.1900	0.1781	0.0731	0.1007	1.0532	1.6096	3.1438	2.4683

Notes:

 $\begin{array}{l} PCE = tetrachloroethene \\ TCE = trichloroethene \\ cisDCE = cis-1,2-dichloroethene \\ VC = vinyl chloride \\ \mu g/L = micrograms per liter \\ \mu mol/L = micromoles per liter \\ U = constituent not detected above method detection limit \end{array}$



Figure F-1

Molar Concentrations – EHC-L Test Area

Former Cleanarama (Site #401056) Loudonville, Albany County, New York



MW-8





Figure F-2

Molar Concentrations – EVO Test Area

Former Cleanarama (Site #401056) Loudonville, Albany County, New York









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