FINAL
Feasibility Study Report for JCI Jones Chemicals, Inc. Facility, Caledonia, New York
Administrative Order on Consent, Index No. II, CERCLA 10210

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1.0 INTRODUCTION

This Feasibility Study (FS) report is completed for the JCI Jones Chemicals, Inc., (Jones) Caledonia, New York site ("the Site") as required by the Administrative Order on Consent, Index No. II, under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) 10210 ("the Order"), Section VII (Work To Be Performed), Paragraph 23H, Task IX: Draft Feasibility Study Report. Jones and the U.S. Environmental Protection Agency (U.S. EPA) entered into the Order on March 26, 1991.

The purpose of this FS is to identify and evaluate remedial alternatives to address affected soil and groundwater at the Site. The FS relied on the data presented in the Remedial Investigation (RI; LFR 1999b) and the Health Risk Assessment (HRA; LFR 1999a) Reports conducted at the Site by LFR. The U.S. EPA approved the RI and HRA reports on April 27, 1999 and August 20, 1999, respectively.

1.1 Feasibility Study Scope and Organization

The FS, as required by the Order, develops and evaluates remedial alternatives as the primary basis for the U.S. EPA's selection of a remedy for the Site. The FS is consistent with the requirements of the National Contingency Plan (NCP) and Guidance for Conducting Remedial Investigations and Feasibility Indices Under CERCLA (U.S. EPA 1988a).

Potential technologies that could be incorporated into FS remedial alternatives were screened, and included the following:

Soil Medium	Groundwater Medium
No Action	No Further Action
Capping	Pump and Treat/Hydraulic Containment
Excavation (off-site disposal)	Dual-Phase Extraction
Excavation (on-site disposal)	Co-solvent Flushing
Soil Vapor Extraction	In-situ Oxidation
Dual-Phase Extraction	Air Sparging
Institutional Controls	HRC®/ ORC® Injection
	Potassium Permanganate Injection
	Institutional Controls

The above list of technologies considered:

- the results of the RI and HRA;
- ability to contain and/or reduce contaminant mass;
- minimization of further downgradient migration of affected groundwater;
- the fact that an air stripper was already in operation at the Site, and could be used in the future treatment of groundwater; and
- the complexities of groundwater restoration due to the potential presence of dense nonaqueous phase liquid (DNAPL).

1.2 Site Background

JCI Jones Chemicals, Inc., is located east of State Route 5 and on the northern side of Iroquois Road in Caledonia, northwestern Livingston County, New York (Figure 1). The Site is centered on latitude 42°58'40.9"N and longitude 77°50'49.1"W and is situated in a relatively flat, sparsely populated, lightly industrialized suburban area of the Village of Caledonia. The Site is bordered by Iroquois Road to the south, farmlands to the north, and homes with acreage to the east and west. A construction company (formerly a lumberyard) and a printing company are located immediately northwest of the Site. A golf course, baseball field, and tennis court are present immediately south of Iroquois Road (Figure 2). The site vicinity to the west and southwest is populated with light service industries such as hardware stores, gasoline stations, dry cleaners, restaurants, and other commercial businesses. Potable water to the Site and its vicinity is supplied through Village of Caledonia production wells located to the south.

1.2.1 Present Operations

The Site has nine buildings that comprise office space, drum storage sheds, interconnected warehouse buildings, a bleach manufacturing building, and chlorine and sulfur dioxide repackaging building (Figure 2). A railway line known as the Main Service Railway enters from the west, extends to within the eastern boundary, and runs to the north of the buildings.

Much of the Site is flat, and areas around the buildings are paved with asphalt. A large area south of the buildings, facing Iroquois Road, is landscaped with a maintained lawn. The area north of the buildings is also known as the "north property." The east portion of the north property is covered by gravel, the west portion by grass. The drum storage sheds, called the "pole barns," which were originally located west of the warehouse/office complex, were moved north of the three unlined ponds (lagoons A, B, and C) in 1994 (Figure 2).

Commercial activities at the Site presently include:

- manufacture of sodium hypochlorite (bleach) through the reaction of chlorine and dilute sodium hydroxide

- manufacture of sodium bisulfite through the reaction of dilute sodium hydroxide and sulfur dioxide
- repackaging and distribution of chlorine, sulfur dioxide, sodium hydroxide, and various minerals acids, such as muriatic acid and hydrofluosilicic acid, from bulk to small containers
- distribution of various inorganic water treatment chemicals such as soda ash and lime

The raw materials that are used in the production and distribution processes are stored in large aboveground storage tanks (ASTs) on site. These tanks range in size from 1,000 gallons to 16,300 gallons and have typically been constructed of stainless steel, fiberglass-reinforced plastic, cross-linked polyolefin, or other suitable synthetic material.

The non-contact cooling water for the plant was originally supplied through three on-site production wells, the West Well, the Middle (South Well), and the East Well. The West and East Wells are completed in the upper portions of bedrock zone; the Middle Well is reportedly screened at the base of overburden zone overlying the bedrock zone. The West, East, and Middle Wells were reported to be 45.3, 55.5, and 42.1 feet deep, respectively (CRA 1984). In response to increasing water capacity requirements, the North Well was installed in March 1985 immediately south of the lagoons (Figure 2). The North Well is 4 feet in diameter and 24 feet below ground surface (bgs), and is completed in the overburden glacial outwash sediment. Groundwater from the North Well is extracted at 300 to 400 gallons per minute (gpm). Because of their poor yields, groundwater withdrawal from the East and Middle Wells was discontinued. At the present time, groundwater usage is served entirely by the North and West Wells. The groundwater extraction rate from the West Well; however, is comparatively lower at 15 gpm. The on-site production wells are reported to pump continuously with periodic shut downs for maintenance (Gaffney 1999).

The principal waste stream from the plant has been wastewater from tank washings, floor washings, and other waste liquids from handling and packaging. This waste stream is first treated by the on-site elementary neutralization system (ENS) through the addition of sulfur dioxide or caustic soda. The wastewater is then mixed in an approximately 1-to-99 ratio with non-contact cooling water (one part wastewater to 99 parts non-contact cooling water). This mixture is discharged to the lagoon system, in accordance with the New York State Pollutant Discharge Elimination System (SPDES), Permit No. NY0072079. The lagoon system has been in operation at least since 1954. Currently, the discharge water to the lagoon is monitored on a continuous basis for total flow; on a weekly basis for pH; and on a monthly basis for volatile organic compounds (VOCs), iron, chloride, sulfate, and total dissolved solids. Other waste material includes off-specification or contaminated products. These wastes are containerized in drums for off-site disposal.

A sludge that forms in the lagoons is excavated periodically. Available records indicate that the sludge has been excavated from the lagoons at least three times. The excavated sludge from the first two excavation events was spread on the ground in the vicinity of the lagoons, while the sludge from the third excavation event was disposed of in a municipal landfill. The sludge samples were analyzed in accordance with Resource Conservation and Recovery Act (RCRA) extraction procedure (EP) toxicity testing protocols and were determined to be non-hazardous (CRA 1993).

1.2.2 Past Operations

The operational history of the Site has been summarized from information present in the RI (LFR 1999b).

Jones purchased the property on which the Site is located in August 1939. Prior to the Jones purchase, the Site included an orchard, agricultural fields, and pasturelands. Reportedly, the property had been used as a food packaging facility prior to purchase.

Soon after the purchase of the property, Jones began production of sodium hypochlorite (bleach). In 1942, Jones purchased adjacent properties to the north and east, and Jones began repackaging chlorine from bulk sources to cylinders and 1-ton containers. Titanium tetrachloride was briefly manufactured between 1942 and 1943 for the U.S. government during World War II for use in smoke-screen operations. Repackaging of anhydrous ammonia and acids began in 1947. The production of aqua ammonia and bulk storage of hydrochloric, sulfuric, nitric, and hydrofluosilicic acids was started in 1953.

Between 1960 and approximately 1977, solvents and petroleum products, such as tetrachloroethene (PCE), trichloroethene (TCE), toluene, 1,1,1-trichloroethane (1,1,1-TCA), methylene chloride, and Stoddard solvent, were repackaged from bulk to smaller containers for distribution. Aqua ammonia was produced by combining water and ammonia until 1995.

In 1971, Jones began to transport commercial hazardous waste not generated by Jones. The hazardous waste materials were temporarily stored on site prior to transport and disposal off site. The hazardous waste materials were stored on the former Agway Property, which was located on the eastern side of the Site, and in the two pole barns, formerly located in the central portion of the Site immediately west of the warehouse/office complex. Jones discontinued the transportation and on-site storage of hazardous waste in 1980.

Repackaging of chemicals from bulk to small containers has been one of the primary activities at the plant. These repackaged chemicals not only include the chemicals manufactured at the plant, but also those that were brought in bulk loads to the Site for redistribution.

Materials brought to the Site in bulk form were generally stored in shipping containers (i.e., railroad tank cars or tanker trucks), ASTs, and underground storage tanks (USTs). The tanks were typically constructed of stainless steel, fiberglass-reinforced plastic, or other suitable synthetic material. A majority of these tanks were taken out of service and removed between 1981 and 1986. During the removal of ASTs and USTs, soil samples were collected and analyzed, as required by the New York State Department of Environmental Conservation (NYSDEC). The analytical results indicated that product releases from these storage tanks and associated effects on the subsurface have been minimal (CRA 1993).

1.3 Air Stripping

Analytical results of water discharged to the lagoons had indicated the presence of VOCs, which primarily included chlorinated solvents such as PCE and its degradation products TCE and 1,2-dichloroethene (1,2-DCE). Chlorinated solvents were first reported in July 1981 in all on-site production wells and in discharge water to the lagoons. Subsequent hydrogeologic investigation by CRA (1984) reported the presence of VOCs in the on-site soil and groundwater. In June 1986, relatively high PCE concentrations of 1,160 and 765 micrograms per liter (μg/l) were detected in the North and West Wells, respectively.

Affected groundwater from the North and West Wells was used for non-contact cooling water in the manufacture of bleach until 1996. To address this problem, comply with the SPDES permit, and to collect data for the treatability study related to the RI/FS, Jones installed an air stripper to treat the affected groundwater prior to discharge to the lagoon. In November 1994, LFR conducted hydraulic testing of the North and West Wells to design an air stripping tower to treat affected groundwater. An air-stripping tower, with the capacity of treating up to 500 gpm, was installed in May 1996. Since 1996, affected groundwater from the North Well (300 to 400 gpm) and the West Well (approximately 15 gpm) has been treated prior to its being used as non-contact cooling water in the plant and subsequent discharged to the lagoons. Monitoring of the discharge water indicates that VOCs are below method detection limits (MDLs; Gaffney 1999).

The Identification of Candidate Remedial Technologies Memorandum (LFR 1996) identified air stripping as one of the remedial technologies in the potential extraction and treatment of affected groundwater at the Site. A Treatability Study Evaluation Report (TSER) for the air stripper, which was being used in the remediation of the affected groundwater from the North and West Wells, was prepared by LFR in January 1997 (LFR 1997). The TSER provides the construction and design details of the air stripper as well as results of data collected during the treatability study. Results indicate that the air stripper is operating at a greater than 99.5 percent removal efficiency of chlorinated solvents (LFR 1997). The TSER concluded that air stripper with appropriate modification may be a suitable remedial alternative to address groundwater contamination at the Site. The air stripper effluent samples analyzed continue to be below MDL for VOCs.

1.4 Climate

The climate of the Village of Caledonia is characteristic of western New York State, with warm summers and cold winters with moderate to heavy snowfall. Average daily temperatures range from 24 degrees Fahrenheit (°F) in January to 71°F in July. The average annual precipitation is 30 inches. Long continual droughts are rare, but periods of one or two months with a total rainfall of less than 3 inches are common. Rainy periods with low temperatures occur in the spring, and heavy showers are common in the summer. Snow occurs between November and March.

1.5 Floodplains, Wetlands, Critical Habitats, and Cultural Resources

A summary of the status of floodplains, wetlands, and critical habitats has been generated from the RI Report for the Site (LFR 1999b). The Site lies entirely within Zone C, an area of minimal flooding outside both the 100- and 500-year flood zones. The isolation of the Site from the flood-prone zones documents that floodplain management concerns are not applicable to the Site.

Although seven (NYSDEC Region 8 Bureau of Wildlife wetlands CA-5, CA-4, CA-1, CA-9, CA-16, CA-15, and WH-8) were identified within a 2-mile radius of the Site; no wetlands were identified on the Site or adjacent properties. The nearest wetland area, CA-1, is approximately 0.5 mile west of the Site, and is associated with Spring Creek, also located to the west of the Site. The Site characteristics that include flat topography, lack of off-site surface water runoff, highly permeable soils (Palmyra type), developed commercial, residential and recreational properties in the Site vicinity, and a lack of wetlands area on-site indicate that Site activities do not pose a potential concern to the wetlands.

LFR contacted the NYSDEC Region 8, Bureau of Wildlife to inquire about ecological habitat and sensitive species identification at and in the vicinity of the Site. According to the Bureau, no records of "exemplary natural communities, significant wildlife habitats, or threatened, endangered, or rare species" are present at or in the vicinity of the Site.

LFR contacted New York State Office of Park, Recreation, and Historic Places (OPRHP) for identification of cultural resources on site or those eligible for listing on the National Registry of Historic Places. The OPRHP stated that the State Historic Preservation Office has concluded that RI/FS activities on the Site will have no effect upon cultural resources eligible for inclusion in the National Register of Historic Places.

1.6 Hydrogeology

The hydrogeology and groundwater quality was evaluated through a network of monitoring wells and direct-push sampling points shown on Figure 3; the monitoring well construction details are provided in Table 1. The summary below was generated from the RI Report for the Site (LFR 1999b).

The Site is underlain by two distinct stratigraphic zones, an upper overburden zone and an underlying bedrock zone (Figure 4). The overburden zone can be grouped into two separate lithologic units consisting of an upper gravel-sand-silt mixture and lower gravelly silt. The gravel-sand-silt mixture unit includes varying amounts of gravel, sand, and silt, and was encountered from 25 to 40 feet bgs. The gravel-sand-silt mixture unit grades below into the gravelly silt unit, which is characterized by sediments with decreasing amounts of gravel and increased silt content. The gravelly silt unit directly overlies the bedrock between the depths of 40 to 70 feet bgs.

A carbonate bedrock (dolomite) was encountered at depths ranging between 30 and 80 feet bgs. The surface of the bedrock was found to slope steeply to the east. The upper portions of the bedrock are highly weathered and fractured. The thickness of the weathered zone varies, but was found to be less than 10 feet thick. The dolomitic bedrock at the Site appears to be equivalent to the Onondaga Formation of Upper Devonian age. Because the bedrock monitoring wells were completed only within the first 15 feet of the competent bedrock, the thickness of the Onondaga Formation at the Site is not known. Regionally, the Onondaga Formation is believed to be approximately 140 feet thick.

The overburden zone was found to be highly transmissive yielding significant quantities of water. Many of the production wells in the region are completed in the overburden zone. Hydraulic testing conducted at the Site indicates the transmissivity of the overburden zone to range between 25 and 41 square-feet per minute. Groundwater yield in the underlying bedrock, however, was found to be low and influenced greatly by fractures.

During non-pumping conditions, the principal groundwater flow direction of the overburden zone is toward the northeast. The average hydraulic gradient across the Site was estimated 0.002 foot/foot (ft/ft). During pumping of the North Well and West Well, groundwater flow in the overburden zone, with the exception of the area around North Well, is also toward northeast (Figures 5). A cone of influence due to pumping is present in the vicinity of the North Well. The cone of influence has an approximate radius of 200 feet around North Well. A steeper hydraulic gradient of 0.04 ft/ft was observed in the overburden zone in the vicinity of the North Well during pumping.

Groundwater flow in the bedrock zone during non-pumping conditions is both to the west and northeast (Figures 6). A groundwater "mound," or divide, appears to occur at monitoring well BP-1, located in the central portion of the Site. East of BP-1, the groundwater flow is toward the northeast. The hydraulic gradient in the bedrock zone was estimated to range between be 0.005 and 0.008 ft/ft. Pumping of the North and West Wells does not appear to have significant influence on the groundwater flow in the bedrock zone.

1.7 Summary of Contamination

The results of soil and groundwater sampling conducted at the Site are presented in detail in the RI report for the Site (LFR 1999b). The results indicate the presence of VOCs, primarily PCE and TCE, in subsurface at the Site. Approximate concentrations of potential chemicals of concern at the Site are listed in Table 2. Detailed historic sampling results of monitoring wells are presented in Table 3. The geologic cross section and the vertical distribution of chemicals in soil and groundwater in the vicinity of the source area (former solvent tank location) are presented on Figure 7. Groundwater PCE isoconcentrations at various depths are presented on Figures 8, 9, and 10.

In soil, the PCE concentrations detected ranged between the MDL and 330,000 micrograms per kilogram (µg/kg), and the concentrations of TCE detected ranged between the MDL and 320 µg/kg. The highest soil concentrations of PCE were detected in the former solvent tank storage area, located in the western portion of the Site. The former solvent tank storage area appears to be the source of chlorinated solvents detected (Figure 6). The partitioning calculations (Pankow and Cherry 1995) using the highest PCE concentration (330,000 µg/kg) detected in soil samples indicate the presence of residual DNAPL at the Site. Outside the former solvent tank source area, PCE and TCE levels in soil are relatively low ranging between 2J µg/kg (estimated value) and 310 µg/kg. The chlorinated solvent concentrations in soils outside the source area at the Site are below the NYSDEC (1994) Recommended Soil Cleanup Objectives (RSCOs).

Groundwater sampling and analysis conducted at the Site, indicate that the concentrations of PCE ranged between the MDL and 62,000 µg/l, and TCE concentrations ranged between the MDL and 100 µg/l (Table 2). The highest concentrations of PCE (62,000 µg/l) and TCE (100 µg/l) were detected in the monitoring well OP-16, located in former solvent tank area. The PCE concentrations detected in the on-site North and West production wells were 140 and 340 µg/l, respectively. In the North Well, PCE concentrations decreased from 570 µg/l (1996) to 140 µg/l (1998) whereas they remained approximately the same in the West Well. Relatively low concentrations of PCE or TCE (less than 10 µg/l) were detected in the bedrock zone.

The magnitude of PCE concentration (62,000 µg/l in the monitoring well OP-16, located in the former solvent tank area) indicate the potential presence of DNAPL in this area. PCE concentrations of this magnitude were found to be limited primarily to the former solvent tank area. Relatively lower levels of PCE (ranging from 3 to 120 µg/l) were detected in the groundwater samples taken outside the former solvent tank area, indicating that the DNAPLs may be limited to a small area at the source.

PCE groundwater plume extends from the former solvent tank source area to east of sulfur dioxide/chlorine department, and to the northeastern property boundary in the vicinity of the pole barns. The length and width of the PCE-affected groundwater plume is slightly over 1,100 feet (along the northeast–southwest axis) and 500 feet (along the north–south axis). Vertically, PCE in the source area extends to at least 48 feet bgs in the source area.

Recent sampling and analyses of the Village of Caledonia production well water (samples collected from well head prior to treatment) indicated volatile organic compounds to below the method detection limit of 1 μg/l (LFR 1999b). The Village of Caledonia production wells are located hydraulically upgradient of the Site.

1.8 Summary of Health Risk Assessment

RI data compiled to date were used to evaluate potential health risks and impacts to ecological receptors at and in the vicinity of the Site. The methods and assumptions developed in this HRA (LFR 1999a) are consistent with U.S. EPA and NYSDEC risk assessment methodologies for evaluating releases of chemicals from the environment and associated human health risks. For this HRA, it was assumed that the Site would remain industrial into the foreseeable future. Therefore, the potential human receptors evaluated in this document were on-site workers and off-site adult and child residents. The HRA evaluates the exposure pathways that may potentially affect the on- and off-site receptors evaluated. It should be noted that the current and anticipated future use of the Site will remain industrial, and off-site residential, commercial, and agricultural.

In an effort to prevent the dilution of estimated risks by jointly considering small areas with high concentrations with large areas with low concentrations, the Site was divided into three Risk Management Zones in this HRA based on soil and groundwater quality at the Site. The three zones are defined below:

- The Source Management Zone includes the area on the westernmost end of the Site where significant levels of PCE was detected in soils/groundwater in vicinity of the former solvent storage tank source area.
- The Lagoon Management Zone includes the three lagoons A, B, and C and the immediately surrounding area.
- The Site Management Zone includes the remainder of the Site.

Results of the risk assessment indicate the following:

- Estimated cancer risks for on-site workers and off-site residents at the Site were found to be lower than or within the acceptable excess cancer risk range established by the U.S. EPA. Cancer risks to the surrounding community are likely to be much lower than cancer risks estimated in this HRA.
- The presence of non-carcinogenic chemicals in soil and groundwater at the Site do not represent a health hazard to adult and child residents under the assumed exposure scenarios. Estimated hazard indices (HIs) and hazard quotients (HQs) for individual chemicals and combinations of chemicals were less than unity (1.0), indicating that there is not a concern for potential chronic adverse health effects from chemicals at the Site.

- The screening ecological assessment conducted at the Site identified no endangered or threatened animal or plant species at the Site or its immediate vicinity. In addition, chemicals currently found in soil and groundwater at the Site were found to be inaccessible to ecological receptors in the area.
- The calculated human health and ecological risks incorporate a number of conservative assumptions that tend to overestimate potential risks. Actual risks posed by current conditions at the Site are likely to be much lower than estimated in this HRA.

The HRA assumed that the Site will remain industrial, the on-site wells will continue to be in operation, and the extracted water will be treated before it is used at the facility as non-contact water. If any of these conditions were to change in the future, the potential health risks assessed may have to be reevaluated for the modified conditions.

1.9 Future Land Use

The Site has been used for industrial purposes since August 1939. The conceptual future land use for the property is expected to be industrial (Gaffney 1999). Groundwater from on Site is presently treated through an air stripper and used only as non-contact cooling water, with minimum exposure to on site workers. Potable water is obtained from the Village of Caledonia. There are no future plans to install drinking water supply wells on site. As part of this FS, a restriction would be recorded into the property deed limiting groundwater usage to non-potable purposes only.

The future land use for the property located immediately north of the former solvent AST area is anticipated to be industrial. The future land use for the properties located to the northeast and east is reported to be agricultural. Future land use to the west and southwest of the Site is reported to be light service industries such as hardware stores, gasoline stations, dry cleaners, restaurants, and other commercial businesses.

1.10 Feasibility Study Approach

This FS report is organized into five sections:

- Section 1: Introduction. This section presents the FS objectives, scope and organization, and summarizes Site background information.
- Section 2: Remedial Action Objectives. This section presents goals and requirements that affect the extent of remediation needed at the Site. Also, presents a listing of chemical-specific, action-specific and location-specific applicable or relevant and appropriate requirements (ARARs).
- Section 3: Identification and Screening of Technologies. This section is a listing, description and screening of technologies that could potentially be incorporated into remedial alternatives.

- Section 4: Development of Soil and Groundwater Alternatives. In this section, the screened technologies are developed into suitable remedial alternatives.
- Section 5: Detailed Analysis and Comparative Evaluation of Alternatives. This section conducts a detailed analysis of alternatives against "threshold" and "primary balancing" criteria of NCP and compares the relative performance of each alternative in relation to each specific evaluation criterion.

2.0 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS, REMEDIATION GOALS, AND REMEDIAL ACTION OBJECTIVES

This section identifies the federal, state, and local regulations that are potentially applicable to the development of remedial alternatives; develops and presents the remediation goals for soil and groundwater; and identifies the Remedial Action Objectives (RAOs) for evaluating the effectiveness of remedial alternatives for the Site.

NCP requires that remediation goals be established based on exposure levels for the protection of human health and the environment; cost-effective; and developed by considering the federal, state, and local ARARs. Federal and state non-promulgated standards, policies, and guidance documents are not ARARs. However, they may be considered when determining actions necessary to protect human health and the environment and are categorized as "to be considered" (TBC) standards.

As defined in the NCP:

- Applicable Requirements are "those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site" (40 CFR 300.5).
- Relevant and Appropriate Requirements are "those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not applicable to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those found at the CERCLA site that their use is well suited to the particular site" (40 CFR 300.5).

2.1 Determination of ARARs

A two-step process is used to determine whether a requirement is applicable or relevant and appropriate at a particular hazardous substance release site. First, a federal or state law or regulation should be analyzed to determine if it is applicable using the definitions stated above; an applicable requirement is an ARAR.

If a requirement is not applicable, then a determination should be made if it is relevant and appropriate. A candidate requirement must satisfy both the relevant and the appropriate tests to be considered an ARAR. In some cases, a requirement may be relevant but not appropriate given site-specific circumstances; such a requirement would not be an ARAR for the Site. It is also possible for only part of a requirement to be considered relevant and appropriate in a given case. If a determination is made that a requirement or part of a requirement is both relevant and appropriate, such a requirement is an SCG and should be complied with to the same degree as if it were applicable.

2.2 Identification of ARARs

Identification of ARARs and TBCs for a hazardous substance release site typically involves several steps, and the ARAR may be categorized as chemical-specific, action-specific, or location-specific. The ARARs and TBCs for the Site are listed in Table 4. The most significant ARARs are described below.

2.2.1 Chemical-Specific ARARs

Chemical-specific ARARs define acceptable exposure levels or action levels to a given substance, and therefore may be used in developing the remediation goals. The primary chemicals of concern at the Site include chlorinated solvents such as PCE, TCE, cis-DCE, trans-DCE, 1,1-DCE, and vinyl chloride. Based on historical practices, future land use, and physical and toxicity characteristics, chlorinated solvents have the greatest potential for human health and environment impact. Potential chemical-specific ARARs identified for soil and groundwater media include NYSDEC TAGM No. HWR-94-4046 (RSCOs) and New York State Groundwater Quality Standards (6 NYCRR Part 703.5).

NYSDEC developed the RSCOs to protect human health and environment. A variety of factors including soil contact and ingestion, land use, cancer risk, impact on groundwater resulting from leaching were considered by NYSDEC in developing these RSCOs.

The New York State Groundwater Quality Standards (6 NYCRR part 703.5) were developed to protect groundwater and surface water resources. These values were developed based on protection of drinking water resources, fish propagation/survival, human and wildlife consumption of fish. These standards also incorporate the federal and state MCLs.

NYSDEC TAGM No. HWR-94-4046 and New York State Groundwater Quality Standards (6 NYCRR part 703.5) were the primary ARARs considered in developing the remediation goals for soil and groundwater at the Site. The remediation goals for chlorinated solvents are listed in Table 5.

2.2.2 Action-Specific ARARs

Action-specific ARARs may set controls or restrictions for particular treatment and disposal activities related to hazardous waste remediation and management. Federal, state and local guidelines were used to identify potential action-specific ARARs.

The potential action-specific ARARs for the Site include Occupational Health and Safety Act (OSHA; 29 CFR 1910 120); RCRA (40 CFR Part 261, 262, 263, 264), Clean Water Act (40 CFR Parts 6, 50, 61, 63), Land Disposal Restrictions (LDRs; 40 CFR Part 268; 6 NYCRR part 376); SPDES (6 NYCRR Parts 703.6, 750 - 758) and New York State Ambient Air Quality Standards (6 NYCRR Part 257).

2.2.3 Location-Specific ARARs

Location-specific ARARs may set restrictions on activities within specific locations such as floodplains, wetlands, or areas where critical habitats for endangered or threatened species have been identified.

Federal, state and local guidelines were used to identify potential location-specific ARARs for the Site. However, the regulatory guidelines were found not applicable to the Site for the following reasons:

- No significant historic properties or archaeological digs have been identified at or in the vicinity of the Site.
- No wetlands are present at or in the vicinity of the Site.
- The Site is not located within the 100-year floodplain.
- No critical habitats for endangered or threatened species are present at or in the vicinity of the Site.
- Site activities will not impact streams or rivers.

2.3 Remediation Goals

Remediation goals are chemical-specific target cleanup goals used to assist in the selection of a preferred remedial action. Remediation goals are based on the ARARs and can be developed for specific media and land use scenario. Remediation goals serve as a starting point for evaluating and selecting remedial actions.

The remediation goals for the chemicals of concern in the soil and groundwater media at the Site are listed in Table 5. NYSDEC RSCOs listed in TAGM #HWR-94-4046 are used as the soil remediation goals for the chemicals of concern. Remediation goals for the groundwater medium for the Site are the New York State Groundwater Standards (6 NYCRR part 703.5) for Class GA (i.e., for any groundwater).

2.4 Remedial Action Objectives

RAOs are specific goals to protect human health and the environment. These objectives are based on available information and standards such as ARARs and risk-based levels established in the risk assessment. The RAOs for the Site include the following:

- Restore groundwater to levels that meet state and federal drinking-water standards within a reasonable time frame
- Mitigate the potential for chemicals to migrate from soils into groundwater;
- Mitigate the migration of affected groundwater; and
- Prevent future human and ecological contact with affected media.

3.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

This section identifies potentially suitable remedial technologies for affected soil and groundwater at the Site. A preliminary screening of technologies (Table 6) was conducted with respect to effectiveness, implementability, and cost in order to evaluate whether a technology could be retained for further development into a feasible remedial alternative that would address the remediation goals and RAOs for the Site. Technologies that passed this screening are used in Section 4 to develop soil and groundwater remedial alternatives.

Technologies have been categorized into the following general response actions:

- no action
- institutional controls
- containment
- in situ treatment/DNAPL remedial technologies
- ex situ treatment
- source removal

3.1 No Action

Evaluation of a No Action alternative is a requirement under the NCP. The No Action alternative provides a basis for comparison of costs and benefits in analyzing the need for site remediation. This alternative includes periodic monitoring to identify temporal changes in site conditions. No Action is retained for further analysis; detailed costs for periodic monitoring are provided in Appendix A.

3.2 Institutional Controls

Institutional controls are legal means of limiting or eliminating potential human exposures from a site. Specific examples for the Site include establishing deed restrictions covering future site use (including the use of groundwater). Institutional controls can be effective, especially when used in conjunction with other remediation technologies. The cost to implement institutional controls at the Site would be low. Several institutional controls were retained for further analysis.

3.3 Containment

Containment is another general response action that is evaluated as part of the FS. Whereas containment technologies do not aggressively treat chemicals to remediation goals, they are used to contain chemicals on site. Containment technologies can be very effective, especially at sites where future land use is industrial. Containment technologies are frequently used at sites where health or environmental risks are minimal. The following containment technologies were evaluated for the Site.

3.3.1 Capping

Cap systems are used at hazardous waste sites to prevent the transfer of contaminants to the atmosphere and to prevent or minimize surface water infiltration and migration of affected groundwater. The vegetation and topsoil over a cap temporarily store the rainwater and ultimately evapotranspirate a large part of it. The remaining moisture percolates downward toward the waste and must be drained laterally above a liner.

Caps are used by themselves or in conjunction with other waste treatment technologies such as barrier walls, groundwater pump-and-treat systems, and in situ treatment. A cap by itself cannot prevent horizontal flow of groundwater through the waste, only vertical entry of water into the waste. Caps are most effective where most of the underlying waste is above the water table. Caps serve to isolate untreated wastes and treated hazardous wastes, prevent generation of contaminated leachate, contain waste while treatment is being applied, and control gas emissions from underlying waste. Moreover, a cap can be used to create a land surface capable of supporting vegetation. Caps have been shown to successfully contain a variety of contaminants, including VOCs, SVOCs, metals, radioactive materials, corrosives, oxidizers, and reducers.

The cost of a cap system (0.5 to 1 acre) can vary from $500,000 for a one-layer system to several million dollars for a multi-layer cap. The cost is highly dependent on the availability of local soil suitable for construction and the requirements for monitoring, leachate collection, and gas collection.

Capping only the source area on the JCI site will not be effective; to prevent infiltration, large areas hydraulically upgradient of the source areas will have to be capped. Because chlorinated solvent sources are present in limited portions, it would not be cost-effective to cap the entire JCI site. Also, capping will not prevent lateral migration unless groundwater flow is contained. Based on these considerations, capping is not retained for further analysis.

3.3.2 Subsurface Barrier Walls

Engineered subsurface barrier walls are constructed containment systems that control horizontal migration of groundwater. Such barriers are referred to as vertical barriers. Vertical barriers typically used to control sources of hazardous waste are soil-bentonite, soil-cement-bentonite, cement-bentonite, sheet pile (steel or high-density polyethylene [HDPE]), and clay barriers. Soil-bentonite barriers are the most widely used in the United States. Historically, vertical barriers have been used on construction projects to prevent inflow of groundwater into deep excavations, as well as to support excavation. Sheet pile walls (first of wood and later of steel) have been installed throughout the world for many decades. The 1950s saw the development of slurry trenching technology, in which bentonite was used to support the sides of trenches under excavation before they were backfilled.

More recently, by the late 1970s and early 1980s, vertical engineered barriers have been widely used in the United States to isolate hazardous wastes from groundwater, as slurry walls, primarily soil-bentonite cutoffs. Initially, the goal was to contain contaminated groundwater for a limited period of time; a 30-year life span for the containment was often the objective. By the late 1980s, the concept of establishing a reverse gradient appeared. In such applications, an extraction system, or pumping system, is installed in the contaminated zone, in addition to the peripheral cutoff wall. This approach allows for the maintenance of an inward flow through the wall at a very low rate. This approach has its advantages, since it decreases, if not eliminates, the risk arising from deficiency in design or installation or even localized anomalies in the aquitard layer.

Barrier walls were not considered for the JCI site 1) because of leakage potential and 2) because effective hydraulic containment and groundwater treatment could be achieved through pump-and-treat technology discussed below.

3.3.3 Hydraulic Control/Pump-and-Treat

The objectives of the hydraulic control/pump-and-treat system are to contain the migration of affected groundwater and to remediate the portions of the water-bearing zone that contain the dissolved-phase plume.

This technology involves pumping groundwater from strategically located recovery wells. Recovery wells can accomplish the following:

- extract affected groundwater for remediation
- control and remediate chlorinated solvent source areas
- hydraulically contain affected groundwater

Pump-and-treat is the most common form of containing and remediating groundwater plumes. It is typically used to contain affected groundwater by establishing a reverse hydraulic gradient; the reverse gradient is accomplished by pumping groundwater at an optimum rate. The extracted groundwater is remediated and discharged either to a publicly owned treatment works (POTW) or re-injected on site. It is often associated with treatment technologies such as air stripping and granular activated carbon (GAC) systems.

Pumping minimizes groundwater migration by influencing the direction and rate of groundwater flow. It also reduces the chemical mass present in the subsurface. Feasible technologies that may be implemented at the JCI site include several nested vertical extraction wells in the source area.

Groundwater recovery wells are constructed of pipes and well screens placed to draw water from the target geologic units. Pumping creates a pressure drop near the well bore and leads to formation of a cone of depression that may be sufficient to reverse the local hydraulic gradient and prevent the advancement of affected groundwater.

The groundwater recovery well locations and construction design, pumping system, and treatment are dependent on the JCI site's hydraulic characteristics and contaminant type. It is not uncommon to find multiple wells extracting groundwater at the same time. These wells may be screened at different levels to maximize effectiveness. A major component of any groundwater extraction system is a groundwater monitoring program to verify its effectiveness. Monitoring the cleanup allows the operator to make adjustments to the system in response to changes in subsurface conditions.

Another component of a pump-and-treat system is determining when to turn the system off. Termination requirements are based on the cleanup objectives defined in the initial stage of the remedial process, combined with site-specific aspects observed during remedial operations.

Pumping depresses the water table and extracts affected groundwater but leaves residual contaminants sorbed to the soil. After the groundwater level returns to normal, contaminants sorbed onto soil dissolve into groundwater; this phenomenon is called "rebound." Rebound tests should be performed frequently in the first few years after the system is turned off and after major precipitation or flooding events.

Hydraulic control is applicable to the chemicals of concern at the JCI site and has a proven performance history. Implementation of this technology would be relatively straightforward at the JCI site. Preliminary hydraulic modeling was conducted using the MODFLOW and MODPATH groundwater flow models contained within the Groundwater Modeling System pre- and post-processing program. The objective of the simulations was to determine the location and flow rate of extraction wells required to capture groundwater. Using the assumed hydraulic gradients, hydraulic conductivity values, and saturated thickness, a groundwater flow rate of 330 gpm for the overburden water-bearing zone and 70 gpm for the bedrock zone was estimated to capture the affected. The results of the preliminary modeling, including the proposed locations of the extraction wells, are shown in Appendix B. The cost to implement this technology is low to moderate. This technology is retained for further evaluation; detailed costs and design considerations are provided in Appendix A.

3.4 In Situ Treatment/DNAPL Technologies

In situ treatment remediates affected groundwater without extraction. Technologies considered implementable are air sparging; soil-vapor extraction (SVE); installation of a permeable reactive barrier (PRB) wall; dual-phase extraction; natural attenuation; and several emerging technologies such as Hydrogen Release Compound™/Oxygen Release Compound® (HRC™/ORC®) injection, ethanol injection, potassium permanganate ($KMnO_4$) injection, and co-solvent flushing. Many of these innovative in situ technologies are being considered for remediation of sites affected with DNAPLs. Application of these technologies is generally limited to homogeneous subsurface formations, preferably of uniform saturated thickness.

3.4.1 Air Sparging

Air sparging is the process of injecting air directly into groundwater. Air sparging remediates groundwater by volatilizing contaminants and enhancing biodegradation. It is akin to blowing bubbles through a straw into a bowl of water; as the bubbles rise, the contaminants are removed from the groundwater by physical contact with the air (i.e., stripping) and are carried up into the unsaturated zone (i.e., soil). As the contaminants move into the soil, an SVE system is usually used to remove vapors. The addition of oxygen to contaminated groundwater and soil also enhances biodegradation of certain contaminants in and above the water table. Air sparging has been shown to be effective for remediation of VOCs that are aerobically degraded, such as petroleum constituents, in sandy aquifers. Over the years, several enhancements have been made to the air sparging technology.

The effectiveness of this technology depends to a large extent on site-specific soil and groundwater conditions. Its main limitation is the achievement of uniform air dispersion in the subsurface. If soil permeability is too low or the subsurface is highly layered, air sparging may not be effective due to hindered diffusion or preferential air movement through more permeable materials. Another limitation is the potential need to capture untreated vapors.

At the Site, the effectiveness of air sparging may be limited because of sand-gravel-silt water-bearing zones and because PCE does not readily biodegrade under aerobic conditions. Additionally, in the gravelly water-bearing zones, the radius of influence of air sparging is reduced significantly. Because of the smaller radius of influence in gravelly water-bearing zone, a greater number of air sparging wells may be required to effectively treat the contaminants. Consequently, a large SVE system will be required to treat the large volume of air resulting from an increased number of air sparging wells. A larger SVE system to accommodate the increased number of air sparging wells will lead to significantly higher implementation and operation and maintenance costs.

Air sparging systems increase oxygen levels in the subsurface, which may significantly reduce the rate of dechlorination of PCE (dechlorination of PCE is rapid in an anaerobic environment under appropriate conditions). Because air sparging has a potential to limited potential effectively in reducing PCE concentration at the Site, it is not retained for further analysis.

3.4.2 Soil-Vapor Extraction

SVE is the most frequently selected innovative treatment for remediating affected soil at hazardous waste sites. It is a relatively simple process that physically separates contaminants from soil. SVE extracts contaminants from the soil in vapor form; therefore, SVE systems are designed to remove contaminants that have a tendency to volatilize or evaporate easily. By applying a vacuum through a system of underground wells, contaminants are pulled to the surface as vapor or gas. In addition to vacuum extraction wells, air inlet wells are often installed to increase the airflow and improve the removal rate of the contaminant. SVE is sometimes called in situ volatilization, enhanced volatilization, in situ soil venting, forced soil venting, in situ air stripping, or soil-vacuum extraction.

The first step to constructing an SVE system is to install vapor-extraction wells and inlet wells (or air vents) in the contaminated area. Air vents serve the same function as air injection wells but are passive; instead of pumping air, they provide a passage for air to be drawn into the ground. When incoming air passes through the soil on its way to the extraction wells, contaminants evaporate out of the spaces between the soil particles and are pulled by the air to the wells and removed. Vapor-extraction wells can be placed either vertically or horizontally. Typically, they are placed vertically and are designed to penetrate the lower portion of the unsaturated zone.

Vapors extracted by the SVE process are typically treated using carbon adsorption, incineration, catalytic oxidation, or condensation. At the JCI site, extracted vapors will be treated using a GAC system. Carbon adsorption is the most commonly used treatment for contaminated vapors and is adaptable to a wide range of VOCs. When properly designed and operated, SVE is a safe, low-maintenance process. SVE is retained for further analysis. Detailed costs and design considerations are provided in Appendix A.

3.4.3 Dual-Phase Extraction

Dual-phase extraction (DPE), also known as multi-phase extraction, vacuum-enhanced extraction, or sometimes bioslurping, is a technology that uses a high-vacuum system to remove various combinations of contaminated groundwater, separate-phase product, and hydrocarbon vapor from the soil and groundwater media. Extracted liquids and vapor are treated and collected for disposal, or re-injected to the subsurface (where permissible under applicable state laws).

In DPE systems for liquid/vapor treatment, a high-vacuum system is used to remove liquid and gas from low permeability or heterogeneous formations. The vacuum extraction well includes a screened section in the zone of contaminated soil and groundwater. It removes contaminants from above and below the water table. The system lowers the water table around the well, exposing more of the formation. Contaminants in the newly exposed vadose zone are then accessible to vapor extraction. Once above ground, the extracted vapors or liquid-phase organic compounds and groundwater are separated and treated. DPE for liquid/vapor treatment is generally combined with bioremediation, air sparging, or bioventing when the target contaminants include long-chained hydrocarbons. Use of DPE with these technologies can shorten the cleanup time at a site. It also can be used with pump-and-treat technologies to recover groundwater in higher-yielding aquifers. DPE is a full-scale technology.

DPE is similar to using SVE in conjunction with pump-and-treat systems. The major difference is that during DPE, water table is significantly lowered so that more of the affected formation is exposed to vapor extraction. In highly permeable water-bearing zones, such as those at the Site, lowering groundwater table may require pumping groundwater at very high flow rates resulting in additional above-ground treatment of large quantities of affected groundwater. There is also a slight potential for re-mobilizing DNAPLs during lowering of water table. DPE is not retained for further analysis.

3.4.4 Monitored Natural Attenuation

Monitored Natural Attenuation is not a "technology," per se. It generally involves monitoring a range of unaided physical and biological processes that reduce the concentration, toxicity, or mobility of contaminants. Natural attenuation makes use of natural processes to contain the spread of contamination and reduce the concentration. Monitored Natural Attenuation—also referred to as intrinsic remediation, bioattenuation, or intrinsic bioremediation—is an in situ treatment method. This means that environmental contaminants are left in place while natural attenuation works on them. Monitored Natural Attenuation is often used as one part of a site cleanup that also includes the control or aggressive cleanup and/or removal of the source of the contamination.

The processes contributing to natural attenuation are typically acting at many sites, but at varying rates and degrees of effectiveness, depending on the types of contaminants present, and the physical, chemical and biological characteristics of the soil and groundwater. Natural attenuation processes are often categorized as destructive or non-destructive. Destructive processes destroy the contaminant. Non-destructive processes do not destroy the contaminant but cause a reduction in contaminant concentrations.

Natural attenuation processes may reduce contaminant mass (through destructive processes such as biodegradation and chemical transformations); reduce contaminant concentrations (through simple dilution or dispersion); or bind contaminants to soil particles so the contamination does not spread or migrate very far (adsorption). Biodegradation, also called bioremediation, is a process in which naturally occurring microorganisms (yeast, fungi, or bacteria) breakdown, or degrade, hazardous substances into less toxic or nontoxic substances. Biodegradation can occur in the presence of oxygen (aerobic conditions) or without oxygen (anaerobic conditions). In most subsurface environments, both aerobic and anaerobic biodegradation of contaminants occur. The microorganisms break down the organic contaminants into harmless products—mainly carbon dioxide and water in the case of aerobic biodegradation. Once the contaminants are degraded, the microorganism populations decline because they have depleted their food sources.

Biodegradation processes can effectively cleanse soil and groundwater of hydrocarbon fuels such as gasoline and also can break down chlorinated solvents, like PCE and TCE in groundwater. When chlorinated compounds are biodegraded, it is important that the degradation be complete, because some products of the breakdown process can be more toxic than the original compounds.

The effects of dilution and dispersion appear to reduce contaminant concentration but do not destroy the contaminant. Relatively clean water from the ground surface can seep underground to mix with and dilute contaminated groundwater. Clean groundwater from an underground location flowing into contaminated areas, or the dispersion of pollutants as they spreading out away from the main path of the contaminated plume also lead to a reduced concentration of the contaminant in a given area. Adsorption occurs when contaminants attach or sorb to underground particles. Sorption, like dilution and dispersion, appears to reduce the concentration and mass of contamination in the groundwater, but does not destroy the contaminants.

In certain situations, Monitored Natural attenuation is an effective, inexpensive cleanup option and the most appropriate way to remediate some contamination problems. Monitored Natural attenuation is a proactive approach that focuses on the confirmation and monitoring of natural remediation processes. Monitored Natural attenuation is non-invasive, and, unlike many elaborate mechanical site cleanup techniques, while natural attenuation is working below ground, the ground surface may continue to be used. Natural attenuation can be less costly than other active engineered treatment options, especially those available for groundwater, and requires no energy source or special equipment.

To estimate how well natural attenuation will work and how long it will take requires a detailed study of site conditions. Natural attenuation may be an acceptable option for sites where active remediation is being conducted to reduce the concentrations of contaminants. Long-term monitoring is necessary to demonstrate that contaminant concentrations are continually decreasing at a rate sufficient to ensure that they will not become a health threat.

Within the Superfund program, natural attenuation has been selected as one of the cleanup methods at over 73 groundwater-contaminated sites—but is the sole treatment option at only at a limited number of these sites. Monitored Natural attenuation is retained for further analysis. The costs to implement Monitored Natural attenuation is presented in Appendix A.

3.4.5 Hydrogen Release Compound™/Oxygen Release Compound® Injection

HRC™, developed by Regenesis, is a food-grade lactic acid polymer. When placed in water (e.g., a groundwater monitoring well), this polymer decomposes to a simple alcohol combined with lactic acid. The alcohol and lactic acid appear to be electron donors and PCE, TCE, and DCE are electron acceptors in the reductive dechlorination process. PCE is degraded to TCE in the first biochemical reaction; TCE is dechlorinated to DCE; and DCE is dechlorinated to vinyl chloride. The dechlorination of vinyl chloride to ethene may occur in some aquifers; however, the biochemical kinetics are generally much slower than the aforementioned dechlorination of PCE, TCE, and DCE.

ORC®, patented by Regenesis, is a formulation containing magnesium peroxide that slowly releases molecular oxygen in the presence of water. Molecular oxygen has the effect of promoting aerobic degradation of organic molecules within the area affected by the ORC®. Vinyl chloride appears to degrade more quickly in an aerobic environment than in an anaerobic environment. By injecting ORC® into a vinyl chloride plume or downgradient from HRC™ injection (where vinyl chloride is present as a degradation product of PCE, TCE, and DCE), it is believed that a chlorinated solvent barrier can be established. This barrier could easily be maintained by periodically replenishing the ORC® and, as necessary, replenishing the HRC™.

The biochemical reactions associated with the dechlorination of PCE, TCE, DCE, and vinyl chloride are believed to occur only in the aqueous phase and have limited applicability for reducing the mass of the DNAPL phase; therefore, this treatment process is generally considered only for dissolved groundwater phase. In addition, numerous field applications indicate that injecting HRC™ substance (generally molasses or lactic acid) to depths of 30 feet bgs or greater is difficult to accomplish as the substance is typically viscous. Preliminary design considerations from Regenesis indicated that over 200 injection points would be required in the source area. This technology is not retained for further analysis.

3.4.6 Potassium Permanganate Injection

Injection of dissolved $KMnO_4$ is an emerging technology; laboratory and field studies have shown it may be an effective DNAPL PCE remediation technology (Gonullu et al. 1994; Truax et al. 1994; Schnarr et al. 1998; West et al. 1997). $KMnO_4$ has been used in water treatment and wastewater treatment processes for several decades. In these processes, $KMnO_4$ is used to oxidize dissolved compounds such as iron and manganese. Oxidation of these compounds in a well-mixed reactor generally requires a contact time of one to two hours (Montgomery 1985). The oxidation reactions result in precipitation of oxidized forms of these compounds, which allows for easier separation. Recently, laboratory and field studies have indicated that $KMnO_4$ is capable of oxidizing dissolved-phase PCE and possibly DNAPL PCE.

The complete oxidization reaction believed to occur between PCE and $KMnO_4$ is:

$$C_2Cl_4 + 2\,KMnO_4 \rightarrow 2CO_2 + 2MnO_2 + 2KCl + Cl_2$$

The rate of oxidation is much faster than the rate of dissolution of PCE from DNAPL to the aqueous phase, which results in a reaction process that is mass-transfer-limited rather than reagent- or rate-limited.

The mass flux from DNAPL PCE to an aqueous phase is governed by the following equation (Whitman 1923):

$$N = ka(c^* - c)$$

where

N = the mass flux from DNAPL PCE to the aqueous phase (mass/time-volume)
k = the mass transfer coefficient (length/time)
a = the specific surface area of the DNAPL globule (area/volume [length^{-1}])
c* = the solubility of DNAPL in groundwater
c = the groundwater concentration (mass/volume)

The "k" and "a" terms can be lumped into one parameter, referred to as the overall mass transfer coefficient, which is difficult to measure and is media- and compound-specific. However, it is small compared to the (c*- c) term (commonly referred to as the driving force), which limits the rate of mass flux from the NAPL phase to the aqueous phase. This type of case is generally referred to as "mass transfer limited" and is the primary "bottle neck" in NAPL remediation by technologies such as pump and treat and in situ air sparging.

Understanding these factors is crucial to designing a successful pilot test. For a site that contains a large mass of DNAPL PCE, or for which a rapid and aggressive remedial approach is the dominant criterion, $KMnO_4$ oxidation would likely not provide a satisfactory result because of the mass transfer limitations described above. However, if the site has a smaller mass of DNAPL present (such as the Site), and if the DNAPL is present in the form of disseminated, irregularly distributed stringers and thin lenses, $KMnO_4$ injection may be the appropriate remedial approach. The very high specific surface area of the DNAPL may partly offset the mass transfer limitations because mass flux from the DNAPL to the aqueous phase is area-dependant. The mass transfer coefficient is a property of the PCE-water system and is not changed by the addition of $KMnO_4$. The concentration driving force is small (even at its maximum). The only remaining aspect of the mass transfer flux equation that affects rate is the area over which mass transfer occurs. As area increases, rate increases in a linear fashion.

Another type of DNAPL PCE that may be suitable for remediation with $KMnO_4$ is one in which the mass of DNAPL PCE is not mobile and the groundwater plume is not being attenuated sufficiently by natural processes. At these sites it may be feasible to establish a program of periodic injection of $KMnO_4$ within the source area, with injection timing and mass flow rate designed to provide chemical oxidation of PCE in the aqueous phase within the source area. Field tests performed to date suggest that both of these favorable scenarios may hold true.

$KMnO_4$ injection will likely suppress or eliminate microbial activity in the injection zone. However, if used in conjunction with pump-and-treat system, microbial activity may be restored through the movement of microbes from areas where dechlorination is occurring into the injection zone . Downgradient of the injection zone, where little or no $KMnO_4$ will reach, microbial activity should not be adversely affected.

Low levels of trace metals such as arsenic and chromium and secondary parameters such as color, chloride content, and manganese have been reported in field studies using $KMnO_4$. However, field applications conducted by LFR (1999b) indicate that exceedance of trace metals or secondary parameters is not significant, if $KMnO_4$ is injected at dilute concentrations and/or especially if used in conjunction with a pump-and-treat system. This technology is retained for further evaluation. The costs associated with this technology is provided in Appendix A.

3.4.7 Co-Solvent Flushing

Co-solvent flushing is an emerging technology for remediating LNAPL- or DNAPL-affected aquifers. This technology has been under consideration for use in groundwater remediation since the mid 1980s (Rao et al. 1985). Much of the current knowledge about co-solvency was developed by pharmaceutical researchers over the past 20 to 30 years. Co-solvent flushing also has been investigated for enhancing the recovery of petroleum from aquifers. The effects of a co-solvent mixture have also been observed at a site where alcohols, ketones, and other co-solvents are present in the subsurface as a result of past releases.

The purpose of injecting a co-solvent, such as alcohol or acetone, into an aquifer is to reduce the polarity of the aqueous phase, resulting in a significant increase in the rate of interfacial mass transport between DNAPL and the aqueous phase (groundwater) and an increase in the solubility of nonpolar compounds, such as PCE, in groundwater. Interfacial mass transport properties govern the rate at which mass moves from DNAPL to the aqueous phase. The solubility of nonpolar compounds, such as PCE, in the aqueous-phase mixture is dependent on the chemical thermodynamic equilibrium property that governs the amount of solute that can be dissolved by a mixture. Co-solvents also reduce the interfacial surface tension between the aqueous phase and the nonaqueous phase, enhancing transport via bulk, undissolved DNAPL movement.

Brandes and Farley (1993), Imhoff et al. (1995), and others have shown the effectiveness of the co-solvent flushing technology in laboratory studies. Rao et al.

(1997) provide information on field testing of the co-solvent technology on a mixed LNAPL from a kerosene and chlorinated solvents disposal area at Hill U.S. Air Force Base in Utah. Brusseau et al. (1997) present several papers with data demonstrating the effectiveness of in situ flushing using co-solvents and surfactants. The research data and observations acquired at complex solvent sites indicate that the groundwater/alcohol mixture should effectively enhance the removal of PCE by significantly increasing PCE mass transfer from DNAPL to groundwater and increasing PCE solubility.

As stated above, co-solvent flushing is an emerging technology and would require extensive bench scale and/or field scale studies at the JCI site prior to implementation. Moreover, because of insufficient data, accurate costs to implement this technology at the JCI site are not known. This technology is not retained for further analysis.

3.5 Ex Situ Treatment

Ex situ treatment refers to technologies that are applied following removal of the affected medium or chemicals of concern. Types of ex situ technologies evaluated for treating exhaust streams include chemical, physical, and biological treatments, such as air stripping, liquid-phase carbon adsorption, vapor-phase carbon adsorption, vapor thermal oxidation, and catalytic oxidation. Air stripping, liquid-phase carbon adsorption (for polishing), and vapor-phase carbon treatment were retained for further analysis. These ex situ treatments will be implemented with hydraulic control/pump-and-treat and SVE technologies described above.

3.5.1 Air Stripping

Air stripping involves the transfer of VOCs from water to air. If necessary, the stripper off-gas can be treated by adsorption described below.

Operating parameters affecting the performance of an air stripping system are the volatility of the target VOCs (as determined by the Henry's Law constant), water temperature, pressure, air-to-water ratio, liquid loading, contact time, and stripper configuration. A packed tower maximizes the air-to-water contact area, resulting in optimum stripping efficiency.

Air stripping has been shown to be effective in treating water containing chlorinated solvent VOCs and SVOCs. The efficiency of air stripping systems can be adversely affected by precipitation of iron hydroxide and carbonates or by formation of bacterial growth on the media. These conditions can be controlled by periodic treatment with appropriate chemicals. Air stripping has been used with pump-and-treat methods for treating chlorinated solvent VOC-affected groundwater. At the JCI site, treated water would be used in the plant as non-contact cooling water and eventually discharged to the lagoon under an approved permit. This technology is considered as a process option. Detailed costs are provided in Appendix A.

3.5.2 Liquid-Phase Carbon Adsorption

Liquid-phase adsorption onto GAC is a widely used technology for removing VOCs, including a majority of the chlorinated solvents, from extracted groundwater. Adsorption occurs when organic molecules are brought into contact with the GAC surface and are held by physical forces. The amount adsorbed is a function of the type and concentration of organic compounds in water and the available GAC surface area. Factors affecting the efficiency of GAC include solubility in water and molecular size of the target compound.

VOCs are adsorbed onto the GAC to the point of saturation, after which the chemicals will pass through the carbon unit. The chemical-laden carbon is either disposed in landfills or regenerated in high-temperature furnaces where the VOCs are destroyed. Regeneration is usually performed off site. Treatment of extracted groundwater by liquid-phase GAC is considered as a process option for polishing groundwater after treatment via air stripping. Associated costs are provided in Appendix A.

3.5.3 Vapor-Phase Carbon Adsorption

Vapor-phase adsorption onto GAC is a process for removing VOCs, including a majority of the chlorinated solvents, from air. It can be used to treat the exhaust from air stripping or SVE units. Removal efficiency is dependent on temperature, residence time, and relative humidity. One field test has demonstrated that air stripping with vapor-phase GAC treatment is very effective and economical compared with liquid-phase GAC treatment. Other studies have shown that the life-cycle costs of these technologies are similar. The technology of vapor-phase carbon treatment is considered as a process option for treating vapors in conjunction with SVE operation. Associated costs are provided in Appendix A.

3.5.4 Biological Treatment

Biological treatment includes various types of ex situ reactors such as trickling filters, activated sludge, sequencing batch reactors, and submerged fixed-film reactors. With these technologies, specific species of bacteria are introduced or existing bacteria are enhanced to degrade a particular chemical or group of chemicals. Reaction conditions can be optimized to increase the rate and extent of biodegradation.

Design of a dedicated biological treatment system for the extracted groundwater at the JCI site would require many special considerations. Biological treatment is generally effective in the treatment of non-chlorinated VOCs; however chlorinated VOCs are typically poor candidates for aerobic biological treatment. These types of compounds are generally not considered degradable in conventional biological treatment systems. This treatment technology is not retained for further consideration.

3.5.5 Vapor Thermal Oxidation

Vapor thermal oxidation is a well-established technology for the destruction of organic compounds in air and can also be used to treat air stripper exhaust streams. A thermal oxidizer consists of an enclosed, refractory-lined chamber with a fuel burner in one end capable of heating the chamber to the required incineration temperature. The chamber is designed to provide a retention time of approximately 0.3 to 1.0 second.

The main advantage of vapor thermal oxidation is its high destruction efficiency. A properly designed and operated thermal oxidizer can reduce organic emissions by at least 80 percent. The main disadvantage of thermal oxidation is the high fuel cost, which can be reduced somewhat by heat recovery. The burner is fired with fuel oil or natural gas. The primary combustion products are carbon dioxide and water. Some carbon monoxide, unburned organic compounds, nitrogen oxides, and (if any chlorides are present) hydrogen chloride are also emitted along with nitrogen and excess oxygen. This treatment technology is not retained for further analysis.

3.5.6 Catalytic Oxidation

Catalytic oxidation is another technology for treating contaminated air, which destroys gaseous waste at low VOC concentrations (less than 25 percent of the lower explosive limit). A catalyst is used to increase the oxidation rate, allowing combustion at much lower temperatures. Catalytic oxidizers can dramatically reduce energy demand by operating at a temperature hundreds of degrees lower than conventional thermal oxidizers and can save a considerable amount of space for equipment compared with vapor thermal oxidizers. In most cases, the gases are preheated by a small auxiliary burner and then passed directly through the catalyst bed for combustion. Because it can operate efficiently at lower temperatures than vapor thermal oxidation, and thus reduce operating costs, catalytic oxidation is preferred over thermal oxidation. However, catalytic incineration of the chemicals of concern for the JCI site would likely require a scrubber to control hydrogen chloride emissions, and the scrubber waste would require pH neutralization and disposal. This technology is not considered for further evaluation.

3.6 Source Removal

This general response action involves excavation of the source area on the JCI site. If applied, this process would involve excavating affected soil and disposing off site at a licensed hazardous waste treatment facility or treating on site using a mobile thermal desorption unit.

Soil excavation using conventional equipment such as backhoes, bulldozers, or large-diameter augers is typically employed in site remediation. Soil excavation is very effective and readily implementable resulting in removal of significant contaminant mass in the subsurface. Clean and/or treated soil is used to fill the excavated zone, and the surface is revegetated. Excavation at the JCI site would occur in the former solvent tank area.

Based on the extent of contamination (Figure 7), the approximate dimension of excavation in the source area is 150 feet long, 20 feet wide, and 15 feet deep. The soil would be excavated from ground surface to approximately 15 feet bgs, which is approximately the groundwater surface. The sides of the excavation would be sloped at 1 horizontal to 1 vertical. The resultant footprint at the surface would be 180 by 50 feet. The estimated volume of soil to be removed due to sloping is 3,300 cubic yards, of which 1,667 cubic yards may be affected. The excavated contaminated soil could be disposed off site or treated on site. Off site disposal would be through a RCRA compliant waste management facility for disposal. Clean soil is used to fill the excavated zone and the surface is revegetated.

Soil excavation with both off-site disposal and on-site treatment options is retained for further analysis. Detailed costs for excavation, off-site disposal and on-site treatment are provided in Appendix A.

3.7 Screening of Technologies

A preliminary screening of technologies against the criteria of effectiveness, implementability, and cost is presented in Table 6. Screening criteria for effectiveness include the degrees to which an alternative reduces toxicity, mobility, and treatment through volume; minimizes residual risks and affords long-term protection; complies with ARARs; minimizes short-term impacts; and expediency with which protection of human health and environment is achieved. Alternatives providing significantly less effectiveness than other more promising alternatives may be eliminated. Alternatives that do not provide adequate protection of human health and environment shall be eliminated from further consideration. Implementability considers technical feasibility, availability of the technology, and the administrative feasibility of implementing a technology. Cost can be used as a screening criterion to retain or eliminate a technology from further consideration.

Suitable technologies were retained for further analysis based on the screening. The retained technologies will be developed into feasible remedial alternatives that can meet the RAOs. Development and evaluation of remedial alternatives are discussed in Section 4.

4.0 DEVELOPMENT OF REMEDIAL ALTERNATIVES

In this section, potentially applicable technologies identified in Section 3 are assembled into remedial alternatives to address affected soil and groundwater at the Site. The remedial alternatives are then analyzed in accordance with the U.S. EPA guidance (U.S. EPA 1988a) in Section 5. A summary of costs for each alternative is provided in Table 7; detailed costs are provided in Appendix A.

As described in Section 1, a PCE source exists in the former solvent tank area. In the unsaturated soils, PCE concentrations range from the MDL to 330,000 μg/kg. In soil samples taken outside the former solvent tank source area, PCE levels ranged from 2 μg/kg to 310 μg/kg and are below the NYSDEC (1994) Technical and Administrative Guidance Memorandum's (TAGM) Recommended Soil Cleanup Objectives (RSCOs; Table 5).

In groundwater, PCE ranged from the MDL to 62,000 μg/l (Table 2). The highest concentrations of PCE (62,000 μg/l) were detected in the overburden monitoring well OP-16 located in former solvent tank area. The PCE concentrations detected in the on-site North and West production wells were 140 and 340 μg/l, respectively.
In groundwater samples taken from outside the source area (i.e., near the lagoon or in the eastern portions of the Site), PCE concentrations were low ranging from MDL to 22 μg/l. At the Site boundary, PCE levels are at or below the groundwater standard of 5 μg/l. Relatively low concentrations of PCE or TCE (less than 10 μg/l) were detected in the bedrock zone wells.

The magnitude of PCE concentration (62,000 μg/l in monitoring well OP-16, and 330,000 μg/kg in soil sample DP-1, both located in the former solvent tank area) indicate the potential presence of DNAPL. PCE concentrations of this magnitude were found to be limited primarily to the former solvent tank area. Relatively lower levels of PCE in groundwater (ranging from 3 to 120 μg/l) and soil (ranging from 2 to 310 μg/kg) were detected outside the former solvent tank area, indicating that the DNAPLs are limited to a small area at the source.

The PCE groundwater plume extends from the former solvent tank source area to east of sulfur dioxide/chlorine department, and to the northeastern property boundary in the vicinity of the pole barns. The length and width of the PCE-affected groundwater plume is slightly over 1,100 feet (along the northeast–southwest axis) and 500 feet (along the north–south axis). Vertically, PCE extends to at least 48 feet bgs in the source area.

In other areas of the Site, such as in the vicinity of OP-6, OP-3, and OP-10, low levels of PCE ranging from 8 to 22 μg/l were detected in groundwater. Although extensive soil sampling was conducted in these areas, no apparent sources were detected.

Development of Remedial Alternatives

The technologies retained in Section 3 are assembled in this Section into suitable remedial alternatives for the soil and groundwater media for the Site.

4.1 SOIL MEDIUM

4.1.1 Soil Alternative #1: No Action

Direct and Indirect Capital Costs:	$0
Annual OM&M:	$0
Net Present Value of operation, maintenance, and monitoring (OM&M):	$0
Net Present Value (Total):	$0

See Table 7 or Appendix A for a detailed breakdown of OM&M costs.

The Superfund program requires that the No Action alternative be considered as a baseline for comparison with the other alternatives. The No Action alternative does not include any physical remedial measures that address affected soil.

Because this alternative would result in contaminants remaining on site above health-based levels, CERCLA requires that the site be reviewed every five years. If justified by this assessment, remedial actions may be implemented in the future to remove or treat the waste.

4.1.2 Soil Alternative #2: SVE of PCE-Affected Soils

Direct and Indirect Capital Costs:	$365,088
Annual OM&M:	$121,632
Net Present Value of OM&M:	$319,201
Net Present Value (Total):	$684,289

See Table 7 or Appendix A for a detailed breakdown of OM&M costs.

Under this alternative, PCE-affected soil in the former solvent tank source area would be remediated by SVE. Site-specific details for the SVE operation is present in Appendix A. The exhaust stream from the SVE would be treated by vapor-phase GAC. The approximate dimensions of the source area are 150 feet long, 20 feet wide, and 15 feet deep. The estimated volume of affected soil is 1,667 cubic yards. Assuming the unit weight of soil is 1.5 tons per cubic yard, the weight of soil requiring remediation is approximately 2,500 tons. Assuming an average PCE concentration of 100 mg/kg, the mass of PCE in the unsaturated soil is 227 kg. It is estimated that the SVE system will operate for a period of three years to effectively treat the affected soils at the source. Routine OM&M will be conducted to evaluate the effectiveness of the SVE system during its operation. In addition, fencing around the lagoons would be implemented to minimize potential exposure.

Under this alternative, the monitoring would be conducted until the SVE process is completed (in three years). The cost to operate and maintain the SVE process would be part of the capital cost.

As noted above, soil concentrations outside the source area such as the lagoons or elsewhere on the Site are below NYSDEC TAGM's (1994) RSCOs.

4.1.3 Soil Alternative #3: Excavation of PCE-Affected Soil

This alternative would involve excavation of affected soil from the former solvent tank storage area. The soil would be excavated from ground surface to approximately 15 feet bgs. The sides of the excavation would be sloped at 1 horizontal to 1 vertical. The resultant footprint at the surface would be 180 feet and 50 feet; the estimated volume of soil to be removed is 3,300 cubic yards, 1,667 cubic yards of which may be affected. Under this alternative, two options to handle and dispose the excavated soil from the source area are discussed below.

Soil Alternative #3A: Off-Site Disposal

Direct and Indirect Capital Costs:	$3,268,816
Annual OM&M:	$0
Net Present Value of OM&M:	$0
Net Present Value (Total):	$3,268,816

See Table 7 or Appendix A for a detailed breakdown of OM&M costs.

Soil exceeding remediation goals would be excavated; confirmatory soil sampling and analysis will be performed. Soil exceeding the remediation goals would be transported to an off-site RCRA compliant waste management facility for disposal. Clean soil would be used to backfill the excavated area.

Soil Alternative #3B: On-Site Treatment

Direct and Indirect Capital Costs:	$1,154,016
Annual OM&M:	$0
Net Present Value of OM&M:	$0
Net Present Value (Total):	$1,154,016

See Table 7 or Appendix A for a detailed breakdown of OM&M costs.

Under this option, excavated soils would be treated on site using a low temperature thermal desorption unit. The off-gas would be treated using a GAC system. Once the treated material achieves NYSDEC TAGM objectives, it would be tested in accordance with the Toxicity Characteristic Leaching Procedures (TCLP) to evaluate whether it constitutes a RCRA hazardous waste. If the material passes the TCLP tests, it would be used to back the area of excavation. Treated material above TCLP levels would undergo further treatment or be disposed of at an approved off-site facility, as appropriate.

4.2 GROUNDWATER MEDIUM

4.2.1 Groundwater Alternative #1: No Further Action

Direct and Indirect Capital Costs:	$0
Annual OM&M:	$50,736
Net Present Value of OM&M:	$629,585
Net Present Value (Total):	$629,585

See Table 7 or Appendix A for a detailed breakdown of OM&M costs.

The Superfund program requires that the No Action alternative be considered as a baseline for comparison with other alternatives. The No Further Action alternative does not include any physical remedial measures that address the affected groundwater at the Site. This alternative would, however, include a long-term groundwater-monitoring program. Under this monitoring program, groundwater samples would be collected and analyzed semi-annually.

For purposes of cost comparisons, it is assumed that semi-annual monitoring of selected wells at the Site would continue for 30 years.

Because this alternative would result in chemicals remaining on site, CERCLA requires that the site be reviewed every five years. If justified by the review, remedial actions may be implemented in the future to remove or treat the wastes.

4.2.2 Groundwater Alternative #2: Source Area Pump-and-Treat/Monitored Natural Attenuation/Institutional Controls

Direct and Indirect Capital Costs:	$362,286
Annual OM&M:	$80,850
Net Present Value of OM&M:	$1,003,275
Net Present Value (Total):	$1,365,561

See Table 7 or Appendix A for a detailed breakdown of OM&M costs.

Under this alternative, the affected groundwater at the source area would be treated through a pump-and-treat system. Because DNAPLs are limited to a very small area at the source, it is anticipated that pump-and-treat would be effective in the overall containment and treatment of the affected groundwater.

Two extraction wells in the overburden zone and one in the bedrock zone at the source and immediately downgradient would be installed to extract the affected groundwater. A sufficient quantity of groundwater (estimated to be 400 gpm) would be extracted to capture large portions of the affected groundwater. Reversing the gradient would hydraulically control migration of affected groundwater.

Groundwater modeling was conducted to estimate the flow rate (400 gpm) required to hydraulically control, capture, and treat the affected groundwater. The results are shown on Figure B-1 in Appendix B. Groundwater extraction wells would be placed in the overburden and bedrock zones in the former solvent tank source area. In addition, an overburden well would be installed to the west of lagoon system to capture the affected groundwater from the vicinity of well OP-9. The overburden and bedrock extraction wells in the source area would be pumped at a flow rate of 100 and 70 gpm, respectively. The overburden extraction well west of the lagoon system would be pumped at a flow rate of 100 gpm. The North Well would be pumped at a flow rate of 130 gpm. The groundwater flow lines and approximate extent of capture zone due to pumping of extraction wells under this alternative are presented on Figure B-1.

The groundwater pump-and-treat system will initially be operated for a period of 15 years. If routine OM&M indicate that groundwater concentrations are not restored to remediation goals, the pump-and-treat system will be extended for additional time.

Extracted groundwater would be pumped to the existing air stripper for treatment and used as non-contact cooling water within the plant prior to being discharged to the on-site lagoons, in accordance with the approved SPDES discharge permit. The present air stripper has a capacity of treating up to 500 gpm (LFR 1997). If required, appropriate air emission controls such as air stripper discharge height modification and/or treatment through GAC would be implemented for compliance with the New York Air Guide regulations.

There would be no active remediation for affected groundwater outside the source area in the vicinity of OP-3, OP-6, northeast of lagoons, and in the eastern portions of the Site (Figure 2). In these areas, the low levels of PCE (less than 22 μg/l) in groundwater would be addressed by monitored natural attenuation (through processes such as biodegradation, dispersion, sorption, volatilization, oxidation-reduction reactions). As part of a long-term groundwater monitoring program, groundwater samples would be collected and analyzed periodically (quarterly for the first two years and semi-annually thereafter) in order to verify that the groundwater concentrations (e.g., chlorinated solvents) are declining and that conditions are protective of human health and the environment. In addition, natural attenuation indicator parameters (e.g., dissolved oxygen, nitrate, sulfate, methane, ethane, ethene, alkalinity, redox potential, pH, temperature, conductivity, chloride, and total organic carbon) would be used to assess the progress of the degradation process.

Institutional controls such as deed restrictions limiting future groundwater use to non-drinking purposes only would be established. Additionally, because of the potential to draw contaminants to deeper water-bearing zones, pumping from the West Well would be discontinued.

4.2.3 Groundwater Alternative #3: Site Wide Pump-and-Treat/ Institutional Controls

Direct and Indirect Capital Costs:	$1,416,565
Annual OM&M:	$181,221
Net Present Value of OM&M:	$1,650,520
Net Present Value (Total):	$3,067,085

See Table 7 or Appendix A for a detailed breakdown of OM&M costs.

Under this alternative, 10 overburden and six bedrock extraction wells would be placed in the source area, northeast of the lagoon system, and in the vicinity of OP-3 and OP-10 to extract and treat affected groundwater (Figures B-2 and B-3). The groundwater pump-and-treat system will initially be operated for a period of 15 years. If routine OM&M indicate that groundwater concentrations are not restored to remediation goals, the pump-and-treat system will be extended for additional time.

Groundwater modeling was conducted to determine optimum number of extraction wells and flow rates required to hydraulically control, capture, and treat affected groundwater at the entire Site including the source area. The results of groundwater modeling is presented in Figures B-2 and B-3 in Appendix B. Preliminary groundwater modeling results indicate that a total flow rate of approximately 1,200 gpm (950 gpm from the overburden zone and 250 gpm from the bedrock zone) would be required to hydraulically control, capture, and treat the affected groundwater. Ten overburden and six bedrock extraction wells would be installed at the Site in locations shown on Figures B-2 and B-3. To prevent "short-circuiting" of flow from the lagoons into the cone of influence, groundwater pumping from the North Well would be ceased. The groundwater flow lines and approximate extent of capture zone due to pumping of extraction wells under this alternative is depicted on Figures B-2 and B-3.

Because the present capacity of the air stripper (500 gpm) would be exceeded, an additional air stripper would be designed and constructed to treat the extracted groundwater. On-site discharge of treated groundwater is very critical in effectively capturing the extent of the affected groundwater. Groundwater modeling results indicate that discharging 300 gpm of treated groundwater to the on-site lagoons and the remaining 900 gpm to an infiltration gallery to be constructed to the northeast of the lagoon system would result in an effective capture of the affected groundwater as shown in Figures B-2 and B-3.

If required, air stripping of groundwater would include appropriate air emission controls such as air stripper discharge height modification and/or treatment using GAC for compliance with the New York Air Guide regulations.

Under this alternative, institutional controls such as deed restrictions limiting future groundwater use to non-drinking purposes only would be established. Additionally, because of the potential to draw contaminants to deeper water-bearing zones, pumping from the West Well would be discontinued.

4.2.4 Groundwater Alternative #4: Source Area Pump-and-Treat/Monitored Natural Attenuation/Institutional Controls/$KMnO_4$ Injection

Direct and Indirect Capital Costs:	$478,596
Annual OM&M:	$115,170
Net Present Value of OM&M:	$1,143,993
Net Present Value (Total):	$1,622,589

See Table 7 or Appendix A for a detailed breakdown of OM&M costs.

This groundwater alternative is similar to Groundwater Alternative #2; in addition to pump-and-treat of the source area, $KMnO_4$ solution would be injected in the source area to enhance treatment of DNAPL PCE.

$KMnO_4$ solution would be injected in the source area only after hydraulic control has been achieved. Because DNAPL appears to be limited to a small portion at the source, a program of periodic injection of small volumes of dilute $KMnO_4$ solution within the source area, with injection timing and mass flow rate designed to provide chemical oxidation of PCE, will be implemented to accelerate DNAPL remediation. For free flow grade of $KMnO_4$ solution at 3 percent (30 grams per liter [g/l]), the Chromium^{+6} (Cr^{+6}) concentration was measured at 392 mg/l. Based on this relationship it was estimated that if $KMnO_4$ solution of 3.85 was injected, Cr^{+6} concentration would be less 50 μg/l. New York State groundwater standard for Cr^{+6} is 50 μg/l; federal groundwater standard is 100 μg/l. It is also expected that trace metal concentrations would be below the groundwater standards if dilute $KMnO_4$ solution of 3.85 g/l or less was injected. Secondary standards such as color and hardness may be exceeded during injection of $KMnO_4$. Because a small volume of $KMnO_4$ solution would be injected within the influence of the pump-and-treat system, problems associated with color and hardness are expected to be minimal.

Extraction wells in the overburden and bedrock zone would be installed in the source area and pumped at 100 and 70 gpm, respectively. In addition, another overburden extraction well would be installed west of the lagoon system and pumped at 100 gpm. The North Well would continue to be pumped at a flow rate of 130 gpm. A total of 400 gpm would be pumped from the source area and its vicinity to hydraulically control and treat affected groundwater (Figure B-1). Affected groundwater outside the source area would be addressed by monitored natural attenuation. Institutional controls limiting future groundwater usage would be established to minimize exposure.

Extracted groundwater will be pumped to the existing air stripper for treatment and later use as non-contact cooling water within the plant prior to being discharged to the on-site lagoons in accordance with the approved SPDES discharge permit. The present air stripper can treat up to 500 gpm (LFR 1997). If required, air stripping of groundwater would include appropriate air emission controls such as air stripper discharge height modification and/or treatment using GAC unit for compliance with the New York Air Guide regulations.

There would be no active remediation for affected groundwater outside the source area in the vicinity of OP-3, OP-6, northeast of lagoons, and in the eastern portions of the Site (Figure 2). In these areas, the low levels of PCE (less than 22 μg/l) in groundwater would be addressed by monitored natural attenuation as described above.

The groundwater pump-and-treat system will be initially operated for a period of 15 years; periodic injection of $KMnO_4$ solution will be conducted for five years. If routine OM&M indicate that groundwater concentrations are not restored to remediation goals, the pump-and-treat system will be extended for additional time. Monitored natural attenuation will be conducted for a period of 30 years.

4.2.5 Groundwater Alternative #5: Site Wide Monitored Natural Attenuation/Institutional Controls

Direct and Indirect Capital Costs:	$84,820
Annual OM&M:	$80,850
Net Present Value of OM&M:	$1,003,275
Net Present Value (Total):	$1,088,095

See Table 7 or Appendix A for a detailed breakdown of OM&M costs.

Under this alternative, there would be no treatment of affected groundwater with the exception of continued pump-and-treat of groundwater from the North Well for use in the daily plant operations. As permitted by SPDES, the approximately 280 gpm of groundwater being pumped from North Well for use as non-contact cooling water would continued to be treated by the existing on-site air stripper prior to its discharge to the on-site lagoon system.

Affected groundwater at the source and remainder of the Site would be addressed by natural attenuation. Periodic sampling of natural attenuation indicator parameters would be conducted to monitor groundwater quality. Monitored natural attenuation would be conducted for a period of 30 years. Institutional controls, such as deed restrictions limiting future groundwater usage to non-drinking purposes only would be established to minimize potential exposure.

5.0 DETAILED ANALYSIS AND COMPARATIVE EVALUATION OF REMEDIAL ALTERNATIVES

The remedial alternatives described in Section 4 are analyzed in greater detail in this section against the criteria specified in the NCP and U.S. EPA guidance (U.S. EPA 1988a); the nine evaluation criteria are defined below. The alternatives are then compared in Section 5.3 to identify their advantages and disadvantages.

5.1 Evaluation Criteria

The nine evaluation criteria are described below.

The first two criteria are the "threshold" factors that must be met in order for an alternative to be considered for implementation.

1. Overall Protection of Human Health and the Environment. This criterion assesses whether an alternative is protective of human health and the environment, considering the Site's characteristics and the expected risk reduction achieved. Assessment is based on the protection provided by each alternative and how each is affected by other criteria, especially long-term effectiveness and permanence, short-term effectiveness, toxicity, mobility, and volume reduction, and compliance with ARARs.
2. Compliance with ARARs. This criterion determines whether a remedial alternative will comply with regulatory requirements. Compliance with chemical-specific, location-specific, and action-specific ARARs is required. RAOs and PRGs for the Site were established.

There are five "primary balancing" criteria used to make comparisons and to identify the major trade-offs among the remedial alternatives. Alternatives that satisfy the threshold criteria are evaluated further using the following five criteria:

3. Long-Term Effectiveness and Permanence. This criterion examines the impact of an alternative in the long term, defined in U.S. EPA guidance as the time after remedial action objectives have been met (U.S. EPA 1988a). The magnitude of residual risk and the adequacy and reliability of controls are considered.
4. Reduction of Toxicity, Mobility, and Volume through Treatment. This criterion evaluates the degree to which treatment processes are used to reduce the toxicity, mobility, and volume of affected material compared to conditions prior to the remedial action. By including this criterion, U.S. EPA has explicitly stated that treatment is preferred to other options. Production and management of hazardous residuals resulting from the treatment process must be considered to evaluate the potential for continued toxicity and mobility.
5. Short-Term Effectiveness. This criterion considers the impact of an alternative in the short term, defined in U.S. EPA guidance as the time required for planning, construction, and operation of remediation systems until remedial action objectives are achieved (U.S. EPA 1988a). Impacts on workers, the community, and the environment must be considered. The amount of time required to attain remedial action objectives, i.e., the estimated duration of the short term, is also a factor.
6. Implementability. This criterion evaluates the technical and administrative feasibility of implementing an alternative. Technical feasibility focuses on factors related to construction and operation of the alternative and also includes the availability of required equipment, materials, and services ranging from heavy construction equipment to laboratory services. Administrative feasibility addresses

the practical availability of requirements such as construction permits, permits for groundwater extraction, permits for discharge, access agreements, etc.

7. Costs. This criterion includes costs considerations such as capital and operation and maintenance costs, and net present-worth costs. Operating life is controlled by the time required to remediate VOC-affected groundwater. For No Action, this could be a relatively long period. A period of 30 years is assumed for purposes of cost estimation since the actual remediation time cannot be determined precisely. U.S. EPA guidance (U.S. EPA 1988a) recommends limiting such analyses to 30 years, and a longer analysis period would not result in substantial differences in estimated present worth.

The remaining two criteria, regulatory acceptance and community acceptance, are "modifying" factors. Both these criteria are evaluated by the regulatory agencies.

8. State Acceptance. This criterion evaluates an alternative with respect to the concerns of state or local agencies as ascertained through guidance documents and input solicited during preparation of this study.
9. Community Acceptance. This assessment evaluates the issues and concerns of the community regarding each alternative.

5.2 Detailed Analysis of the Remedial Alternatives

Analysis of remedial alternatives for the soil and groundwater media are analyzed in detail against seven of the nine criteria described above (U.S. EPA 1988a). Criteria 8 and 9, State Acceptance and Community Acceptance, will be evaluated by the U.S. EPA in the Proposed Plan and Record of Decision (ROD), respectively.

5.2.1 Soil Medium

Three remedial alternatives for the soil medium are analyzed below. The alternatives include: (1) No Action, (2) SVE, and (3) Soil Excavation.

5.2.1.1 Soil Alternative #1: No Action

The Superfund program requires that the No Action alternative be considered as a baseline for comparison with the other alternatives. The No Action alternative does not include any physical remedial measures that address the affected soil.

Because this alternative would result in contaminants remaining on site above health-based levels, CERCLA requires that the site be reviewed every five years. If justified by this assessment, remedial actions may be implemented in the future to remove or treat the waste.

- **Overall Protection of Human Health and the Environment.** The PCE concentrations in the unsaturated soils at the former solvent tank source area range from 110 μg/kg to 330,000 μg/kg. The concentrations of this magnitude in the shallow depth soils at the source represent a potential risk to on-site workers via inhalation or dermal contact. Without remediation, the affected soils will continue to leach contaminants to the groundwater. Therefore, the No Action alternative cannot be considered as protective of human health and the environment.

- **Compliance with ARARs.** The chemical-specific ARARs identified for the study area is the attainment of remediation goals for the chemicals of concern, and for RAOs for the Site. This alternative would not achieve compliance with the remediation goals or meet RAOs for many decades, because there would be no active remediation of the source area. Chemicals in the soil would continue to leach and act as sources of contamination for the groundwater. This alternative does not invoke any location-specific or action-specific ARARs.
- **Long-Term Effectiveness and Permanence.** Because the RAOs would not be met for many years, assessment of long-term effectiveness and permanence of this alternative is not possible. There would be no remedial construction in the source to assure permanent compliance with RAOs other than periodic sampling and analysis of wells to monitor groundwater flow and quality.
- **Reduction of Toxicity, Mobility, and Volume through Treatment.** Toxicity, mobility, and volume would not be reduced under in this No Action alternative. The volume of affected groundwater could actually increase, because of a lack of active source remediation.
- **Short-Term Effectiveness.** The time to achieve RAOs would be longer with this alternative than any other. No other potential impacts are anticipated because of the lack of a remediation system with this alternative.
- **Implementability.** This alternative could be easily implemented.
- **Cost.** There are no costs for this No Action alternative for the soil medium.

5.2.1.2 Soil Alternative #2: SVE of PCE-Affected Soil

This alternative includes source area treatment via SVE. The approximate dimensions of the PCE-affected source area are 150 feet in length, 20 feet wide and 15 feet deep. The estimated volume of affected soil is 1,667 cubic yards. Assuming the unit weight of soil is 1.5 tons per cubic yard, the weight of soil requiring remediation is approximately 2,500 tons. Assuming an average PCE concentration of 100 mg/kg, the mass of PCE in the unsaturated soil is 227 kg. It is estimated that SVE and associated OM&M would be conducted for period of three years.

In addition to SVE, fencing around the source area and lagoons would be implemented to minimize exposure.

- **Overall Protection of Human Health and the Environment.** Active remediation by SVE technology would treat the unsaturated soils at the source to remediation goals in a relatively short period of time. Further protection of human health and environment would be provided through fencing the source area and lagoons. This alternative would provide effective protection for human health and environment.

- **Compliance with ARARs.** This alternative would comply with the chemical-specific ARARs. SVE treatment of PCE-affected soil in the source area would achieve the soil remediation goals (Table 5). This alternative would comply with the action-specific ARARs related to treatment and discharge of the SVE exhaust stream. The extracted vapors would be treated using GAC. Spent GAC would be tested to determine its classification under RCRA and would be managed in compliance with RCRA requirements. This alternative does not invoke any location-specific ARARs.
- **Long-Term Effectiveness and Permanence.** After soil remediation goals have been met, no further treatment would be required. Long-term protection of human health and environment can be maintained as there would be no residual chemicals left at the source.
- **Reduction of Toxicity, Mobility, and Volume through Treatment.** Under this alternative, the SVE system would significantly reduce the toxicity, mobility, and volume by effectively remediating the affected soils in the source area. Remediation of affected soil in the source area would eliminate further leaching of chemicals to groundwater. Because chemicals are destroyed at the source, the treatment is irreversible. Potential toxicity resulting from exhaust streams would be addressed by treating the vapors via GAC adsorption.
- **Short-Term Effectiveness.** It is estimated that the soil remediation goals would be attained in three years or less using the SVE technology. Remediation of the source area a significant reduction of exposure to the affected shallow-depth soils through ingestion or inhalation. There is a potential for on-site construction workers to come into contact with affected soil during installation and OM&M of the SVE system. However, this may be minimized through use of appropriate protective equipment and clothing. Exposure of SVE off-gas will be addressed via GAC adsorption. Because the source area is relatively small, disturbances to local neighborhood will be minimal. Construction time is estimated to 20 working days.
- **Implementability.** This alternative could be easily implemented and maintained throughout its operational period. SVE has been implemented successfully in similar situations to treat soil affected with chlorinated solvents. Equipment, services, and materials for this work are readily available. GAC units are readily available to treat off-gas. Monitoring the effectiveness of the system can be easily accomplished through vapor and soil sampling and analysis. As there are no off-site or surface discharges, approvals and permits from local agencies can be obtained with relative ease. SVE has been selected as a remedy at numerous State and Superfund Sites. Fencing is also relatively easy to implement.
- **Cost.** As shown in Appendix A, the total net present value for Alternative 2 is estimated at $684,289. These costs include a program for SVE off-gas sampling to monitor its effectiveness. The cost also includes confirmatory soil sampling and analysis.

5.2.1.3 Soil Alternative #3: Excavation of PCE-Affected Soil

This alternative would involve excavation of affected soil from the source area; the former solvent tank storage area. The soil would be excavated from the ground surface to about 15 feet bgs. The sides of the excavation would be sloped at 1 horizontal to 1 vertical. The resultant footprint at the surface would be 180 feet and 50 feet; the estimated volume of soil to be removed is 3,300 cubic yards, 1,667 cubic yards of that may be affected. There are two options to handle and dispose the excavated soil from the source area. Under soil alternative #3A, excavated soils exceeding remediation goals would be transported off site and disposed through a licensed hazardous waste contractor. Clean soil would be brought in to fill the excavated area. Under soil alternative #3B, excavated soil exceeding remediation goals would be treated on site using a mobile low temperature thermal desorption unit; the off-gas would be treated using a GAC system. The affected soil would be treated to below remediation goals, tested in accordance with chemical-specific cleanup levels and TCLP and backfilled in the excavation.

- **Overall Protection of Human Health and the Environment.** This alternative would provide effective protection for human health and environment because it represents removal of the source area. The unsaturated soils exceeding remediation goals would be excavated. The affected soil would be either disposed off site or treated on site and backfilled in the excavation area after testing for effectiveness. Because the source will be removed, further leaching to groundwater would be eliminated. Additional protection of human health and environment would be provided by fencing the lagoons.
- **Compliance with ARARs.** This alternative would comply with the chemical-specific ARARs. Excavation of the affected soils in the source area would achieve the soil remediation goals. This alternative would comply with the action-specific ARARs related to excavation, transportation, and off-site treatment/disposal of hazardous waste through a licensed contractor. This alternative would also comply with the action-specific ARARs related to on-site treatment and off-gas discharge during treatment of excavated soil. Spent GAC would be tested to determine its classification under RCRA and would be managed in compliance with RCRA requirements. This alternative does not invoke any location-specific ARARs.
- **Long-Term Effectiveness and Permanence.** After soil excavation and off-site disposal or on-site treatment, no further remediation would be required in the source area. This alternative would provide reliable, long-term protection and permanence.
- **Reduction of Toxicity, Mobility, and Volume through Treatment.** Under this alternative, the excavation and off-site disposal or on-site treatment of PCE-affected soil would significantly reduce the toxicity, mobility, and volume. Remediation of the source area would eliminate leaching of chemicals to groundwater. Toxicity associated with off-gas treatment during on-site treatment of affected soil could be reduced via a GAC unit. Remedy through this alternative can be considered irreversible because there would be no residuals left at the source.

- **Short-Term Effectiveness.** Soil remediation goals may be attainable in one year or less under this alternative. There is a potential for construction workers to come into contact with affected soil during excavation, disposal, and/or on-site treatment. However, this may be minimized through use of appropriate protective equipment and clothing. Exposure to off-gases from the mobile low temperature thermal desorption unit would be minimized by using a GAC system. This alternative would cause excessive disruption to local residential neighborhoods especially during operation of the heavy equipment used for excavation, movement of trucks carrying hazardous waste for off-site disposal, and noise levels associate with on-site treatment of soils using a low thermal desorption unit. Fugitive dust associated with the excavation may also impact local residential neighborhoods. Alternative of surface topography is expected to be minimal due to the small area of excavation. Completion time for this alternative is estimated to be 45 working days.
- **Implementability.** Technically, this alternative could be implemented with relative ease. Equipment for excavation and off-site disposal are readily available. Equipment for on-site treatment of the affected soil using a low thermal desorption unit and GAC are readily available. Effectiveness of remedy through this alternative can be easily monitored through confirmatory sampling. However, obtaining regulatory permits for excavation, off-site disposal and/or on-site treatment of soils could pose administrative difficulty. Coordination between several state and local agencies will be necessary in order to implement this alternative.
- **Cost.** As shown in Appendix A, the total net present value for soil Alternatives #3A and #3B is estimated at $3,268,816 and $1,154,016, respectively.

5.2.2 Groundwater Medium

Five remedial alternatives described in Section 4 for the groundwater medium are analyzed in detail here. The alternatives include: (1) No Further Action, (2) Source Area Pump-and-Treat/Monitored Natural Attenuation/Institutional Controls, (3) Site Wide Pump-and-Treat/Institutional Controls, (4) Source Area Pump-and-Treat/Monitored Natural Attenuation/Institutional Controls/$KMnO_4$ Injection, and (5) Site Wide Monitored Natural Attenuation/Institutional Controls

5.2.2.1 Groundwater Alternative #1: No Further Action

Under this alternative, there would be no physical remediation of affected groundwater at the Site. A program would be established to monitor groundwater flow and contaminant distributions over time. Semi-annual monitoring of selected wells at the Site would be conducted for 30 years.

The purpose this alternative is to provide a baseline for comparison with other remedial alternatives.

- **Overall Protection of Human Health and the Environment.** PCE concentrations in the source area (former solvent storage tank area) ranging up to 62,000 μg/l, clearly exceed the groundwater remediation goals (Table 5). Although slightly, the concentrations in the plume exceed remediation goals. Without remediation or adequate control, the groundwater plume will continue to migrate hydraulically downgradient, resulting in potential exposure. Therefore, this alternative cannot be considered protective of human health and the environment.
- **Compliance with ARARs.** This alternative would not achieve compliance with the remediation goals or meet RAOs for many decades, because of a lack of active remediation. Chemicals in the groundwater would continue to result in groundwater plumes. This alternative does not invoke any location-specific or action-specific ARARs.
- **Long-Term Effectiveness and Permanence.** Because the RAOs would not be met for many years, assessment of long-term effectiveness and permanence of this alternative is not possible. There would be no remedial construction to assure long-term effectiveness or permanent compliance other than periodic sampling and analysis of wells to monitor groundwater flow and quality.
- **Reduction of Toxicity, Mobility, and Volume through Treatment.** Toxicity, mobility, and volume would not be reduced through treatment under this alternative. The volume of affected groundwater could actually increase, because of a lack of active source remediation.
- **Short-Term Effectiveness.** The time to achieve RAOs would be longer with this alternative than any other, probably several decades. No potential impacts to on-site workers or local residential neighborhoods are anticipated because of a lack of remediation system under this alternative.
- **Implementability.** This alternative could be easily implemented.
- **Cost.** As shown in Appendix A, the total net present value for this alternative is estimated at $629,585. These costs include a program where groundwater samples and water levels are collected and measured semi-annually for 30 years to evaluate changes in groundwater flow and quality.

5.2.2.2 Groundwater Alternative #2: Source Area Pump-and-Treat/Monitored Natural Attenuation/Institutional Controls

Under this alternative, the source area at the former solvent tank storage area would be remediated by pump-and-treat technology. It is estimated that it would require 15 years to reach remediation goals. It is anticipated that two overburden wells and one bedrock well would be installed (Figure B-1) in the source area and hydraulically downgradient to pump-and-treat the groundwater. An estimated 400 gpm (100 gpm each from the overburden wells OEW-1, OEW-2; 130 gpm from North well; and 70 gpm from the bedrock well BEW-1) would be extracted and treated. The extracted groundwater would be treated with the existing air stripper; the treated water would be used in the plant operations as non-contact cooling water prior to discharging to the lagoons. The exhaust streams would need to comply with New York State Air Guidelines. Therefore, to meet these requirements, appropriate modifications and/or GAC treatment would be implemented, if necessary.

Under this alternative, the groundwater outside the source would be addressed by monitored natural attenuation processes. It is expected that by aggressively remediating the source, the low levels of PCE outside the source would naturally attenuate. Groundwater data collected over a two-year period show significant reductions in chlorinated solvent concentrations. For the purposes of this FS, monitoring of the natural attenuation would be conducted for a period of 30 years; quarterly for a period of two years and semi-annually thereafter.

Although the Site has been industrial since 1939 and is expected to remain industrial for the conceivable future, under this alternative, institutional controls such as deed restrictions limiting future groundwater use for non-potable purposes would be established. Drinking water at the Site and much of its vicinity is supplied through the Village of Caledonia Water Supply system. Pumping from West well will be ceased, because of a potential to draw chemicals to deeper water-bearing zones.

- **Overall Protection of Human Health and the Environment.** Because the affected groundwater would be hydraulically contained via a pump-and-treat system, this alternative would provide adequate protection for human health and environment. Pump-and-treat operations would result in a significant reduction of the dissolved-phase chemical mass at the source. The relatively low PCE concentrations in the plume are expected to attenuate naturally, especially with pump-and-treat/hydraulic control implemented in the source area. Further protection would be provided through institutional controls such as deed restrictions limiting future groundwater use to non-potable only.
- **Compliance with ARARs.** This alternative may not comply with the chemical-specific ARARs. Potential DNAPLs at the source may continue to act as long-term sources. Due to "rebound" effects (described in Section 3), contaminants sorbed onto soil dissolve into groundwater upon cessation of pump-and-treat systems. The low levels of PCE outside the source area will likely attenuate naturally with time and comply with chemical-specific ARARs in reasonable time. Groundwater monitoring data (Table 3) show significant decrease in PCE concentrations over a relatively short period of two years. This alternative would comply with the action-specific ARARs related to treatment and discharge of extracted groundwater. Spent GAC would be tested to determine its classification under RCRA and would be managed in compliance with RCRA requirements. This alternative does not invoke any location-specific ARARs.
- **Long-Term Effectiveness and Permanence.** This alternative would afford long-term effectiveness and permanence as long as the pump-and-treat system is operational. Migration of affected groundwater would be contained, minimizing potential exposures. In addition, due to treatment of affected groundwater significant mass reductions may be achieved. The existing air stripper would be

used to treat the extracted groundwater. The treated water would be used in the plant as non-contact cooling water prior to discharging it to the lagoons.

- **Reduction of Toxicity, Mobility, and Volume through Treatment.** Pump-and-treat system would not only contain further migration of affected groundwater but also treat dissolved-phase chemicals. Therefore, this alternative would achieve reduction of toxicity, mobility and volume. Based on groundwater monitoring data, monitored natural attenuation would be effective in restoring the slightly affected groundwater outside the source.
- **Short-Term Effectiveness.** Groundwater remediation goals may not be attainable in reasonable time due to the potential DNAPL presence. However, hydraulic control due to pump-and-treat can be achieved in a relatively short period of time. With active remediation of the source, the slightly affected groundwater outside the source area would be restored by natural attenuation processes. There is a slight potential for construction workers to come into contact with the affected groundwater during installation of extraction wells, pump-and-treat and/or OM&M. However, with this exposure may be minimized through use of appropriate protective equipment and clothing. If required, exposure to the air stripper off-gas will be addressed by modifying the discharge height of the air stripper or using a GAC system. The time required to construct and conduct startup activities is estimated to be 45 days.
- **Implementability.** This alternative is easy to construct, operate, and maintain. Pump-and-treat systems have been implemented successfully in similar situations to treat and hydraulically control groundwater affected with chlorinated solvents. Equipment, services, and materials for this work are readily available. Because an air stripper is already in operation at the Site, implementing the groundwater pump-and-treat system would be relatively easy. New extraction wells would be drilled in the source area and its vicinity. The affected groundwater from the newly installed extraction wells would be pumped via submersible groundwater pumps and buried pipes to the air stripper for treatment. The treated groundwater would be used in the plant as non-contact cooling water and discharged to the lagoons consistent with the technical requirement of an SPDES permit. Monitored natural attenuation and institutional controls such as deed restrictions, are also relatively easy to implement. This action would be terminated once remediation goals have been met for an extended period of time under non-pumping conditions.
- **Cost.** As shown in Appendix A, the total net present value for this is estimated at $1,365,561. These costs include pump-and-treat for 15 years with routine OM&M, a program to conduct monitored natural attenuation for 30 years and institutional controls to establish deed restrictions limiting groundwater usage to non-potable only.

5.2.2.3 Groundwater Alternative #3: Site Wide Pump-and-Treat/Institutional Controls

Under this alternative, the affected groundwater at the Site would be remediated by pump-and-treat. The pump-and-treat system would be operated for an estimated 15 years.

Groundwater modeling was conducted to determine the optimum number of extraction wells and flow rates required to hydraulically control, capture, and treat affected groundwater at the entire Site (Figures B-2 and B-3). To effectively capture the affected groundwater, 10 overburden and 6 bedrock wells are proposed at strategic locations at the Site. Approximately 1,200 gpm or 1.7 million gallons a day (950 gpm from the overburden zone wells and 250 gpm from the bedrock zone wells) would be extracted to hydraulically control, capture, and treat the affected groundwater. To prevent "short-circuiting" of flow from the lagoons into the cone of influence, groundwater pumping from the North Well would be ceased. The groundwater flow lines and approximate extent of the capture zone due to pumping of extraction wells under this alternative is depicted on Figures B-2 and B-3.

Because the present capacity of the air stripper (500 gpm) would be exceeded, an additional air stripper would be designed and constructed to treat the extracted groundwater. About 300 gpm of treated groundwater would be discharged to the on-site lagoons and the remaining 900 gpm to an infiltration gallery, to be constructed to the northeast of the lagoon system (Figures B-2 and B-3).

If required, air stripping of groundwater would include appropriate air emission controls such as air stripper discharge height modification and/or treatment using GAC for compliance with the New York Air Guide.

Under this alternative, institutional controls such as deed restrictions limiting future groundwater use to non-potable, would be established. Additionally, because of the potential to draw contaminants to deeper water-bearing zones, pumping from the West well would be discontinued.

- **Overall Protection of Human Health and the Environment.** This alternative would provide adequate protection because affected groundwater would be hydraulically contained via pump-and-treat. Pump-and-treat operations would significantly reduce the dissolved-phase chemical mass at the source. Further protection would be provided through institutional controls such as deed restrictions limiting future groundwater use to non-potable only.
- **Compliance with ARARs.** As discussed above, pump-and-treat remedy under this alternative may not comply with the chemical-specific ARARs because of potential DNAPLs at the source. Monitored natural attenuation would be effective in complying with the chemical specific ARARs for the slightly affected groundwater outside the source. Groundwater sampling at the Site indicates significant decreases in PCE concentrations over a relatively short period of two years (Table 3).

This alternative would comply with the action-specific ARARs related to treatment and discharge of extracted groundwater. Spent GAC would be tested to determine its classification under RCRA and would be managed in compliance with RCRA requirements. This alternative does not invoke any location-specific ARARs.

- **Long-Term Effectiveness and Permanence.** Long-term effectiveness and permanence would be achieved as long the site wide pump-and-treat is in operation. Significant mass reductions are likely through the treatment of the dissolved phase. The existing air stripper would continue to treat the extracted groundwater. The treated water would be used within the plant as non-contact cooling water prior to discharging it to the lagoons.
- **Reduction of Toxicity, Mobility, and Volume through Treatment.** The pump-and-treat system under this alternative would not only contain further migration of affected groundwater but also treat dissolved-phase chemicals. Therefore, this alternative would achieve reduction of toxicity, mobility, and volume. Based on groundwater monitoring data, monitored natural attenuation would be effective in restoring the slightly affected groundwater outside the source.
- **Short-Term Effectiveness.** Although hydraulic control can be achieved in a reasonable time frame via pump-and-treat, groundwater at the source may not be restored for a long time (possibly many decades) due to the potential presence of DNAPLs. Affected groundwater outside the source would be restored to remediation goals in a reasonable time frame. There is a potential for construction workers to be exposed to affected soils and groundwater during installation of the 10 overburden and 6 bedrock extraction wells extraction wells, pump-and-treat system and/or routine OM&M. However, potential exposure may be minimized through use of appropriate protective equipment and clothing. If required, exposure to the air stripper exhaust stream would be addressed by modifying the discharge height of the air stripper and/or using a GAC system. Trenching activities to pipe the extracted groundwater to treatment units would disrupt onsite traffic and affect on-site personnel. The extensive drilling would result in noise disruption to local residential neighborhoods. The time required to construct and conduct start-up activities under this alternative is approximately 90 days.
- **Implementability.** This alternative will not be easy to construct, operate, and maintain, both technically and administratively. Installation and development of 16 extraction wells would involve extensive drilling and handling investigation derived waste potentially exposing on-site construction workers. Although equipment is readily available, installation operation and maintenance of 16 submersible pumps, and trenching/piping to route extracted groundwater (about 1.7 million gallons a day) to the air stripper for treatment will not be easy. OM&M will be extensive requiring large sampling events. Institutional controls such as deed restrictions are relatively easy to implement.
- **Cost.** As shown in Appendix A, the total net present value for this is estimated at $3,067,085. These costs include pump-and-treat for 15 years with routine OM&M, and institutional controls to establish deed restrictions limiting groundwater usage to non-potable only.

5.2.2.4 Groundwater Alternative #4: Source Area Pump-and-Treat/Monitored Natural Attenuation/Institutional Controls/$KMnO_4$ Injection

This groundwater alternative is similar to Groundwater Alternative #2; but under this alternative, an additional technology ($KMnO_4$ Injection) would be implemented to treat DNAPLs.

$KMnO_4$ solution would be injected in the source area to enhance treatment of dissolved-phase and DNAPL PCE. $KMnO_4$ solution would be injected only after hydraulic control has been achieved. Because DNAPL appears to be limited to a small portion at the source, periodic injection of small volumes of dilute $KMnO_4$ solution within the source area, with injection timing and mass flow rate designed to provide chemical oxidation of PCE, will be implemented for a period of five years.

As discussed in Section 4 and in Appendix A, by injecting $KMnO_4$ solution at concentrations of 3.85 μg/l, the Cr+6 concentrations would be below the New York State groundwater standard of 50 μg/l. It is also expected that the concentrations of trace metals would be below the groundwater standards, if dilute $KMnO_4$ solution of 3.85 μg/l strength is injected. Secondary standards such as color and hardness may be exceeded during injection of $KMnO_4$. Because a small volume of $KMnO_4$ solution would be injected within the cone of influence of the pump-and-treat system, exceedances of color or hardness standards are expected to be minimal.

- **Overall Protection of Human Health and the Environment.** This alternative would provide protection of human health and environment beyond groundwater alternative #2. Under this alternative, pump-and-treat would hydraulically contain and treat the affected groundwater at the source. DNAPLs would be treated by $KMnO_4$ injection. By aggressively treating and hydraulically containing the source, it is expected that low levels of PCE (less than 22 μg/l) outside the source will be attenuate naturally via biodegradation processes. Further protection would be provided through institutional controls such as deed restrictions limiting groundwater use to non-potable only.
- **Compliance with ARARs.** This alternative would comply with the chemical-specific ARARs. The dissolved phase chemicals and DNAPL PCE would be treated via pump-and-treat and $KMnO_4$ injection, respectively. There is a slight potential for color and hardness to exceed secondary standards. However, with hydraulic containment in place via pump-and-treat exceedances of color and hardness standards may be minimal. With aggressive treatment of the source, monitored natural attenuation would be effective in complying with the chemical specific ARARs for the slightly affected groundwater outside the source. Groundwater sampling shows significant decrease in PCE concentration over a relatively short period of two years (Table 3). This alternative would comply with the action-specific ARARs related to treatment and discharge of extracted groundwater. Spent GAC would be tested to determine its classification under RCRA and would be managed in compliance with RCRA requirements. This alternative does not invoke any location-specific ARARs.

- **Long-Term Effectiveness and Permanence.** Because both the dissolved-phase chemicals and DNAPL PCE are being more aggressively treated at the source, this alternative would provide long-term effectiveness and permanence. The relatively low concentrations of PCE in groundwater outside the source area would be addressed by monitored natural attenuation. The existing air stripper would continue to treat the extracted groundwater. The treated water would be used in the plant as non-contact cooling water prior to discharging it to the lagoons under an approved SPDES permit. Natural attenuation would be monitored for a period of 30 years.
- **Reduction of Toxicity, Mobility, and Volume through Treatment.** Under this alternative, treatment of both dissolved phase and DNAPL PCE would significantly reduce the toxicity, mobility, and volume. Toxicity associated with exhaust streams would be reduced via a GAC unit. Remedy through this alternative is irreversible because there would be minimal residuals left at the source. Pump-and-treat would also minimize further migration of affected to groundwater. Monitored natural attenuation would address the low levels of PCE (less than 22 μg/l) outside the source; previous groundwater sampling shows significant decrease in PCE concentrations.
- **Short-Term Effectiveness.** $KMnO_4$ injection and pump-and-treat would be implemented for an estimated period of 5 and 15 years, respectively. Because of a relatively small source area, groundwater remediation goals may be attainable within the duration of the systems' operations. Hydraulic control due to pump-and-treat can be achieved in a relatively short period of time. With active pump-and-treat and $KMnO_4$ injection at the source, the affected groundwater (less than 22 μg/l) outside the source would naturally attenuate. There is a slight potential for construction workers to come in contact with the affected soil and groundwater during installation of extraction wells, pump-and-treat, $KMnO_4$ treatment and/or OM&M. However, the exposure may be minimized through use of appropriate protective equipment and clothing. If required, exposure to the air stripper off-gas would be addressed by modifying the discharge height of the air stripper or using a GAC system.
- **Implementability.** This alternative would be relatively easy to install, operate, and maintain. $KMnO_4$ injection, which is an emerging technology, has been implemented at a few sites across the United States to treat DNAPL PCE. (LFR has successfully implemented $KMnO_4$ injection at other chlorinated solvent sites). $KMnO_4$, mixing tanks, injection pump, and appurtenances are readily available. A field test may be required prior to designing the full-scale system. Pump-and-treat systems have been implemented successfully at numerous sites to treat and hydraulically control groundwater affected with chlorinated solvents. Equipment, services, and materials for this work are readily available. Because an air stripper is already in operation at the Site, implementing the groundwater pump-and-treat system would be relatively easy. New extraction and injection (for injecting $KMnO_4$) wells would be drilled in the source area and its vicinity. Affected groundwater from the newly installed extraction wells would be pumped via submersible groundwater pumps and buried pipes to the existing air stripper for

treatment. The treated groundwater would be used in the plant as non-contact cooling water and discharged to the lagoons under an approved SPDES permit. Monitored natural attenuation and institutional controls such as deed restrictions are also relatively easy to implement. Permits for existing air stripper and discharge of treated groundwater to the on-site lagoons are already in place. If required, this alternative can be extended for additional time. With hydraulic control in place via pump-and-treat, additional remedial actions can be undertaken with relative ease. Many States and local agencies have permitted and approved use of $KMnO_4$ injection to oxidize chlorinated solvents (PCE/TCE).

- **Cost.** As shown in Appendix A, the total net present value for this is estimated at $1,622,589. These costs include pump-and-treat for 15 years, $KMnO_4$ injection for five years, OM&M, a program to conduct monitored natural attenuation for 30 years and institutional controls to establish deed restrictions limiting groundwater usage to non-potable only.

5.2.2.5 Groundwater Alternative #5: Site Wide Monitored Natural Attenuation/Institutional Controls

Under this alternative, the affected groundwater at the Site would be addressed by monitored natural attenuation. A program would be established to sample natural indicator parameters semi-annually for a period of 30 years. Groundwater extraction at approximately 280 gpm would continue from the North well for use in the daily JCI plant operations; the water would be treated via the existing air stripper, routed to the plant for use as non-contact cooling water and discharged to the lagoons under an approved SPDES permit.

- **Overall Protection of Human Health and the Environment.** Although monitored natural attenuation may reduce PCE concentrations, significant mass reductions may not be achieved in a reasonable time frame. DNAPL PCE may continue to result in groundwater plumes hydraulically downgradient resulting in potential exposure. Therefore, this alternative cannot be considered protective of human health and the environment.
- **Compliance with ARARs.** Monitored natural attenuation as a sole remedy would not be effective in reducing the chemical mass. The chemical-specific ARARs identified for the study area is for the attainment of remediation goals for the chemicals of concern, and for RAOs for the Site. Due to potential DNAPL PCE this alternative would not achieve compliance with the remediation goals or meet RAOs for many decades. This alternative does not invoke any location-specific or action-specific ARARs.
- **Long-Term Effectiveness and Permanence.** Because the RAOs would not be met for many years, assessment of long-term effectiveness and permanence of this alternative is not possible. Periodic sampling and analysis of wells to monitor natural attenuation indication parameters, groundwater flow, and quality would be conducted.

- **Reduction of Toxicity, Mobility, and Volume through Treatment.** While natural attenuation might result in a reduction of the toxicity, mobility, and volume, it would not be reduced through treatment.
- **Short-Term Effectiveness.** The time to achieve RAOs would be longer with this alternative than any other, probably several decades. No potential impacts to on-site workers or local residential neighborhoods are anticipated because of a lack of remediation system under this alternative.
- **Implementability.** This alternative could be easily implemented because it involves only periodic sampling to evaluate effectiveness of monitored natural attenuation.
- **Cost.** As shown in Appendix A, the total net present value for this alternative is estimated at $1,088,095. These costs include a program where groundwater samples and water levels are collected and measured semi-annually for 30 years to evaluate changes in natural attenuation indicator parameters, groundwater flow, and quality.

5.3 Comparative Analysis of Remedial Alternatives

This section compares the remedial alternatives based on the threshold and primary balancing criteria described in Section 5.1. The U.S. EPA requires that the selected alternative must protect human health and the environment and comply with ARARs (U.S. EPA 1988a). The purpose of this comparative analysis is to evaluate the advantages and disadvantages of each alternative relative to one another so that key tradeoffs that the decision-maker must balance can be identified. Table 8 summarizes the comparative analysis of the remedial alternatives.

5.3.1 Overall Protection of Human Health and the Environment

Soil Medium

Soil Alternative #1 would be least protective of human health and the environment, because there would be no remediation of affected soils at the source. Affected soils would continue to leach and be a source of groundwater contamination. The affected groundwater would continue to migrate off site, resulting in potential exposure. Alternative 1 is rated poor against this criterion.

Soil Alternative #2 would be effective in treating the soils to below soil remediation goals via SVE. Fencing the source during remediation would provide further protection Therefore, Alternative 2 would be protective of human health and the environment and is rated good against this criterion.

Soil Alternatives #3A or #3B involves excavation of affected soil in the source. Clean fill or treated soil (thorough on-site treatment) would be used to back-fill the area of excavation. Because the source is removed, alternatives #3A and #3B would be protective of human health and environment. Alternatives #3A and #3B are rated good against this criterion.

Groundwater Medium

Groundwater Alternative #1 would be the least protective of human health and environment due to a lack of physical remediation. Affected groundwater would continue to migrate hydraulically downgradient of the Site. This alternative is rated poor against this criterion.

Groundwater Alternative #2 would provide hydraulic containment and treatment of the affected groundwater at the source, minimizing exposure. Potential exposure to the affected groundwater would be minimized due to hydraulic containment. Groundwater outside the source would be addressed by monitored natural attenuation. This alternative is rated good against this criterion.

Groundwater Alternative #3 would also provide site wide hydraulic containment and treatment of the affected groundwater minimizing potential exposure. This alternative is rated good against this criterion.

Groundwater Alternative #4 would not only provide hydraulic containment and treatment of the affected groundwater at the source but also treat DNAPL PCE at the source. Groundwater outside the source would be addressed by monitored natural attenuation. This alternative is rated good against this criterion.

Groundwater Alternative #5 would not afford human health and environment protection in a reasonable time frame. Affected groundwater would be remediated by monitored natural attenuation. Affected groundwater could migrate hydraulically downgradient. This alternative is rated poor against this criterion.

5.3.2 Compliance with ARARs

Soil Medium

Soil Alternative #1 would not comply with action-specific ARARs due to a lack of physical remediation of the source. This alternative is rated poor against this criterion.

Soil Alternative #2 would aggressively treat the affected soils at the source to below remediation goals via SVE treatment. It is estimated that soil remediation goals would be achieved in approximately three years. The low levels of PCE in soils outside the source area are well below the NYSDEC TAGM RSCOs and therefore would not require remediation. This alternative is rated good against this criterion.

Soil Alternatives #3A or #3B would result in removal of the source by excavation. Soil remediation goals could be attained in a relatively short period of time (one year or less) under this alternative. This alternative is rated good against this criterion.

Groundwater Medium

Groundwater Alternative #1 is rated poor against this criterion because action-specific compliance would not be achieved due to a lack groundwater remediation.

Groundwater Alternative #2 would effectively treat the dissolved-phase chemicals and hydraulically contain the affected groundwater at the source. However, because of potential DNAPL presence, compliance with ARARs may not be achieved for several decades. Monitored natural attenuation may be effective in achieving compliance for the slightly affected groundwater outside the source especially with aggressive treatment of the source area. This alternative is rated fair against this criterion.

Groundwater Alternative #3 would also contain the affected groundwater at the Site. However, because of potential DNAPL presence compliance with the ARARs may not be achieved for a long period of time. This alternative is rated fair against this criterion.

Groundwater Alternative #4 would not only contain the source but also treat the dissolved-phase chemicals and DNAPLs via pump-and-treat and $KMnO_4$ injection, respectively. Groundwater outside the source would be addressed by monitored natural attenuation. This alternative would be effective in achieving compliance with the ARARs and is rated good against this criterion.

Groundwater Alternative #5 is rated poor against this criterion because monitored natural attenuation alone will not achieve compliance with the ARARs in a reasonable time frame.

5.3.3 Long-Term Effectiveness and Permanence

Soil Medium

Soil Alternative #1 would not provide long-term effectiveness or permanence, because there would be no remediation of the affected soils at the source. Affected soils would continue to leach and be a source of groundwater contamination. The affected groundwater would continue to migrate off site, resulting in potential exposure. Soil Alternative #1 is rated poor against this criterion.

Soil Alternative #2 would provide long-term effectiveness and permanence through treatment of affected soils by SVE. No other treatment would be required after the soil remediation goals have been met. Fencing the source area and lagoons would provide further protection. Alternative 2 would be is rated good against this criterion.

Soil Alternatives #3A or #3B would result in source removal through excavation. No other remedy would be required after the source area has been removed and back-filled with clean or treated soil. Alternatives #3A or #3B would be provide long-term effectiveness and permanence and are therefore rated good against this criterion.

Groundwater Medium

Groundwater Alternative #1 would not provide long-term effectiveness or permanence because there would be no groundwater remedy in place. This alternative is rated poor against this criterion.

Groundwater Alternative #2 would be effective in treating dissolved-phase chemicals and achieving hydraulic containment of the affected groundwater at the source. However, this alternative would not be effective in treating DNAPLs. Long-term effectiveness or permanence may not be assured due "rebound" effects that may affect groundwater upon cessation of the pump-and-treat system. This alternative is rated fair against this criterion.

Groundwater Alternative #3 would provide hydraulic containment and treatment of dissolved-phase chemicals at the Site. However, DNAPLs may not be remediated in a reasonable time frame. This alternative is rated fair against this criterion.

Groundwater Alternative #4 would not only provide hydraulic containment and treatment of the dissolved-phase chemicals at the source but would also address DNAPLs. Because of active remediation of the source, slightly affected groundwater outside the source would naturally attenuate. This alternative would be provide long-term effectiveness and permanence, and is rated good against this criterion.

Groundwater Alternative #5 would not provide long-term effectiveness or permanence. Affected groundwater would be addressed by monitored natural attenuation although not within reasonable time. Affected groundwater could continue to migrate hydraulically downgradient of the Site. This alternative is rated poor against this criterion.

5.3.4 Reduction of Toxicity, Mobility and Volume Through Treatment

Soil Medium

Soil Alternative #1 would not reduce toxicity, mobility, or volume through treatment. This alternative is rated poor against this criterion.

Soil Alternative #2 would effectively treat soils at the source via SVE. SVE treatment would further eliminate further chemical sources to groundwater via infiltration. This alternative would reduce toxicity, mobility, and volume and is therefore rated good against this criterion.

Soil Alternative #3A or #3B would also result in removal of the affected soils at the source by excavation. Clean or treated soil would be used to back-fill the excavated area. This alternative is rated good against this criterion.

Groundwater Medium

Groundwater Alternative #1 would not reduce toxicity, mobility, or volume due to a lack of treatment. Volume of affected groundwater may actually increase. This alternative is rated poor against this criterion.

Groundwater Alternative #2 can prevent further migration of affected groundwater and treat dissolved-phase chemicals at the source. However, complete reduction of toxicity, mobility, and volume may not be achieved in reasonable time frame due to potential DNAPL presence. This alternative is rated fair against this criterion.

Groundwater Alternative #3 can also prevent further migration of affected groundwater and treat dissolved-phase chemicals at the Site. However, complete reduction of toxicity, mobility, and volume may not be achieved in a reasonable time frame due to potential DNAPLs at the source. This alternative is rated fair against this criterion.

Groundwater Alternative #4 would not only treat and contain migration of affected groundwater but also treat DNAPLs at the source. Slightly affected groundwater outside the source would be addressed by monitored natural attenuation. This alternative would be effective in the reduction of toxicity, mobility, and volume; and is rated good against this criterion.

Groundwater Alternative #5 would not be effective in the reduction of toxicity, mobility, and volume. Monitored natural attenuation may reduce concentrations but not in a reasonable time. This alternative is rated poor against this criterion.

5.3.5 Short-Term Effectiveness

Soil Medium

Soil Alternative #1 is rated good against this criterion because there would be no impact due to a lack of remedial construction. Construction time is minimal.

Soil Alternative #2 would provide short-effectiveness. The minimal impact to on-site workers during construction and OM&M of the SVE system could be easily minimized by protective equipment and clothing. Time required to construct and conduct start up activities under this alternative is approximately 20 working days. This alternative is rated good against this criterion.

Soil Alternatives #3A or #3B would result in potential exposure of on-site construction workers to affected soils during excavation, off-site disposal, and/or on-site treatment. In addition, local residences may be affected by fugitive dust and/or noise during excavation and transport for off-site disposal. Time required to implement and complete remedial activities under this alternative is approximately 45 working days. This alternative is rated fair against this criterion.

Groundwater Medium

Groundwater Alternative #1 is rated good against this criterion because there would be no impact due to a lack of remedial construction. Construction time is minimal.

Groundwater Alternative #2 would result in slight exposure to on-site construction workers during the installation of the three extraction wells, and installation and OM&M of the pump-and-treat system. However, these exposures can be minimized with adequate protective equipment and clothing. Time required to construct and conduct startup activities under this alternative is approximately 45 working days. This alternative is rated good against this alternative.

Groundwater Alternative #3, which would involve the installation of 16 extraction wells, trenching and piping to route about 1.7 million gallons per day to the treatment units, and construction of an infiltration gallery, would result in potential exposure to construction workers. In addition, local residences may be affected by noise during drilling and/or trenching. Time required to construct and conduct startup activities under this alternative is approximately 90 working days. This alternative is rated poor against this criterion.

Groundwater Alternative #4 would result in slight exposure to on-site construction workers during the installation of the three extraction wells; installation and OM&M of the pump-and-treat system; and injection of $KMnO_4$ solution. However, these exposures can be minimized with adequate protective equipment and clothing. Time required to construct and conduct startup activities under this alternative is approximately 45 working days. This alternative is rated good against this criterion.

Groundwater Alternative #5 is rated good against this criterion because it involves periodic sampling for natural attenuation indicator parameters. Construction time is minimal.

5.3.6 Implementability

Soil Medium

Soil Alternative #1 would be easy to implement because it involves no construction. It is rated good against this criterion.

Soil Alternative #2, which involves SVE, is also easy to implement. SVE systems are routinely installed to treat source soils affected by chlorinated solvents-affected. SVE equipment and GAC units are readily available. This alternative is rated good against this criterion.

Soil Alternative #3 would pose no technical difficulties in excavation and off-site disposal or on-site treatment of soils. However, coordination among several agencies would be necessary for off-site transport or on-site treatment of hazardous waste. This alternative is rated fair against this criterion.

Groundwater Medium

Groundwater Alternative #1 would be easy to implement because it involves no construction. This alternative is rated good against this criterion.

Groundwater Alternative #2, which involves installation and OM&M of pump-and-treat systems, and monitored natural attenuation, would be relatively easy to install. The extracted water would be treated using the existing air stripper and discharge to the lagoon under an already approved SPDES permit. This alternative is rated good against this criterion.

Groundwater Alternative #3 would pose technical and administrative difficulties. Under this alternative, 16 extraction wells, an additional air stripper, infiltration gallery and GAC units would be required. Trenching and piping to route 1.7 million gallons per day to treatment systems could be complex. Permitting would be required from local agencies to discharge treated water to the infiltration gallery. Extensive management and handling of investigation derived waste would be required under this alternative. OM&M of this alternative would be elaborate. This alternative is rated poor against this criterion.

Groundwater Alternative #4 is similar to groundwater alternative #2 with one addition: $KMnO_4$ solution would be injected to treat DNAPLs at the source. $KMnO_4$ injection is an emerging technology and has been implemented successfully at few sites across United States to treat DNAPL PCE. LFR has successfully implemented $KMnO_4$ injection to treat DNAPLs at chlorinated solvent sites. $KMnO_4$, mixing tanks, injection pump, and appurtenances are readily available. This alternative is rated good against this criterion.

Groundwater Alternative #5 would be easy to implement because it primarily involved groundwater sampling for natural attenuation indicator parameters. This alternative is rated good against this criterion.

5.3.7 Cost

The costs to implement the soil and groundwater alternatives are presented in Tables 7 and 8.

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Table 1
Monitoring Well Construction Data
Jones Chemicals, Inc.
Caledonia, New York

Well ID	TOC Elevation (feet NGVD)	Well Depth Depth (feet bgs)	Monitoring Zone	Screen Interval (feet bgs)	Well Diameter (inches)	Installation Date	Installed By
OP-1	648.465	30.0	Overburden	25-30	4	06/21/84	CRA
OP-2	650.555	25.3	Overburden	20.3-25.3	4	06/20/84	CRA
OP-3	649.800	31.0	Overburden	26-31	4	NA	CRA
OP-5	650.620	22.0	Overburden	17-22	2	04/24/96	LFR
OP-6	651.460	21.0	Overburden	16-21	2	08/23/94	LFR
OP-7	648.785	23.0	Overburden	18-23	2	04/23/96	LFR
OP-8	652.025	22.0	Overburden	17-22	2	04/23/96	LFR
OP-9	645.465	22.0	Overburden	17-22	2	04/26/96	LFR
OP-10	653.790	22.0	Overburden	17-22	2	04/25/96	LFR
OP-11	653.610	22.0	Overburden	17-22	2	04/25/96	LFR
OP-12	652.980	22.0	Overburden	17-22	2	04/29/96	LFR
OP-13	660.205	31.0	Overburden	26-31	2	11/18/97	LFR
OP-14	653.025	26.0	Overburden	21-26	2	11/19/97	LFR
OP-15	652.660	24.0	Overburden	19-24	2	11/19/97	LFR
OP-16	NS	44.0	Intermediate	39-44	2	08/19/98	LFR
BP-1	650.815	113.5	Bedrock	Open Hole (15 ft.)	6	06/26/84	CRA
BP-2	652.100	75.0	Bedrock	Open Hole (15 ft.)	4	06/18/84	CRA
BP-3	648.990	60.0	Bedrock	Open Hole (5 ft.)	2	02/06/87	CRA
BP-4	652.435	55.0	Bedrock	Open Hole (5 ft.)	2	02/11/87	CRA
BP-5	652.050	90.0	Bedrock	Open Hole (15 ft.)	2	05/02/96	LFR
BP-6	653.800	101.0	Bedrock	Open Hole (15 ft.)	4	05/02/96	LFR
L-1	650.420	21.0	Overburden	16-21	4	06/26/84	CRA
L-2	650.560	67.5	Bedrock	Open Hole (15 ft.)	4	05/30/84	CRA
L-3	649.755	20.0	Overburden	15-20	4	05/24/84	CRA
North Well	650.435	24.0	Overburden	NA	48	03/85	NA
East Well	651.090	55.5	Bedrock	NA	6	NA	NA
West Well	652.340	45.3	Bedrock	NA	6	NA	NA
V-1	NS	NA	NA	NA	NA	NA	NA
V-2	NS	NA	NA	NA	NA	NA	NA
PZ-1	649.885	22.0	Overburden	12-22	2	11/29/94	LFR

Table 1
Monitoring Well Construction Data
Jones Chemicals, Inc.
Caledonia, New York

Well ID	TOC Elevation (feet NGVD)	Well Depth Depth (feet bgs)	Monitoring Zone	Screen Interval (feet bgs)	Well Diameter (inches)	Installation Date	Installed By
PZ-2	649.510	23.0	Overburden	13-23	2	11/29/94	LFR
DEC-1	645.125	23.5	Overburden	21-23.5	NA	12/21/83	NYSDEC
DEC-2	642.930	25.5	Overburden	23-25.5	NA	12/22/83	NYSDEC
DEC-3	643.000	17.5	Overburden	15-17.5	NA	12/22/83	NYSDEC
DEC-4	645.445	34.0	Overburden	NA	NA	10/30/84	NYSDEC
DEC-5	657.095	37.0	Overburden	NA	NA	10/31/84	NYSDEC
DEC-6	643.985	26.0	Overburden	NA	NA	11/01/84	NYSDEC
DEC-7	655.445	27.5	Overburden	25-27.5	NA	11/01/84	NYSDEC
DEC-8	645.905	31.5	Overburden	NA	NA	09/10/85	NYSDEC
DEC-9	649.245	27.0	Overburden	24.5-27	NA	09/12/85	NYSDEC
DEC-10	649.535	19.0	Overburden	16.5-19	NA	09/12/85	NYSDEC

Notes:

TOC = top of casing
NGVD = National Geodetic Vertical Datum
bgs = below ground surface
NS = not surveyed
NA = not available
CRA = Conestoga-Rovers & Associates
LFR = LFR Levine·Fricke
NYSDEC = New York State Department of Environmental Conservation

Table 2
Approximate Concentrations of Potential Chemicals of Concern
JCI Jones Chemicals, Inc. Site, Caledonia, New York

Potential Chemicals of Concern	Unsaturated Soil (mg/kg)	Groundwater Overburden Zone (μg/l)	Groundwater Bedrock Zone (μg/l)
Tetrachloroethene (PCE)	0.002–330	<1–62,000	<1–2
Trichloroethene (TCE)	0.002–0.320	<1–100	<1–8
1,2-Dichloroethene (1,2-DCE)	0.002- 0.010	<1–37	<1–26
1,1-Dichloroethene (1,1-DCE)	<0.005	<1–2	<1
Vinyl Chloride	<0.005	<1	<1

Notes:

bgs = below ground surface

mg/kg = milligrams per kilogram ppm

μg/l = micrograms per liter ppb

< = compound not detected; value is below the detection limit

Table 3
Groundwater Sample Analytical Results
Volatile Organic Compounds
Jones Chemicals, Inc.
Caledonia, New York

Parameter (µg/l)	CRDL	Sample Name (depth in feet below ground surface)																	
		North Well 4/30/96	DUP-1 4/30/96	North Well 11/18/97	DUP-1 11/18/97	North Well ** 8/21/98	West Well 4/30/96	West Well 11/20/97	West Well ** 8/21/98	West Well Dup ** 8/21/98	East Well 5/1/96	East Well 11/18/97	East Well ** 8/21/98	V-1 4/29/96	V-1 11/19/97	V-2 4/29/96	V-2 11/20/97	L-2 4/30/96	L-2 11/21/97
Dichlorodifluoromethane	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
Chloromethane	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
Vinyl Chloride	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
Bromomethane	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
Chloroethane	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
Trichlorofluoromethane	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
1,1-Dichloroethene	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
Methylene Chloride	1	<1	<1	<2	<2	<30 UB	<1	<2	<10 UB	<10 UB	<1	<1	<30 UB	<1	<1	<1	<1	<1	<1
trans-1,2-Dichloroethene	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	**0.6**	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
1,1-Dichloroethane	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
2,2-Dichloropropane	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
cis-1,2-Dichloroethene	1	**210 DL**	**220 DL**	**6**	**6 D**	**9**	**23**	**28**	**30**	**37**	**17**	**18**	**30**	<1	<1	<1	**2**	<1	<1
Bromochloromethane	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
Chloroform	1	<1	<1	<2	<2	<45 UB	<1	<2	<0.5	<0.5	**3**	**36**	<45 UB	<1	<1	<1	<1	<1	<1
1,1,1-Trichloroethane	1	**1**	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
Carbon Tetrachloride	1	**1**	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
1,1-Dichloropropene	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
Benzene	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
1,2-Dichloroethane	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
Trichloroethene	1	**45**	**44**	**4**	**4 D**	**16**	**18**	**16**	**18**	**22**	**3**	**2**	**3**	<1	**1**	<1	**4**	<1	<1
1,2-Dichloropropane	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
Dibromomethane	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
Bromodichloromethane	1	<1	<1	<2	<2	<20 UB	<1	<2	<0.5	<0.5	**2**	<1	<20 UB	<1	<1	<1	<1	<1	<1
cis-1,3-Dichloropropene	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
Toluene	1	<1	<1	<2	<2	**0.6**	<1	<2	<0.5	<0.5	**1**	<1	<0.5	<1	<1	<1	<1	<1	<1
trans-1,3-Dichloropropene	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
1,1,2-Trichloroethane	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
Tetrachloroethene	1	**570 DL**	**570 DL**	**61**	**61 D**	**140 DL**	**300 DL**	**310 DL**	**340 DL**	**340 DL**	**18**	**26**	**31**	<1	<1	<1	<1	<1	<1
1,3-Dichloropropane	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
Dibromochloromethane	1	<1	<1	<2	<2	<3 UB	<1	<5 UB	<0.5	<0.5	**2**	<1	<3 UB	<1	<1	<1	<10 UB	<1	<1
1,2-Dibromoethane	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
Chlorobenzene	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
1,1,1,2-Tetrachloroethane	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
Ethylbenzene	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
m/p-Xylene	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
o-Xylene	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
Styrene	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
Bromoform	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<5 UB	<1	<1
Isopropylbenzene	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
Bromobenzene	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
1,1,2,2-Tetrachloroethane	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
1,2,3-Trichloroethane	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
n-Propylbenzene	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
2\4-Chlorotoluene	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
1,3,5-Trimethylbenzene	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
tert-Butylbenzene	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
1,2,4-Trimethylbenzene	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
sec-Butylbenzene	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
1,3-Dichlorobenzene	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
4-Isopropyltoluene	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
1,4-Dichlorobenzene	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
1,2-Dichlorobenzene	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
n-Butylbenzene	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
1,2-Dibromo-3-chloropropane	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
1,2,4-Trichlorobenzene	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
Hexachlorobutadiene	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
Naphthalene	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
1,2,3-Trichlorobenzene	1	<1	<1	<2	<2	<0.5	<1	<2	<0.5	<0.5	<1	<1	<0.5	<1	<1	<1	<1	<1	<1
# Positive Detects/# Samples	---	5/58	3/58	3/58	3/58	4/58	3/58	3/58	3/58	4/58	7/58	4/58	3/58	0/58	1/58	0/58	2/58	0/58	0/58
Arithmetic Mean	---	165	278	24	24	41	113	118	129	100	7	20.5	21.3	0	1	0	3	0	0

Table 3
Groundwater Sample Analytical Results
Volatile Organic Compounds
Jones Chemicals, Inc.
Caledonia, New York

Parameter (µg/l)	CRDL	Sample Name (depth in feet below ground surface)																				
		DUP-3 11/21/97	L-2 ** 8/22/98	L-3 4/30/96	L-3 11/21/97	L-3 ** 8/22/98	OP-1 4/30/96	OP-1 11/21/97	OP-1 ** 8/21/98	OP-2 4/30/96	OP-2 11/21/97	OP-2 ** 8/20/98	OP-3 5/1/96	DUP-2 5/1/96	OP-3 11/21/97	OP-3 ** 8/20/98	OP-5 4/29/96	OP-5 11/21/97	OP-5 ** 8/20/98	OP-6 4/30/96	OP-6 11/20/97	OP-6 8/21/98
Dichlorodifluoromethane	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Chloromethane	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Vinyl Chloride	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Bromomethane	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Chloroethane	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Trichlorofluoromethane	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,1-Dichloroethene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Methylene Chloride	1	<1	<10 UB	<1	<1	<10 UB	<1	<1	<30 UB	<1	<1	<30 UB	<1	<1	<1	<30 UB	<1	<1	<30 UB	<1	<1	<30 UB
trans-1,2-Dichloroethene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,1-Dichloroethane	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
2,2-Dichloropropane	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
cis-1,2-Dichloroethene	1	<1	**7**	**1**	**1**	**1**	<1	<1	<0.5	**3**	**11**	**3**	<1	<1	<1	**0.7**	<1	<1	<0.5	<1	**4**	<0.5
Bromochloromethane	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Chloroform	1	<1	<0.5	<1	<1	<0.5	<45 UB	<1	<0.5	<1	<1	<45 UB	**12**	**11**	**12**	<45 UB	<1	<1	<45 UB	<1	**2**	<45 UB
1,1,1-Trichloroethane	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	**4**	**4**	**3**	**5**	<1	<1	<0.5	<1	**4**	**5**
Carbon Tetrachloride	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,1-Dichloropropene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Benzene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,2-Dichloroethane	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Trichloroethene	1	<1	<0.5	<1	<1	**0.6**	<1	<1	<0.5	<1	<1	**0.6**	**13**	**13**	**14**	**18**	<1	<1	**0.8**	**9**	**8**	**9**
1,2-Dichloropropane	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Dibromomethane	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Bromodichloromethane	1	<1	<0.5	<1	<1	<0.5	<1	<1	<20 UB	<1	<1	<20 UB	<1	<1	<1	<20 UB	<1	<1	<20 UB	<1	<1	<20 UB
cis-1,3-Dichloropropene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Toluene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
trans-1,3-Dichloropropene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,1,2-Trichloroethane	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Tetrachloroethene	1	<1	<0.5	**1**	**1**	**0.8**	<1	<1	<0.5	<1	<1	<0.5	**10**	**9**	**9**	**14**	<1	<1	<0.5	**29**	**48 DL**	**22**
1,3-Dichloropropane	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<10 UB	<0.5	<1	<1	<0.5	<1	<1	<0.5
Dibromochloromethane	1	<1	<0.5	<10 UB	<1	<0.5	<1	<1	<3 UB	<1	<1	<3 UB	<1	<1	<1	<3 UB	<1	<1	<3 UB	<1	<10 UB	<3 UB
1,2-Dibromoethane	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Chlorobenzene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,1,1,2-Tetrachloroethane	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Ethylbenzene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
m/p-Xylene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
o-Xylene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Styrene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<5 UB	<0.5	<1	<1	<0.5	<1	<1	<0.5
Bromoform	1	<1	<0.5	<5 UB	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<5 UB	<0.5
Isopropylbenzene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Bromobenzene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,1,2,2-Tetrachloroethane	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,2,3-Trichloroethane	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
n-Propylbenzene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
2\4-Chlorotoluene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,3,5-Trimethylbenzene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
tert-Butylbenzene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,2,4-Trimethylbenzene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
sec-Butylbenzene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,3-Dichlorobenzene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
4-Isopropyltoluene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,4-Dichlorobenzene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,2-Dichlorobenzene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
n-Butylbenzene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,2-Dibromo-3-chloropropane	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,2,4-Trichlorobenzene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Hexachlorobutadiene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Naphthalene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,2,3-Trichlorobenzene	1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<1	<<0.5	<1	<1	<0.5	<1	<1	<0.5
# Positive Detects/# Samples	---	1/58	1/58	2/58	2/58	3/58	0/58	0/58	0/58	1/58	1/58	2/58	4/58	4/58	4/58	4/58	0/58	0/58	1/58	2/58	5/58	3/58
Arithmetic Mean	---	7	7	1	1	0.8	0	0	0	3	11	1.8	10	9	9.5	9.4	0	0	0.8	19	13.2	12

Table 3
Groundwater Sample Analytical Results
Volatile Organic Compounds
Jones Chemicals, Inc.
Caledonia, New York

Parameter (µg/l)	CRDL	Sample Name (depth in feet below ground surface)																				
		OP-7 4/29/96	OP-7 11/21/97	OP-7 8/21/98	OP-8 4/29/96	OP-8 11/21/97	OP-8 8/21/98	OP-9 5/1/96	OP-9 11/20/97	OP-9 ** 8/22/98	OP-10 5/2/96	OP-10 11/21/97	OP-10 8/21/98	OP-11 5/2/96	OP-11 11/21/97	OP-11 ** 8/22/98	OP-11 Dup** 8/22/98	OP-12 5/2/96	OP-12 11/20/97	OP-12 ** 8/22/98	OP-13 11/20/97	OP-13 ** 8/20/98
Dichlorodifluoromethane	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
Chloromethane	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
Vinyl Chloride	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
Bromomethane	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
Chloroethane	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
Trichlorofluoromethane	1	<1	<1	<0.5	<1	<2	**0.8**	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
1,1-Dichloroethene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
Methylene Chloride	1	<1	<1	<30 UB	<1	<2	<30 UB	<1	<2	<30 UB	<1	<1	<0.5	<1	<20	<10 UB	<10 UB	<1	<1	<10 UB	<1	<0.5
trans-1,2-Dichloroethene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
1,1-Dichloroethane	1	<1	<1	<0.5	**2**	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
2,2-Dichloropropane	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
cis-1,2-Dichloroethene	1	<1	<1	<0.5	**72 DL**	<2	**3**	**2**	**31**	**1**	<1	<1	<0.5	**9**	<20	**9**	**6**	<1	**2**	<0.5	<1	<0.5
Bromochloromethane	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
Chloroform	1	<1	**1**	<45 UB	<1	<2	<45 UB	<1	<2	<45 UB	<1	<1	<0.5	<1	<20	0.6	<0.5	<1	<1	<0.5	<1	<0.5
1,1,1-Trichloroethane	1	<1	<1	<0.5	**4**	<2	<0.5	<1	<2	<0.5	<1	**1**	**1**	**3**	<20	**5**	**3**	<1	<1	<0.5	<1	<0.5
Carbon Tetrachloride	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
1,1-Dichloropropene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
Benzene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
1,2-Dichloroethane	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
Trichloroethene	1	**1**	**2**	**1**	**26**	**20**	**3**	**110 DL**	**17**	**86 DL**	**1**	**2**	**2**	**70**	**24**	**62**	**44**	<1	**3**	**1**	<1	<0.5
1,2-Dichloropropane	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
Dibromomethane	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
Bromodichloromethane	1	<1	<1	<20 UB	<1	<2	<20 UB	<1	<2	<20 UB	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
cis-1,3-Dichloropropene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
Toluene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
trans-1,3-Dichloropropene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
1,1,2-Trichloroethane	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
Tetrachloroethene	1	<1	<1	**0.8**	**300 DL**	**40**	**79 DL**	**120 DL**	**64**	**120 DL**	**25**	**24**	**8**	**3,100 DL**	**1,300 DL**	**5,400 DL**	**5,500 DL**	**21**	**5**	**3**	<1	<0.5
1,3-Dichloropropane	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
Dibromochloromethane	1	<1	<10 UB	<3 UB	<1	<2	<3 UB	<1	<10 UB	<3 UB	<1	<10 UB	<0.5	<1	<20	<0.5	<0.5	<1	<10 UB	<0.5	<10 UB	<0.5
1,2-Dibromoethane	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
Chlorobenzene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
1,1,1,2-Tetrachloroethane	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	**2**	**1**	<1	<1	<0.5	<1	<0.5
Ethylbenzene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
m/p-Xylene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
o-Xylene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
Styrene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
Bromoform	1	<1	<5 UB	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<5 UB	<0.5	<1	<20	<0.5	<0.5	<1	<5 UB	<0.5	<10 UB	<0.5
Isopropylbenzene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
Bromobenzene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
1,1,2,2-Tetrachloroethane	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
1,2,3-Trichloroethane	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
n-Propylbenzene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
2\4-Chlorotoluene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
1,3,5-Trimethylbenzene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
tert-Butylbenzene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
1,2,4-Trimethylbenzene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
sec-Butylbenzene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
1,3-Dichlorobenzene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
4-Isopropyltoluene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
1,4-Dichlorobenzene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
1,2-Dichlorobenzene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
n-Butylbenzene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
1,2-Dibromo-3-chloropropane	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
1,2,4-Trichlorobenzene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
Hexachlorobutadiene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
Naphthalene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
1,2,3-Trichlorobenzene	1	<1	<1	<0.5	<1	<2	<0.5	<1	<2	<0.5	<1	<1	<0.5	<1	<20	<0.5	<0.5	<1	<1	<0.5	<1	<0.5
# Positive Detects/# Samples	---	1/58	2/58	2/58	5/58	2/58	4/58	3/58	3/58	3/58	2/58	3/58	3/58	4/58	2/58	5/58	5/58	1/58	3/58	2/58	0/58	0/58
Arithmetic Mean	---	1	1.5	0.9	80.8	30	21.5	77.3	37.3	69	13	9	3.7	796	662	1095	1111	21	3.3	2	0	0

Table 3
Groundwater Sample Analytical Results
Volatile Organic Compounds
Jones Chemicals, Inc.
Caledonia, New York

Parameter (µg/l)	CRDL	Sample Name (depth in feet below ground surface)																				
		OP-14 11/20/97	**OP-14 ** 8/20/98**	**OP-15 11/20/97**	**OP-15 ** 8/20/98**	**OP-16 ** 8/20/98**	**PZ-1 4/30/96**	**PZ-1 11/21/97**	**DUP-2 11/21/97**	**PZ-1 8/22/98**	**BP-1 4/30/96**	**BP-1 11/19/97**	**BP-1 8/20/98**	**BP-2 4/29/96**	**BP-2 11/18/97**	**BP-2 8/20/98**	**BP-3 4/29/96**	**BP-3 11/21/97**	**BP-3 8/21/98**	**BP-4 4/29/96**	**BP-4 11/21/97**	**BP-4 8/21/98**
Dichlorodifluoromethane	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Chloromethane	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Vinyl Chloride	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Bromomethane	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Chloroethane	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Trichlorofluoromethane	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,1-Dichloroethene	1	<1	<0.5	<1	<0.5	**2**	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Methylene Chloride	1	<1	<10 UB	<1	<10 UB	<10 UB	<1	<1	<1	<10 UB	<1	<1	<30 UB	<1	<1	<30 UB	<1	<1	<30 UB	<1	<1	<30 UB
trans-1,2-Dichloroethene	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,1-Dichloroethane	1	<1	<0.5	<1	<0.5	**1**	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
2,2-Dichloropropane	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
cis-1,2-Dichloroethene	1	<1	<0.5	<1	<0.5	**2**	**40**	<1	<1	<0.5	<1	**2**	**13**	<1	**7**	**16**	**31**	<1	**11**	**21**	**29**	**21**
Bromochloromethane	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Chloroform	1	<1	<0.5	<1	<0.5	**12**	<1	<1	<1	<0.5	<1	<1	<45 UB	<1	<1	<45 UB	<1	<1	<45 UB	<1	<1	<45 UB
1,1,1-Trichloroethane	1	<1	<0.5	<1	<0.5	**7**	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Carbon Tetrachloride	1	<1	<0.5	<1	<0.5	**1**	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,1-Dichloropropene	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Benzene	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	**0.8**
1,2-Dichloroethane	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Trichloroethene	1	**1**	**1**	**1**	**0.8**	**100**	**16**	<1	<1	**2**	<1	<1	**8**	<1	<1	<0.5	**2**	<1	<0.5	**14**	**10**	**1**
1,2-Dichloropropane	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Dibromomethane	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Bromodichloromethane	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<20 UB	<1	<1	<20 UB	<1	<1	<20 UB	<1	<1	<20 UB
cis-1,3-Dichloropropene	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Toluene	1	<1	<0.5	<1	<0.5	**2**	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
trans-1,3-Dichloropropene	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,1,2-Trichloroethane	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Tetrachloroethene	1	**5**	**6**	<1	<0.5	**62,000 DL**	**120**	**2**	**1**	**16**	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	**15**	**11**	**2**
1,3-Dichloropropane	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Dibromochloromethane	1	<10 UB	<0.5	<10 UB	<0.5	<0.5	<1	<10 UB	<1	<0.5	<1	<1	<3 UB	<1	<1	<3 UB	<1	<1	<3 UB	<1	<1	<3 UB
1,2-Dibromoethane	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Chlorobenzene	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,1,1,2-Tetrachloroethane	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Ethylbenzene	1	<1	<0.5	<1	<0.5	**1**	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
m/p-Xylene	1	<1	<0.5	<1	<0.5	**16**	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
o-Xylene	1	<1	<0.5	<1	<0.5	**22**	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Styrene	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Bromoform	1	<10 UB	<0.5	<10 UB	<0.5	<0.5	<1	<10 UB	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Isopropylbenzene	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Bromobenzene	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,1,2,2-Tetrachloroethane	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,2,3-Trichloroethane	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
n-Propylbenzene	1	<1	<0.5	<1	<0.5	**0.9**	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
2\4-Chlorotoluene	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,3,5-Trimethylbenzene	1	<1	<0.5	<1	<0.5	**10**	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
tert-Butylbenzene	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,2,4-Trimethylbenzene	1	<1	<0.5	<1	<0.5	**20**	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
sec-Butylbenzene	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,3-Dichlorobenzene	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
4-Isopropyltoluene	1	<1	<0.5	<1	<0.5	**0.7**	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,4-Dichlorobenzene	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,2-Dichlorobenzene	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
n-Butylbenzene	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,2-Dibromo-3-chloropropane	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,2,4-Trichlorobenzene	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Hexachlorobutadiene	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
Naphthalene	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
1,2,3-Trichlorobenzene	1	<1	<0.5	<1	<0.5	<0.5	<1	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5	<1	<1	<0.5
# Positive Detects/# Samples	---	2/58	2/58	1/58	1/58	16/58	3/58	1/58	1/58	2/58	0/58	1/58	2/58	0/58	1/58	1/58	2/58	0/58	1/58	3/58	3/58	4/58
Arithmetric Mean	---	3	3.5	1	0.8	3887	59	2	1	9	0	2	10.5	0	7	16	16.5	0	11	16.7	16.7	6.2

Table 3
Groundwater Sample Analytical Results
Volatile Organic Compounds
Jones Chemicals, Inc.
Caledonia, New York

Parameter (µg/l)	CRDL	Sample Name (depth in feet below ground surface)								
		BP-4 DUP 8/21/98	BP-5* 5/23/96	BP-5 11/21/97	BP-5 8/20/98	BP-6* 5/23/96	BP-6 11/19/97	BP-6 8/21/98	Effluent 11/20/97	VW 11/20/97
Dichlorodifluoromethane	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
Chloromethane	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
Vinyl Chloride	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
Bromomethane	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
Chloroethane	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
Trichlorofluoromethane	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
1,1-Dichloroethene	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
Methylene Chloride	1	<0.5	<5	<1	<30 UB	<5	<1	<30 UB	<1	<1
trans-1,2-Dichloroethene	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
1,1-Dichloroethane	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
2,2-Dichloropropane	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
cis-1,2-Dichloroethene	1	**26**	<5	**1**	<0.5	<5	<1	**2**	<1	<1
Bromochloromethane	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
Chloroform	1	<45 UB	<5	<1	<45 UB	<5	<1	<45 UB	<1	<1
1,1,1-Trichloroethane	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
Carbon Tetrachloride	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
1,1-Dichloropropene	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
Benzene	1	**0.7**	<5	<1	<0.5	<5	<1	<0.5	<1	<1
1,2-Dichloroethane	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
Trichloroethene	1	**1**	<5	<1	<0.5	<5	<1	<0.5	<1	<1
1,2-Dichloropropane	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
Dibromomethane	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
Bromodichloromethane	1	<20 UB	<5	<1	<20 UB	<5	<1	<0.5	<1	**2**
cis-1,3-Dichloropropene	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
Toluene	1	<0.5	<5	<1	**0.8**	<5	<1	<0.5	<1	<1
trans-1,3-Dichloropropene	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
1,1,2-Trichloroethane	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
Tetrachloroethene	1	**2**	<5	<1	<0.5	<5	<1	<0.5	<1	<1
1,3-Dichloropropane	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
Dibromochloromethane	1	<3 UB	<5	<1	<3 UB	<5	<1	<0.5	<1	<10 UB
1,2-Dibromoethane	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
Chlorobenzene	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
1,1,1,2-Tetrachloroethane	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
Ethylbenzene	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
m/p-Xylene	1	<0.5	<5	<1	**0.7**	<5	<1	<0.5	<1	<1
o-Xylene	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
Styrene	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
Bromoform	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	**3 JB**
Isopropylbenzene	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
Bromobenzene	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
1,1,2,2-Tetrachloroethane	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
1,2,3-Trichloroethane	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
n-Propylbenzene	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
2\4-Chlorotoluene	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
1,3,5-Trimethylbenzene	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
tert-Butylbenzene	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
1,2,4-Trimethylbenzene	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
sec-Butylbenzene	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
1,3-Dichlorobenzene	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
4-Isopropyltoluene	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
1,4-Dichlorobenzene	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
1,2-Dichlorobenzene	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
n-Butylbenzene	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
1,2-Dibromo-3-chloropropane	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
1,2,4-Trichlorobenzene	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
Hexachlorobutadiene	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
Naphthalene	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
1,2,3-Trichlorobenzene	1	<0.5	<5	<1	<0.5	<5	<1	<0.5	<1	<1
# Positive Detects/# Samples	---	4/58	0/58	1/58	2/58	0/58	0/58	1/58	0/58	1/58
Arithmetric Mean	---	7.4	0	1	0.7	0	0	2	0	2.5

Notes:

Bold indicates positive detection.
Samples were analyzed using EPA Method 524-1.
Non-diluted sample concentrations above diluted sample detection limits should not be used as they were above the instrument calibration limits.
Geometric means and upper 95% concentrations are not included due to minimal number of analytes with positive detections.
* = nondetects; quantitation limit is estimated.
** = All positive detections qualified "J", estimated value due to hold time exceedance ranging from 24 hours to 12 days.
< = method detection limit
CRDL = contract required detection limit
DL = samples were reanalyzed at a higher detection limit.
DUP-1 (11/18/97) = duplicate of North Well
DUP-1 (4/30/96) = duplicate of North Well
DUP-2 (11/21/97) = duplicate of PZ-1
DUP-2 (5/1/96) = duplicate of OP-3
DUP-3 (11/21/97) = duplicate of L-2
Effluent = effluent from air stripper
EPA = U.S. Environmental Protection Agency
JB = estimated, below detection limit; detection limit elevated because of blank contamination.
mg/l= micrograms per liter
UB = below detection limit; detection limit elevated because of blank contamination.
V-1, V-2 = Village of Caledonia production wells.
VW = potable water supplied to the Village of Caledonia

Table 4
Applicable or Relevant and Appropriate Requirements (ARARs)
JCI Jones Chemicals, Inc.
Caledonia, New York

Chemical-Specific ARARs

REQUIREMENTS	CITATION	DESCRIPTION	ARAR or TBC	COMMENT
Federal				
Safe Drinking Water Act (SDWA) National Primary Drinking Water Standards Maximum Contaminant Level Goals (MCLGs)	40 U.S.C. Section 300 40 CFR Part 141 40 CFR 141.50 - 141.51	Establishes maximum contaminant levels (MCLs), which are health-based standards for public water supply systems with at least 15 service connections or that serve a minimum of 25 persons.	Not Applicable	Applicable in establishing remedial action objectives. Site activities will not affect public water supply systems.
Resource Conservation and Recovery Act (RCRA) Identification and Listing of Hazardous Wastes	42 U.S.C. Section 6901 et. seq. 40 CFR Part 261 - 266	Describes criteria for evaluating if a solid waste constitutes a hazardous waste and is subject to regulation.	ARAR	Although these regulations do not set cleanup levels, they may be applicable for excavation and off site disposal of affected soil.
Clean Water Act (CWA) Ambient Water Quality Criteria Guidelines	33 U.S.C. Section 1251 - 1376 40 CFR Part 131	Establishes toxicity-based surface water criteria for protection of human health and aquatic based organisms.	Not Applicable	No surface water body exists in the Site vicinity.
Clean Air Act (CAA) National Ambient Air Quality Standards (NAAQS)	40 U.S.C. Section 7401 - 7642 40 CFR Part 50	Establishes ambient air quality standards for pollutants for the protection of public health.	TBC	These standards are TBC during air stripping of affected groundwater for evaluating air quality impacts.

Table 4
Applicable or Relevant and Appropriate Requirements (ARARs)
JCI Jones Chemicals, Inc.
Caledonia, New York

Chemical-Specific ARARs

REQUIREMENTS	CITATION	DESCRIPTION	ARAR or TBC	COMMENT
State				
NYSDEC Division of Hazardous Substances Regulation Identification and Listing of Hazardous Wastes	6 NYCRR Part 371	Outlines for determining if a solid waste is a hazardous waste and is subject to regulation under 6 NYCRR Parts 373-376.	ARAR	Although these regulations do not set cleanup levels, they may be considered for excavation and off site disposal of affected soil.
NYSDEC Division of Hazardous Waste Remediation Soil Cleanup Objectives	Technical and Administrative Guidance Memoranda (TAGM) HW94-4046, 1994	Establishes soil cleanup objectives based on land use and protecting groundwater quality.	ARAR	Soil is affected in the vicinity of the source area. Applicable for establishing remedial action objectives.
New York State Water Classifications and Quality Standards				
Groundwater Quality Standards	6 NYCRR Part 703.5	Establishes groundwater quality standards. Incorporates federal and state MCLs.	ARAR	These standards are applicable in establishing in remedial action objectives.
Surface Water Standards for Class C Waters	6 NYCRR Parts 701, 702, 704	Defines surface water classifications and ambient water quality standards.	Not applicable.	Surface water bodies not present in the Site vicinity.
NYSDEC Ambient Water Quality Standards and Guidance Values	Division of Water Technical and Operational Guidance Series (TOGS) 1.1.1	Provides a compilation of ambient water quality standards and guidance values.	Not applicable.	Surface water bodies not present in the Site vicinity.
New York State Ambient Air Quality Guidelines	6 NYCRR Part 257 Air Guide-1	Establishes state ambient air quality standards and guidelines for evaluating air quality impacts.	ARAR	These standards are applicable in evaluating air quality impact during air stripping.

Table 4
Applicable or Relevant and Appropriate Requirements (ARARs)
JCI Jones Chemicals, Inc.
Caledonia, New York

Action-Specific ARARs

ACTION	REQUIREMENT	CITATION	DESCRIPTION	ARAR or TBC	COMMENT
Federal					
Site Remediation Activities	Occupational Health and Safety Act. Worker Health and Safety	29 U.S.C. Section 651-678 29 CFR 1910 120 29 CFR 1926	Health and safety considerations of persons involved in hazardous waste site operations. Standards for general construction.	ARAR ARAR	These regulations and standards apply to remedial actions and construction activities involving hazardous waste.
Management of Hazardous Waste On Site	Resource Conservation and Recovery Act (RCRA) Standards for Hazardous Waste Generators, Manifesting, Pre-Transporting, Reporting Requirements.	42 U.S.C. Section 6901 et seq. 40 CFR Part 262 Subparts B, C, D	Regulations governing packaging labeling, reporting, and manifesting of hazardous waste.	ARAR	These regulations apply to remedial actions and construction activities involving off-site transportation of hazardous waste.
Generation, Management, and Treatment of Hazardous Waste	RCRA Subtitle C – Hazardous Waste Management	40 U.S.C. Section 6901 et seq.	Establishes criteria for evaluating if solid waste is hazardous and subject to regulation under 40 CFR Parts 260 – 266.	ARAR	These regulations may apply during various remedial actions and construction activities involving affected soil excavation.
	Identification and Listing of Hazardous Wastes	40 CFR Part 261	Establishes 90-day limit to store hazardous waste generated without permit.	ARAR	Applicable during potential excavation of affected soil.
	90-Day Accumulation Rule	40 CFR Part 262.34	Allows for standards that are more flexible for media and wastes generated during site cleanups.	TBC	May be applicable during potential excavation of affected soil. May be used in conjunction Land Disposal Requirements (LDRs).
	Hazardous Waste Identification Rule (HWIR)	40 CFR Part 260, et. al.			

Table 4
Applicable or Relevant and Appropriate Requirements (ARARs)
JCI Jones Chemicals, Inc.
Caledonia, New York

Action-Specific ARARs

ACTION	REQUIREMENT	CITATION	DESCRIPTION	ARAR or TBC	COMMENT
Water Treatment Discharges	Clean Water Act	33 U.S.C. Section 6901 et seq.	Established permit requirements for point source discharges, effluent standards and requirements for toxic releases.	ARAR	Applicable for discharging treated groundwater.
	Wastewater Discharge Permits, Effluent Guidelines, Best Available Technology (BAT)	40 CFR Parts 122, 125, 401	Establishes requirements for discharging to POTW.	ARAR	May be applicable in discharging groundwater to POTW during hydraulic pumping test.
	Discharge to publicly-owned treatment works (POTW)	40 CFR Parts 144-147			
Air Emissions	Clean Air Act (CAA)	40 U.S.C. Section 7401 – 7642	Establishes ambient air quality.	ARAR	May be applicable in evaluating air quality impacts.
	National Ambient Air Quality Standards (NAAQS).	40 CFR Part 50	Source-specific regulations which establish emission standards for hazardous air pollutants.	ARAR	May be applicable if hazardous pollutants from the site exceed thresholds.
	National Emission Standards for Hazardous Air Pollutants (NESHAPs).	40 CFR Part 61, 63	Applies to process vents associated with air stripping or other vents that manage hazardous waste.	ARAR	May be applicable to on-site remediation of hazardous waste.
	Air Emission Standards for Process Vents	40 CFR Part 6			
Land Disposal of Hazardous Waste	RCRA Subtitle C	40 U.S.C. Section 6901 et seq.	Restricts land disposal of hazardous waste. Establishes Universal Treatment Standards (UTS) to which hazardous waste must be treated prior to land disposal.	ARAR	May be applicable during excavation and disposal of affected soil.
	Land Disposal Restriction (LDRs)	40 CFR Part 268			

Table 4
Applicable or Relevant and Appropriate Requirements (ARARs)
JCI Jones Chemicals, Inc.
Caledonia, New York

Action-Specific ARARs					
ACTION	**REQUIREMENT**	**CITATION**	**DESCRIPTION**	**ARAR or TBC**	**COMMENT**
Groundwater Remediation	Technical Impracticability (TI) Waiver for Groundwater Restoration	U.S. EPA (1993): Guidance for Evaluating the Technical Impracticability of Groundwater Restoration	Provides guidance for obtaining waivers for sites where restoration of groundwater to background levels is not practical or feasible. Also, addresses DNAPL and impracticability of its removal.	TBC	Due to potential presence of DNAPLs, this guidance may be considered.
State					
Generation, Management, and Treatment of Hazardous Waste.	NYSDEC Division of Hazardous Substances Regulation. Identification and Listing of Hazardous Wastes.	6 NYCRR Part 371	Establishes criteria for evaluating if solid waste is hazardous and subject to regulation under 6 NYCRR Parts 372 – 376.	ARAR	These regulations may apply during various remedial actions and construction activities involving affected soil excavation.
Land Disposal of Hazardous Waste.	Land Disposal Restrictions (LDRs).	6 NYCRR Part 376	Restricts land disposal of hazardous waste.	ARAR	May be applicable during excavation and disposal of affected soil.
Treated water discharge.	State Pollution Discharge Elimination System (SPDES). Groundwater Effluent Standards.	6 NYCRR Parts 750 – 758 6 NYCRR Part 703.6	Regulates treated water discharges including those to POTW. Establishes effluent standards.	ARAR ARAR	Applicable for discharge of treated groundwater. May be applicable in groundwater remediation.
Air Emissions	New York State Air Pollution Control Regulations. New York State Ambient Air Quality Standards.	6 NYCRR Parts 120, 200-203, 207, 211, 212, 219 Air Guide-1. 6 NYCRR Part 257	Establishes emission standards for new sources of air pollutants. Establishes state ambient air quality standards and guidelines for protection of human health.	ARAR ARAR	May be applicable in evaluating air quality impacts during operation of the air stripper.
Local					
Treated Water Discharge.	County or local municipality.	Local regulations.	Establishes pretreatment requirements of water prior to discharge including to POTW.	ARAR	May be applicable in groundwater remediation.

Table 4
Applicable or Relevant and Appropriate Requirements (ARARs)
JCI Jones Chemicals, Inc.
Caledonia, New York

Location-Specific ARARs					
LOCATION	REQUIREMENTS	CITATION	DESCRIPTION	ARAR or TBC	COMMENT
Federal					
Cultural Resources	National Historic Preservation Act Preservation of Historic Properties Preservation of Area Containing Artifacts	16 U.S.C. 469, 470. 36 CFR Part 800 36 CFR Part 65	Guidelines for preservation of historic properties and minimize remedial action impacts.	Not applicable.	No significant historic properties or archeological digs have been identified in the vicinity of the Site.
Critical Habitat	Endangered Species Act and Fish and Wildlife Coordination Act Critical Habitat of Endangered Species	16 U.S.C. 1531 50 CFR Part 200, Part 402; 40 CFR Parts 320-330	Guidelines for protection of critical habitats that may be potentially affected by Site activities.	Not applicable.	No endangered or threatened species have been identified in the Site vicinity.
Wetlands	Clean Water Act (CWA) Section 404 Protection of Wetlands Executive Order 11990	33 U.S.C. 1344 40 CFR Part 6 Subpart A	Guidelines for protection of wetlands that may be potentially affected by Site activities.	Not applicable.	No wetlands are present in the Site vicinity.
Floodplain	Floodplain Management	40 CFR 6, Subpart A; 40 CFR 6.302	Regulates activities that may have adverse effect in the floodplain.	Not applicable.	Site is not located within the 100-year floodplain.
Stream or Rivers	Wild and Scenic Rivers Act. Actions in Designated Wild and Scenic Rivers.	16 U.S.C. 1271, Section 7 40 CFR 6.302 (e)	Regulates activities that may have adverse effects on stream or rivers.	Not applicable.	Site activities will not affect streams or rivers in the vicinity.

Table 4
Applicable or Relevant and Appropriate Requirements (ARARs)
JCI Jones Chemicals, Inc.
Caledonia, New York

Location-Specific ARARs

LOCATION	REQUIREMENTS	CITATION	DESCRIPTION	ARAR or TBC	COMMENT
State					
Cultural Resources	New York State Parks, Recreation, and Historic Preservation Law. Preservation of Historic Structures or Artifacts.	Section 14.09	Guidelines for preservation of historic properties and minimize remedial action impacts.	Not applicable.	No significant historic properties or archeological digs have been identified in the vicinity of the Site.
Critical Habitat	Endangered and Threatened Species of Fish and Wildlife.	6 NYCRR Part 182	Guidelines for protection of critical habitats that may be potentially affected by Site activities.	Not applicable.	No endangered or threatened species have been identified in the Site vicinity.
Wetlands	New York State Freshwater Wetlands Act. New York State Freshwater Wetlands Implementation Program.	6 NYCRR Parts 662-665	Guidelines for protection of wetlands that may be potentially affected by Site activities.	Not applicable.	No wetlands are present in the Site vicinity.
Floodplain	Floodplain Management.	6 NYCCR Subpart 373-1	Regulates activities that may have adverse effect in the floodplain.	Not applicable.	Site is not located within the 100-year floodplain.
Stream or Rivers	Protection of Waters Program.	6 NYCRR Part 608	Regulates activities that may have adverse effects on stream or rivers.	Not applicable.	Site activities will not affect streams or rivers in the vicinity.

Table 5
Summary of Soil and Groundwater Remediation Goals
JCI Jones Chemicals, Inc.
Caledonia, New York

Parameter	Soil Medium (mg/kg)[1]	Groundwater Medium (µg/l)[2]
Tetrachloroethene	1.4	5
Trichloroethene	0.7	5
cis-1,2-Dichloroethene	NA	5
Trans-1,2-Dichloroethene	0.3	5
1,1-Dichloroethene	0.4	5
Vinyl Chloride	0.2	2

[1] Values are based on NYSDEC TAGM #HWR-94-4046: Soil Cleanup Objectives to Protect Groundwater Quality. Concentrations are presented in milligrams per kilogram.

[2] Values are based on New York State Groundwater Quality Standards 6 NYCRR Part 703.5. Concentrations are presented in micrograms per liter.

Table 6
Screening of General Response Technologies
JCI Jones Chemicals, Inc. Site, Caledonia, New York

General Response Action	Technology	Medium	Effectiveness	Implementability	Relative Cost[a]	Retain for Evaluation
No Action	None	Soil and Groundwater	It is unlikely this response action will achieve RAOs within a reasonable time frame.	Readily implementable.	Low	Retained to compare with other response actions.
Institutional Controls	Deed restrictions and access control	Soil and Groundwater	Effective at limiting public exposure if procedures are enforced.	Implementable with appropriate legal authority.	Low	Retained.
Containment	Capping with low permeability soil or plastic liner	Soil	Effective at reducing infiltration. Ineffective at minimizing migration of affected groundwater.	Can be implemented with appropriate engineering design considerations.	Medium	Not retained.
	Subsurface Vertical Barrier (Slurry) Wall	Groundwater	Vertical barriers control the subsurface flow of water into or out of a hazardous waste site	Can be implemented with relative ease. Consist of a vertical trench excavated along the perimeter of the site. Keyed into an aquitard. Filled with bentonite slurry and subsequently backfilled with a mixture of low-permeability material (1×10^{-6} cm/sec).	High	Not retained for further evaluation. Will require placement over significantly large area.
	Hydraulic Control/Pump-and-treat	Groundwater	Effective in containing affected groundwater.	Easily implementable. A sufficient amount of affected groundwater is pumped and treated via extraction wells. Treated water is disposed to a POTW.	Medium	Retained. Hydraulic control via pump-and-treat would treat and prevent migration of affected groundwater.

Table 6
Screening of General Response Technologies
JCI Jones Chemicals, Inc. Site, Caledonia, New York

General Response Action	Technology	Medium	Effectiveness	Implementability	Relative Cost[a]	Retain for Evaluation
In Situ Treatment/ DNAPL Remediation Technologies	Air Sparging	Groundwater	Effective in treating affected groundwater. However, this technology can potentially remobilize DNAPLs to deeper depths.	Proven technology, readily implementable. However, would require a complex array of wells in a highly permeable water-bearing zone such as the Site.	High	Not retained.
	Soil Vapor Extraction (SVE)	Soil	Effective in removing VOCs from the vadose zone.	Readily implementable. Soil vapor is extracted through a series of wells in the vadose zone source area and treated.	Medium	Retained for further evaluation. Effective in treating PCE-affected source areas on the Site.
	Dual-Phase Extraction (DPE)	Soil and Groundwater	Effective in extracting VOCs from the vadose zone and affected groundwater at the Site. High vacuum pump extracts affected soil vapors and groundwater from extraction wells that are treated at the surface and discharged appropriately.	This response action would require a complex array of wells, rendering it impractical for this application. Also, lowering of the water table may potentially exacerbate the problem by remobilizing DNAPLs.	High	Not retained for further analysis.
In Situ Treatment (continued)	Monitored Natural Attenuation	Groundwater	Effective, if used in conjunction with other aggressive response actions.	Readily implementable. Requires periodic groundwater monitoring of natural attenuation indicator parameters.	Low	Retained for further evaluation.
	Hydrogen Release Compound™/ Oxygen Release Compound® Injection	Groundwater	Emerging technology. Effective in treatment dissolved phase. Limited applicability in treating DNAPLs.	Difficult to implement. Involves complex array of injection and extraction wells and injecting viscous substances.	Medium	Not retained for further evaluation.

Table 6
Screening of General Response Technologies
JCI Jones Chemicals, Inc. Site, Caledonia, New York

General Response Action	Technology	Medium	Effectiveness	Implementability	Relative Cost[a]	Retain for Evaluation
	Potassium Permanganate Injection	Groundwater	Emerging technology. Effective in treating dissolved phase and addressing DNAPLs.	Can be implemented. May require variance to address inherent contamination associated with trace metals and other secondary standards.	Medium	Retained for further analysis.
In Situ Treatment (continued)	Cosolvent Flushing	Groundwater	Emerging technology. Cosolvent, such as alcohol, ethanol, or acetone is injected into the subsurface to reduce the polarity of the aqueous phase, resulting in a significant increase in the rate of interfacial mass transport between DNAPL and the aqueous phase.	Not readily implementable. Will require extensive field testing, variances for injection and permitting.	High	Not retained for further analysis.
Ex Situ Treatment	Air Stripping	Groundwater	Effective in treating extracted affected groundwater.	Easily implementable. Used in conjunction with hydraulic control/pump-and-treat.	Low	Retained.
	Liquid-Phase Carbon Adsorption	Groundwater	Effective in treating groundwater, especially for polishing prior to discharge to POTW.	Easily implementable. Used in conjunction with hydraulic control/pump-and-treat.	Low	Retained.
	Vapor-Phase Carbon Adsorption	Vapor Phase	Effective in treating exhaust from SVE or air stripping.	Easily implementable. Used in conjunction with SVE operation.	Low	Retained.

Table 6
Screening of General Response Technologies
JCI Jones Chemicals, Inc. Site, Caledonia, New York

General Response Action	Technology	Medium	Effectiveness	Implementability	Relative Cost[a]	Retain for Evaluation
Ex Situ Treatment (continued)	Biological Treatment	Groundwater	Not very effective in treating chlorinated compounds.	Requires special design considerations for treating groundwater through trickling filters, activated sludge, sequencing batch reactors, and submerged fixed-film reactors.	Medium	Not retained for further analysis.
	Vapor Thermal Oxidation	Vapor	Effective in treating air stripping or SVE exhaust streams via thermal oxidation.	Not readily implementable. Involves high fuel costs.	High	Not retained for further analysis.
	Catalytic Oxidation	Vapor	Effective in treating air stripping or SVE exhaust streams via catalytic oxidation.	Not readily implementable. Requires extensive design considerations when treating chlorinated solvents. May require additional scrubbers to address hydrogen chloride emissions.	High	Not retained for further analysis.
Source Removal	Excavation (with off site disposal or on-site treatment)	Soil	Effective in removing affected soils.	Easily implementable. Soil excavation can be accomplished using backhoes, bulldozers, and large diameter augers.	Disposal/ Treatment costs -- High	Retained for further evaluation.

Notes:

[a] Relative Costs:
Low = <$1,000.000
Medium = $1,000,000 to 2,000,000
High = >$3,000,000

DNAPL = dense nonaqueous phase liquid
DPE = dual-phase extraction
PCE = tetrachloroethene
POTW = publicly owned treatment works
RAO = remedial action objective
SVE = soil-vapor extraction
VOC = volatile organic compound

Table 7
Cost Summary of Remedial Alternatives
JCI Jones Chemicals, Inc. Site, Caledonia, New York

Medium	Alternative Number	Technologies	Direct and Indirect Capital Costs	OM&M (Annual)	Years of OM&M	*Net Present Value - OM&M	*Net Present Value - Total
Soil	**Alternative 1**	No Action	$0	$0	0	$0	$0
		Total:	$0	$0	0	$0	$0
	Alternative 2	Soil Vapor Extraction	$280,268	$121,632	3	$319,201	$599,469
		Other Controls	$84,820	$0	0	$0	$84,820
		Total:	$365,088	$121,632	3	$319,201	$684,289
	Alternative 3A	Excavation of PCE Affected Soils with Off-Site Disposal	$3,183,996	$0	0	$0	$3,183,996
		Other Controls	$84,820	$0	0	$0	$84,820
		Total:	$3,268,816	$0	0	$0	$3,268,816
	Alternative 3B	Excavation of PCE Affected Soils with On-Site Treatment	$1,069,196	$0	0	$0	$1,069,196
		Other Controls	$84,820	$0	0	$0	$84,820
		Total:	$1,154,016	$0	0	$0	$1,154,016
Ground-water	**Alternative 1**	No Further Action	$0	$50,736	30	$629,585	$629,585
		Total:	$0	$50,736	30	$629,585	$629,585
	Alternative 2	Source Area Pump and Treat	$277,466	$0	15	$0	$277,466
		Monitored Natural Attenuation	$0	$80,850 **	30	$1,003,275	$1,003,275
		Institutional Controls	$84,820	$0	0	$0	$84,820
		Total:	$362,286	$80,850	30	$1,003,275	$1,365,561
	Alternative 3	Site Wide Pump and Treat	$1,331,745	$181,221 **	15	$1,650,520	$2,982,265
		Institutional Controls	$84,820	$0	0	$0	$84,820
		Total:	$1,416,565	$181,221	15	$1,650,520	$3,067,085
	Alternative 4	Source Area Pump and Treat	$277,466	$0	15	$0	$277,466
		Monitored Natural Attenuation	$0	$80,850 **	30	$1,003,275	$1,003,275
		Potassium Permanganate Injection	$116,310	$34,320	5	$140,719	$257,029
		Institutional Controls	$84,820	$0		$0	$84,820
		Total:	$478,596	$115,170	30	$1,143,993	$1,622,589
	Alternative 5	Monitored Natural Attenuation	$0	$80,850	30	$1,003,275	$1,003,275
		Institutional Controls	$84,820	$0		$0	$84,820
		Total:	$84,820	$80,850	30	$1,003,275	$1,088,095

*assumes a discount rate of 7 percent
**averaged annualized OM&M value
OM&M = operation, maintenance, and monitoring

Table 8
Summary of Comparative Analysis of Remedial Alternatives
JCI Jones Chemicals, Inc.
Caledonia, New York

Alternative Criterion	Soil Alternative #1: —No Action	Soil Alternative #2: —SVE of PCE-Affected Soil at Source —Other Controls	Soil Alternative #3: —Excavation of PCE-Affected Soil —Other Controls	Groundwater Alternative #1: —No Further Action	Groundwater Alternative #2: —Source Area Pump-and-Treat —Monitored Natural Attenuation —Institutional Controls	Groundwater Alternative #3: —Site Wide Pump-and-Treat —Institutional Controls	Groundwater Alternative #4: —Source Area Pump-and-Treat —Monitored Natural Attenuation —Institutional Controls —$KMnO_4$ Injection	Groundwater Alternative #5: —Site Wide Monitored Natural Attenuation —Institutional Controls
Overall Protection of Human Health and the Environment	**Poor** Not protective.	**Good** SVE would be effective in reducing concentrations and, hence, exposure.	**Good** Excavation would remove affected soils.	**Poor** Not protective because of the lack of physical remediation.	**Good** Hydraulic containment would be attained at the source via pump-and-treat, minimizing exposure. Monitored natural attenuation would restore slightly affected groundwater outside the source.	**Good** Hydraulic containment at the Site would be attained via pump-and-treat, minimizing exposure.	**Good** Hydraulic containment at the Site would be attained via pump-and-treat, minimizing exposure. DNAPL treatment would occur via $KMnO_4$ injection. Monitored natural attenuation would address the slightly affected groundwater outside the source.	**Poor** Not protective because it could be several decades before RAOs are met.
Compliance with ARARs	**Poor** Will not comply with ARARs.	**Good** Soil PRGs will be met through SVE in less 3 years.	**Good** Soil excavation would remove the source; clean or treated soil would be used to back-fill the area of excavation.	**Poor** Will not comply with ARARs due to a lack of treatment.	**Fair** Compliance with chemical-specific ARARs may not be attained for several decades.	**Fair** Compliance with chemical-specific ARARs may not be attained for several decades.	**Good** Pump-and-treat in conjunction with $KMnO_4$ Injection would be effective in achieving compliance with ARARs.	**Poor** Will not comply with ARARs for long time, possibly decades.
Long-Term Effectiveness and Permanence	**Poor** Because of the absence of remediation, assessment is not possible.	**Good** There would no treatment required beyond SVE.	**Good** Soil would require no further treatment beyond excavation.	**Poor** Because of the absence of remediation, assessment is not possible.	**Fair** Long-term or permanence cannot be assured due to potential "rebound" effects upon cessation of pump-and-treat system.	**Fair** Long-term effectiveness or permanence cannot be assured due to potential DNAPL presence.	**Good** In addition to hydraulic containment, DNAPLs would be treated at the Site providing long-term effectiveness and permanence.	**Poor** Will not afford long-term effectiveness or permanence for many decades.
Reduction of Toxicity, Mobility, or Volume through Treatment	**Poor** There will be no reduction in toxicity, mobility, or volume.	**Good** SVE would be effective in remediating affected soils to below remediation goals.	**Good** Soil remediation goals would be attained quickly through excavation and removal of the source.	**Poor** There will be no reduction in toxicity, mobility, or volume.	**Fair** Toxicity, mobility, or volume will not be completely reduced because of the potential DNAPLs.	**Fair** Toxicity, mobility, or volume will not be completely reduced due to potential DNAPLs at the source.	**Good** Pump-and-treat and $KMnO_4$ injection would provide hydraulic containment, treatment of dissolved-phase chemicals and treatment of DNAPLs; reduction of toxicity, mobility, and volume would be achieved.	**Poor** Reduction in toxicity, mobility, or volume may not be achieved in a reasonable time frame.

Table 8
Summary of Comparative Analysis of Remedial Alternatives
JCI Jones Chemicals, Inc.
Caledonia, New York

Alternative Criterion	Soil Alternative #1: —No Action	Soil Alternative #2: —SVE of PCE-Affected Soil at Source —Other Controls	Soil Alternative #3: —Excavation of PCE-Affected Soil —Other Controls	Groundwater Alternative #1: —No Further Action	Groundwater Alternative #2: —Source Area Pump-and-Treat —Monitored Natural Attenuation —Institutional Controls	Groundwater Alternative #3: —Site Wide Pump-and-Treat —Institutional Controls	Groundwater Alternative #4: —Source Area Pump-and-Treat —Monitored Natural Attenuation —Institutional Controls —$KMnO_4$ Injection	Groundwater Alternative #5:
Short-Term Effectiveness	**Good** Because of the absence of remediation, there would be no impact on on-site workers or local community.	**Good** Soil PRGs may be attainable in less than three years. There is minimal impact associated with the construction of this alternative. Construction time is estimated to 20 days.	**Fair** On-site workers would be exposed to affected soils during excavation. Local residences may be exposed to fugitive dust and noise during excavation and transport of hazardous waste. Construction time is estimated to be 45 days.	**Good** There would be minimal impacts to construction workers or local community due to a lack of construction.	**Good** Estimated treatment time is 15 years. There would be minimal exposure to construction workers, which may be minimized through protective clothing, equipment, and engineering controls. Construction time is estimated to 45 days	**Poor** Estimated treatment is 15 years. There would be potential exposure to on-site workers during installation of 16 extraction wells, management of IDW, piping and trenching to treat over 1.7 million gallon per day of water. Local communities may be affected by fugitive dust and noise. Construction time is estimated to be 90 days.	**Good** Estimated treatment time is 15 years. There would be slight exposure to on-site workers during OM&M of this alternative. However, this exposure could be minimized by using appropriate protective equipment and clothing. Construction time is estimated to be 45 days.	**Good** There would be minimal potential impacts to construction workers or local community.
Implementability	**Good** Easiest to implement.	**Good** SVE systems are commonly installed for treatment of soils affected with chlorinated solvents.	**Fair** There would be administrative difficulties in coordinating with several agencies for excavation and off-site transport and disposal of hazardous waste.	**Good** Easy to implement.	**Good** Easy to implement.	**Poor** Extensive technical and administrative difficulty associated with installation of numerous extraction wells, management of IDW, permitting of infiltration gallery, pump-and-treat of over 1.7 million gallons per day of water.	**Good** This alternative would be relatively easy to install. $KMnO_4$ injection is an emerging technology and has been implemented successfully to address to chlorinated solvent sites.	**Good** Easy to implement.
Cost (net present value)	**\$0**	**\$684,289**	**3A: \$3,268,816** **3B: \$1,154,016**	**\$629,585**	**\$1,365,561**	**\$3,067085**	**\$1,622,589**	**\$1,088,095**

Notes:

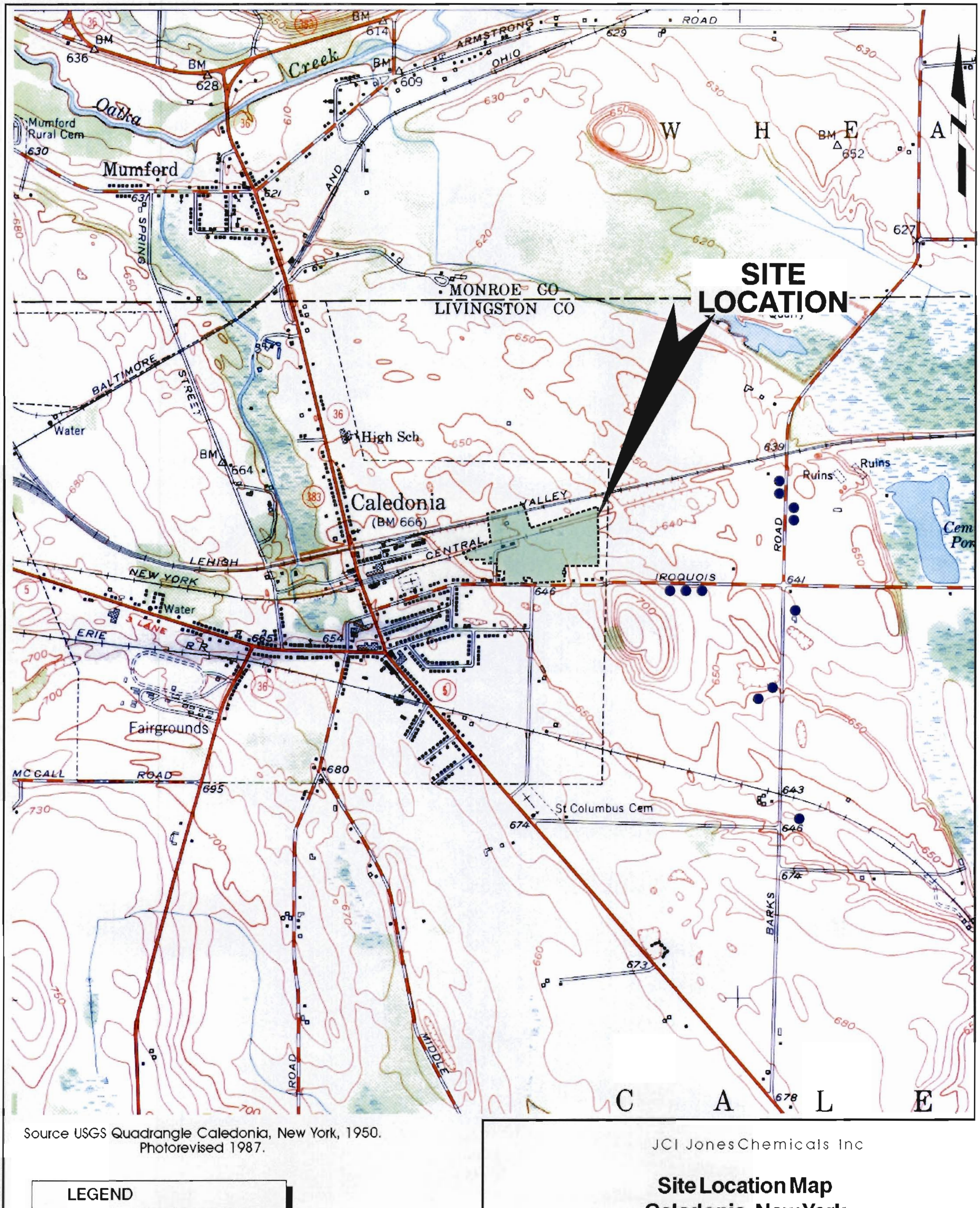
DNAPL = dense nonaqueous phase liquid

PCE = tetrachloroethene

PRG = Preliminary Remediation Goal

RAO = Remedial Action Objective

SVE = soil-vapor extraction



Source USGS Quadrangle Caledonia, New York, 1950.
Photorevised 1987.

LEGEND

● Residential wells sampled NYSDOH, 1996.

0 2000 FEET

JCI Jones Chemicals Inc

Site Location Map
Caledonia, New York

LFR
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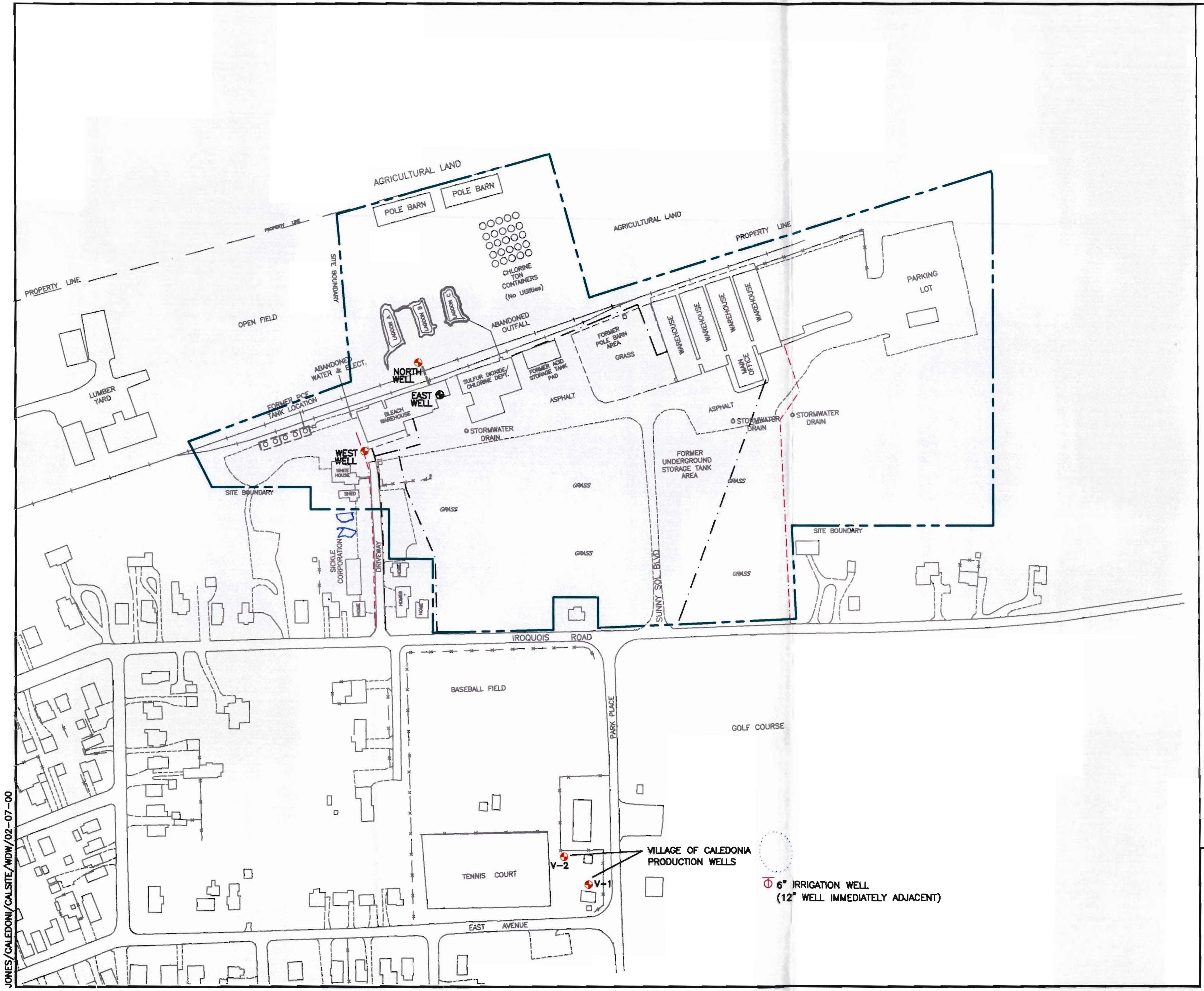
Figure 1

Project No. 3165.20

ARCHGRACHJONES\3165SITEWDW07-30-99



JONES/CALEDONI/CALSITE/MDW/02-07-00

LEGEND

- Production wells
- Former production well
- Irrigation well
- Current water line
- Current gas line
- Site boundary JCI Jones Chemicals, Inc.

Note: White house and shed were razed in 1998.

0 240 FEET

JCI Jones Chemicals, Inc.

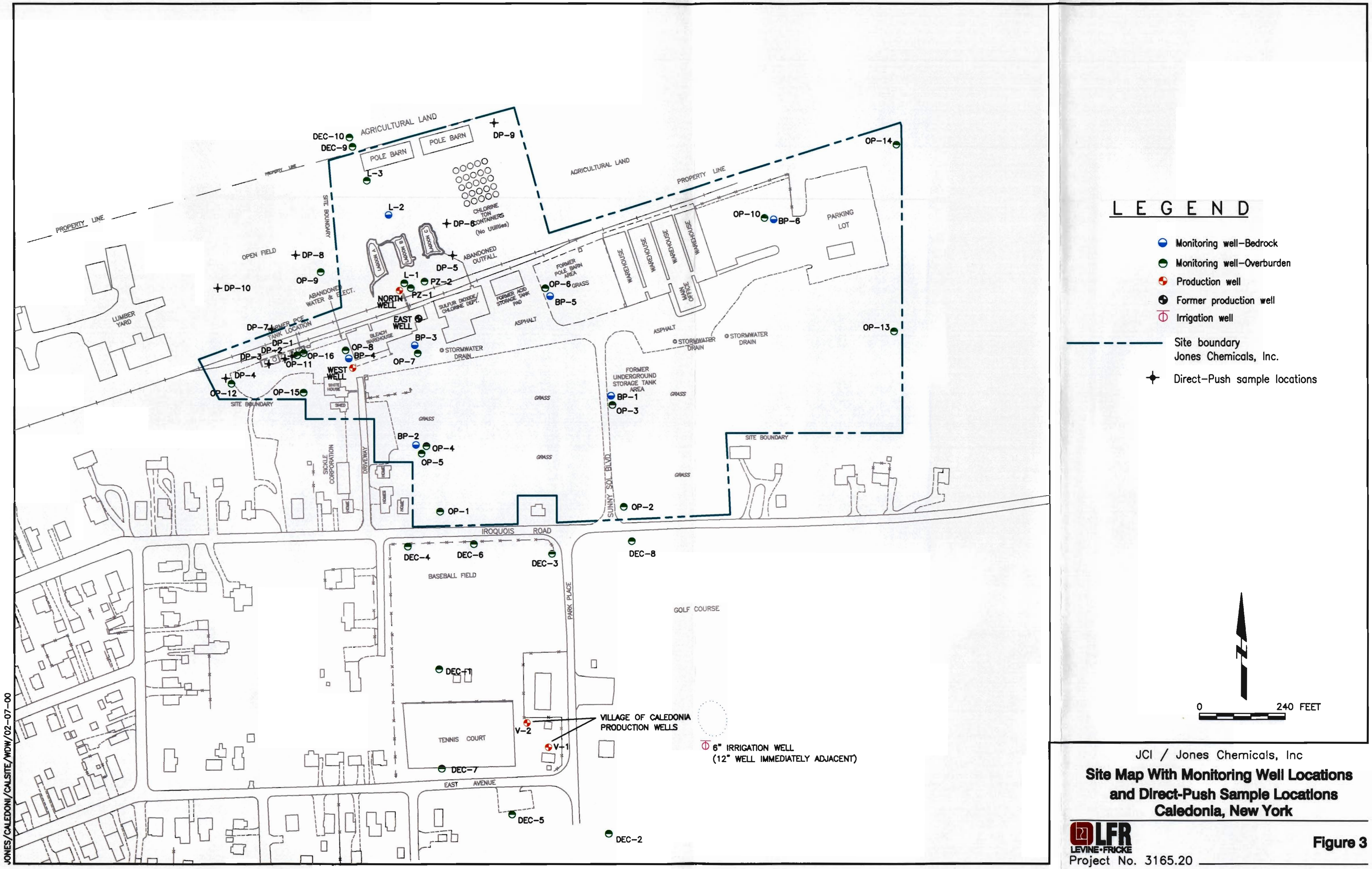
Site Map

Caledonia, New York

LFR LEVINE·FRICKE

Project No. 3165.20

Figure 2



JCI / Jones Chemicals, Inc

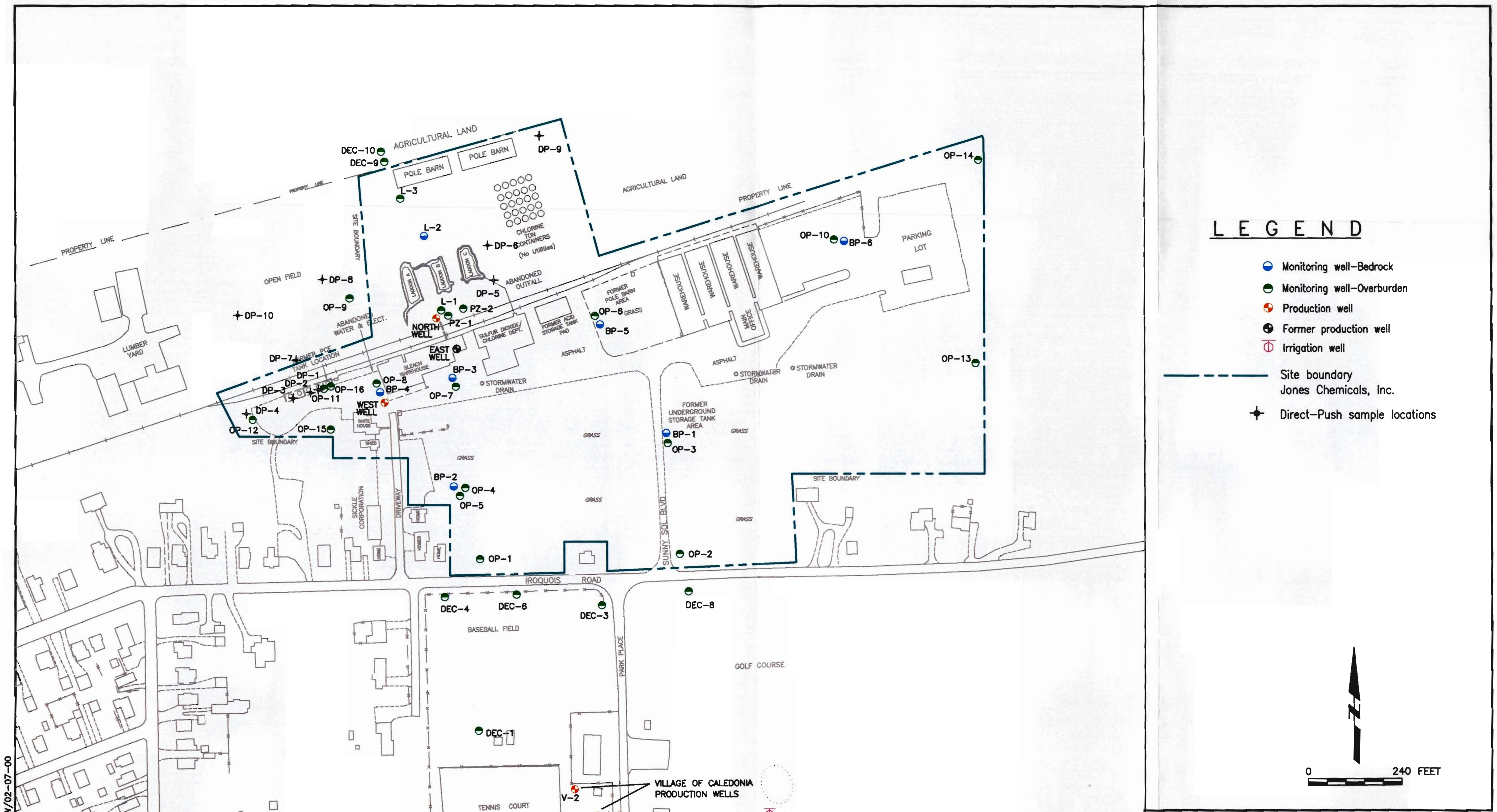
Site Map With Monitoring Well Locations and Direct-Push Sample Locations Caledonia, New York

LFR LEVINE·FRICKE

Project No. 3165.20

Figure 3

JONES/CALEDONI/CALSITE/WDW/02-07-00



JCI / Jones Chemicals, Inc

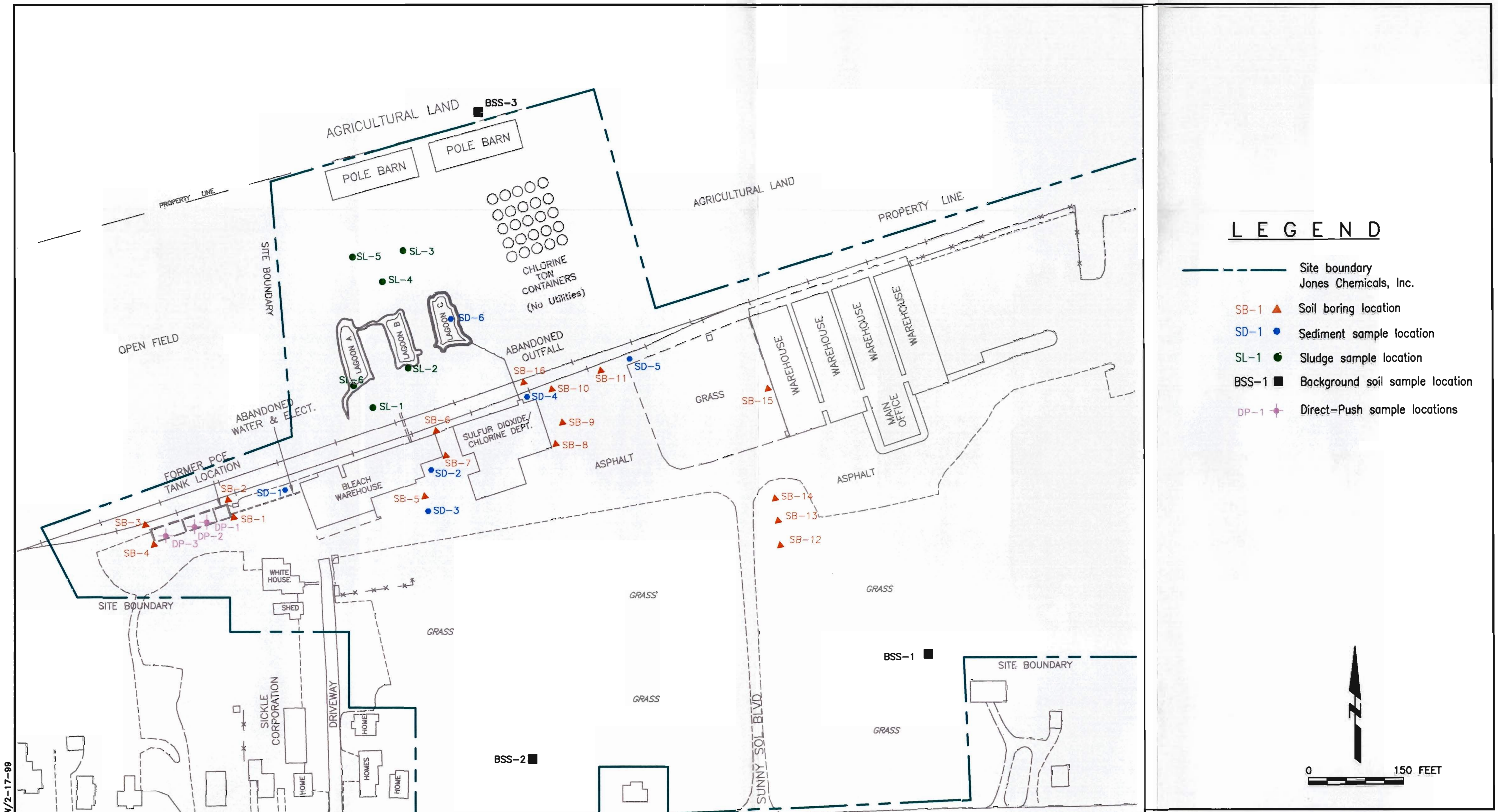
Site Map With Monitoring Well Locations and Direct-Push Sample Locations Caledonia, New York

LFR LEVINE·FRICKE

Project No. 3165.20

Figure 4

JONES/CALEDONI/CALSITE/WDW/02-07-00



L E G E N D

▬ ▬ – ▬	Site boundary Jones Chemicals, Inc.
SB-1 ▲	Soil boring location
SD-1 ●	Sediment sample location
SL-1 ●	Sludge sample location
BSS-1 ■	Background soil sample location
DP-1 ✦	Direct-Push sample locations

JCI / Jones Chemicals, Inc

Locations of Background Soil, Soil Borings, Sediment, Sludge, and Direct-push Soil Samples

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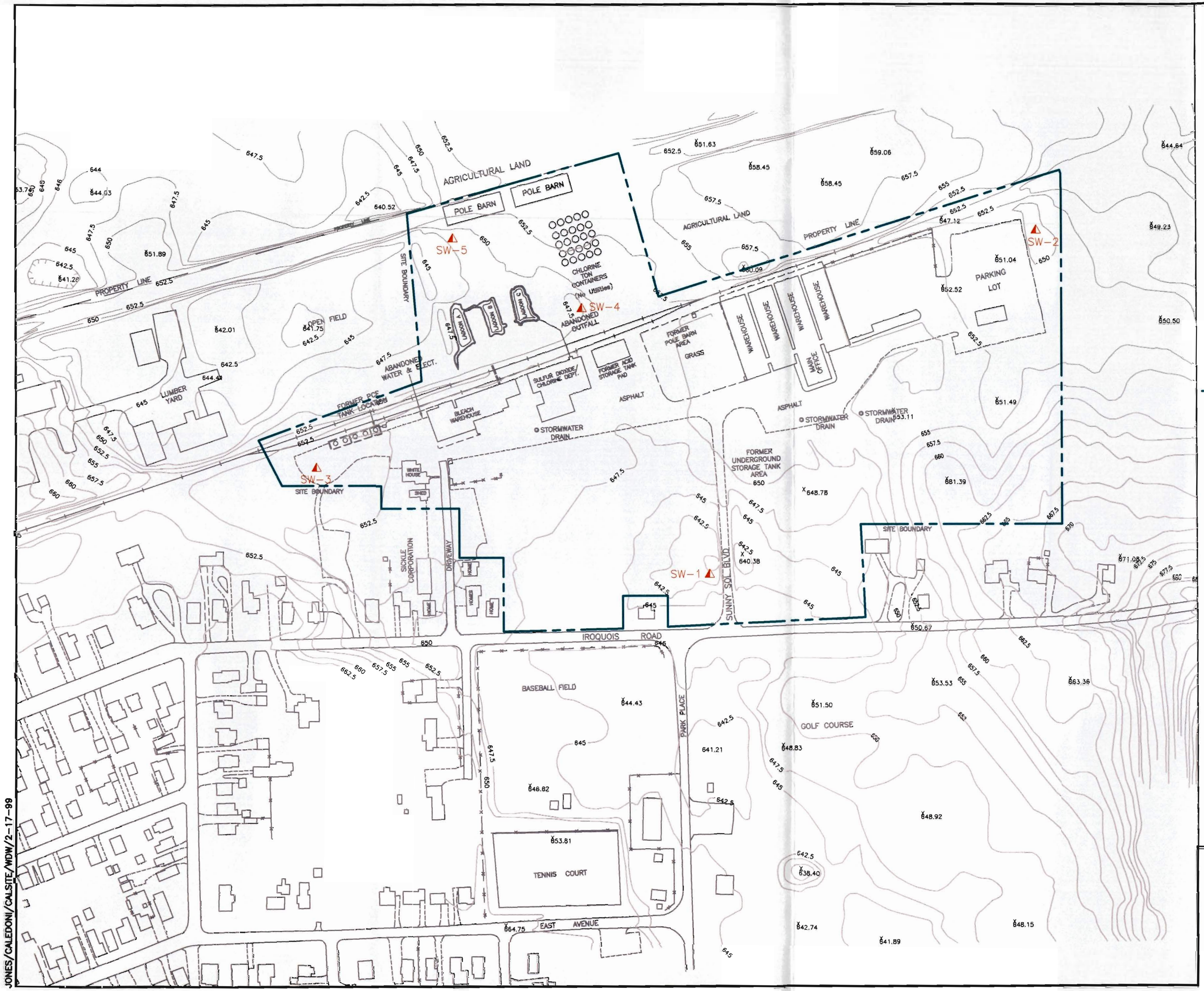
Project No. 3165.01

Figure 5

JONES/CALEDONI/CALSITE/WDW/2-17-99



L E G E N D

Site boundary Jones Chemicals, Inc.

▲ Surface water sample location

Source:
Supplemental RI/FS Land Use Plan
Map, Drawing No. At, 12/1991
(Conestoga-Rovers & Associates 1991)

Contour interval = 2.5 Feet

0 240 FEET

JCI / Jones Chemicals, Inc

Surface Elevation Contour Plot and Surface Water Sample Locations

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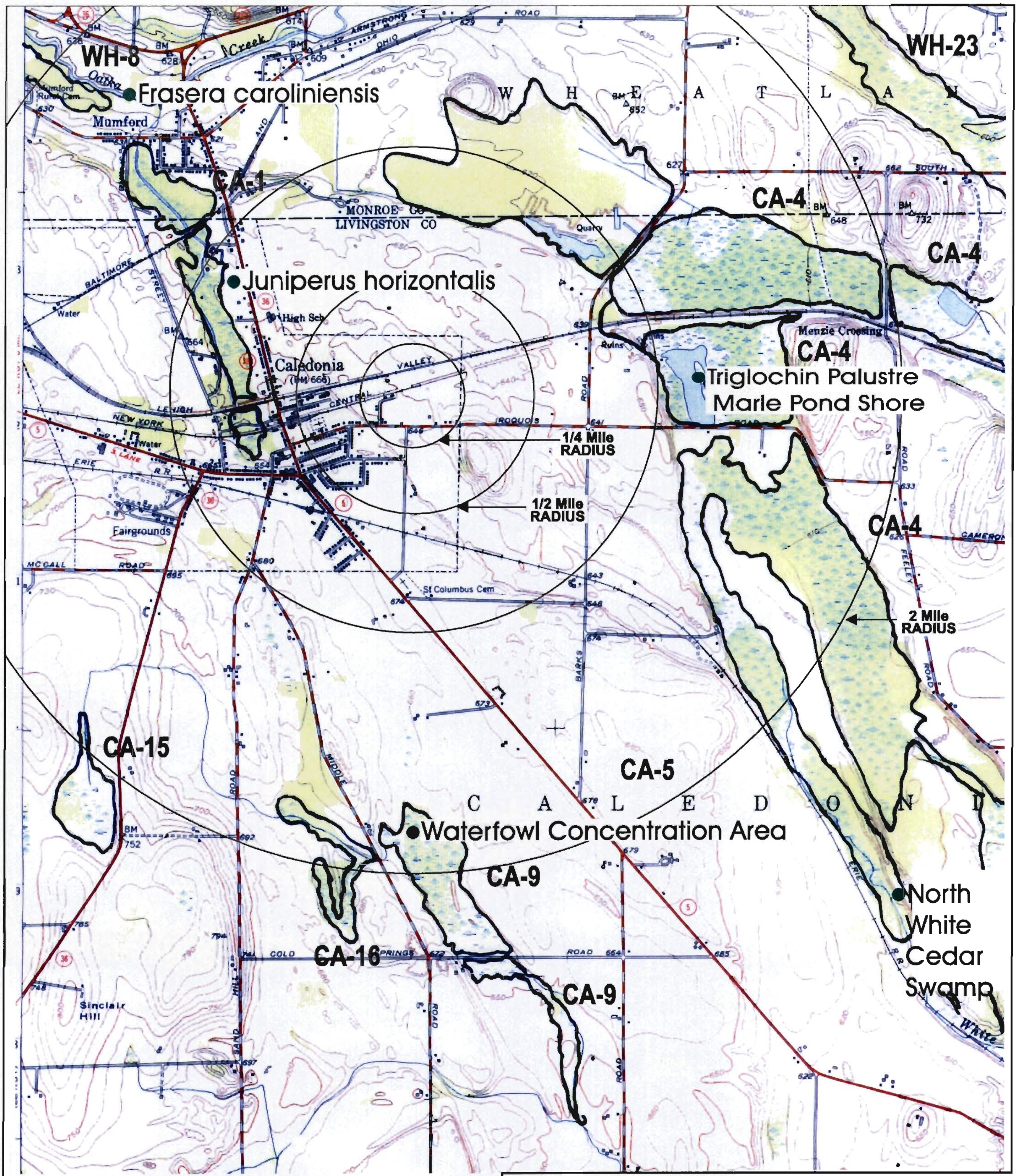
Project No. 3165.01

Figure 6

JONES/CALEDONI/CALSITE/WDW/2-17-99



Source USGS Quadrangle Caledonia, New York, 1950.
Photorevised 1987.

LEGEND

Regulated wetlands CA-5, CA-4, CA-1, CA-9, CA-16, CA-15, WH-8, WH-23

● General area of identified habitats

NOT TO SCALE

JCI/Jones Chemicals, Inc.

Wetlands and Ecological Sensitivities Map

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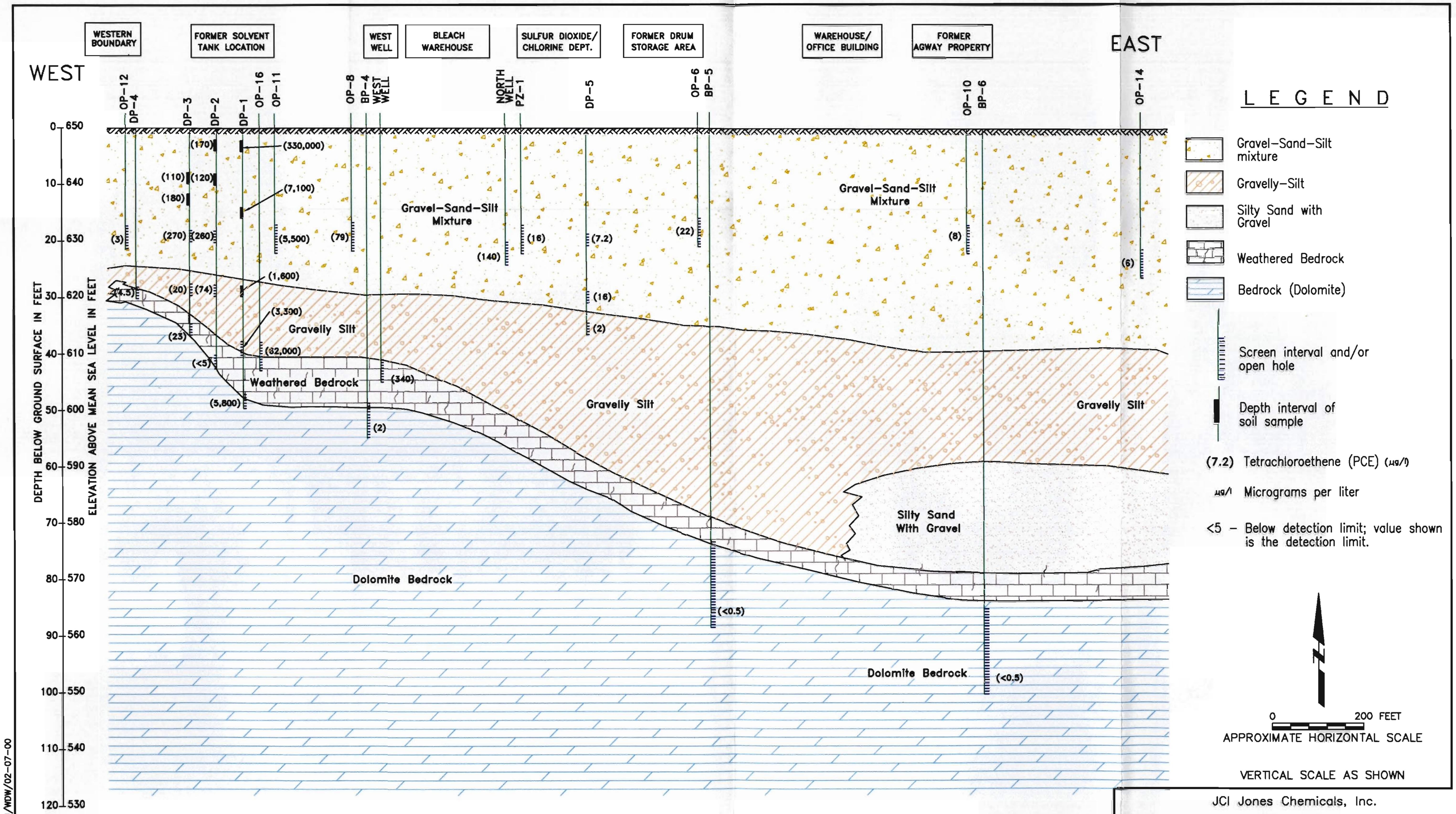
Project No. 3165.01

Figure 7

ARCHGRACH\JONES\3165SITEWDW2-17-99



JCI Jones Chemicals, Inc.

Generalized East-West Geologic Cross Section
Caledonia, New York

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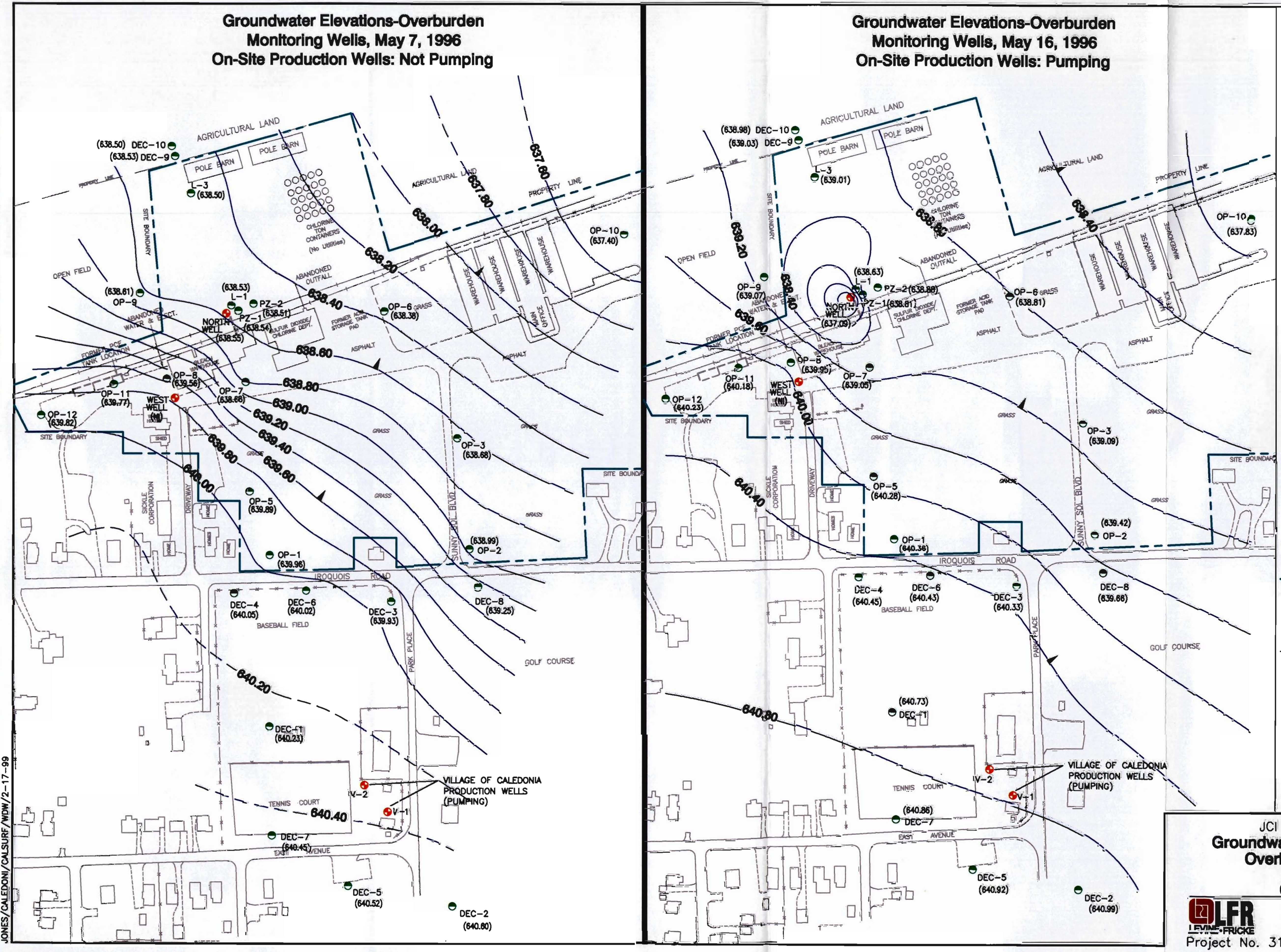
Project No. 3165.20

Figure 8

JONES/CALEDONI/XSECTJ/WDW/02-07-00



LEGEND

●	Monitoring well–Overburden
●	Production wells North Well–Overburden West Well–Bedrock
– – – –	Site boundary Jones Chemicals, Inc.
(639.42)	Groundwater elevation (FT NGVD)
—640.00—	Groundwater elevation contour (FT NGVD)
(NI)	Not included
NGVD	National Geodetic Vertical Datum
►	Groundwater flow direction

0 240 FEET

JCI / Jones Chemicals, Inc

Groundwater Elevation Contour Maps, Overburden Monitoring Wells May 7 and 16, 1996 Caledonia, New York

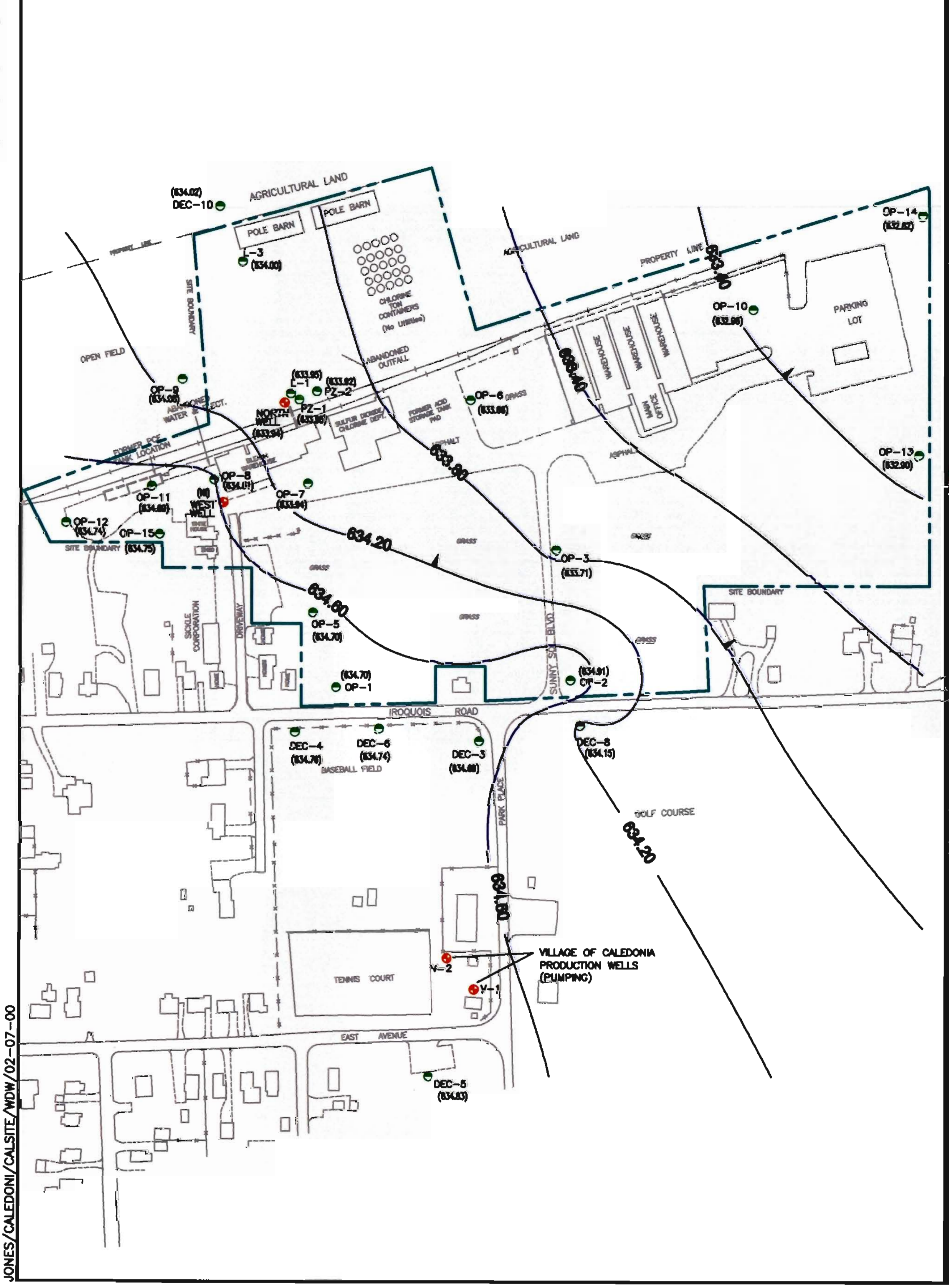
LFR LEVINE·FRICKE

Figure 9

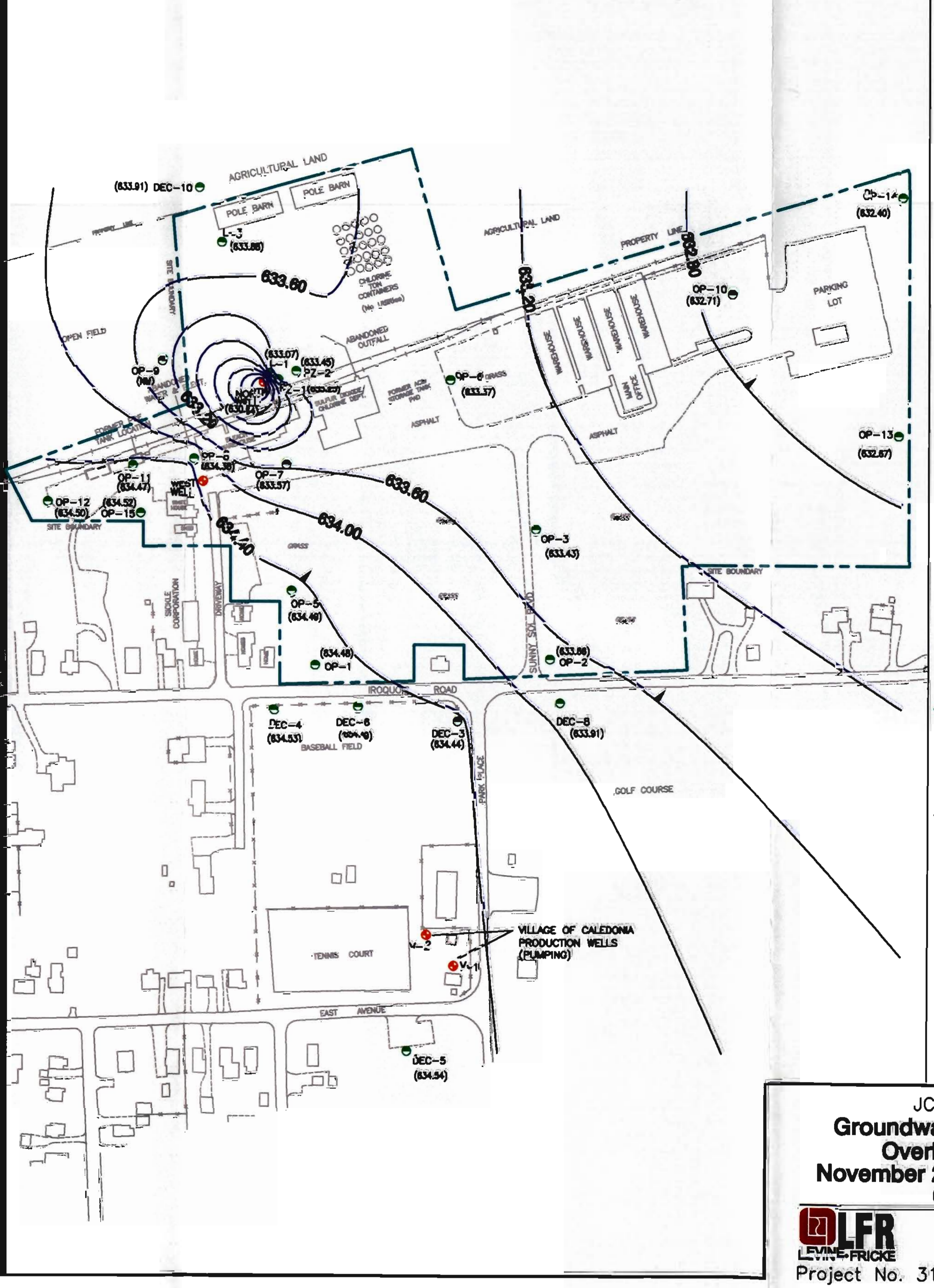
Project No. 3165.01

JONES/CALEDONI/CALSURF/WDW/2-17-99

Groundwater Elevations-Overburden Monitoring Wells, December 1, 1997 On-Site Production Wells: Not Pumping



Groundwater Elevations-Overburden Monitoring Wells, November 26, 1997 On-Site Production Wells: Pumping



LEGEND

●	Monitoring well-Overburden
●	Production wells North Well-Overburden West Well-Bedrock
— - —	Site boundary JCI Jones Chemicals, Inc.
(633.91)	Groundwater elevation (FT NGVD)
—— 634.00 ——	Groundwater elevation contour (FT NGVD)
(NI)	Not included
(NM)	Not measured
NGVD	National Geodetic Vertical Datum
►	Groundwater flow direction

0 300 FEET

JCI Jones Chemicals, Inc.

Groundwater Elevation Contour Maps, Overburden Monitoring Wells November 26, 1996, and December 1, 1997 Caledonia, New York

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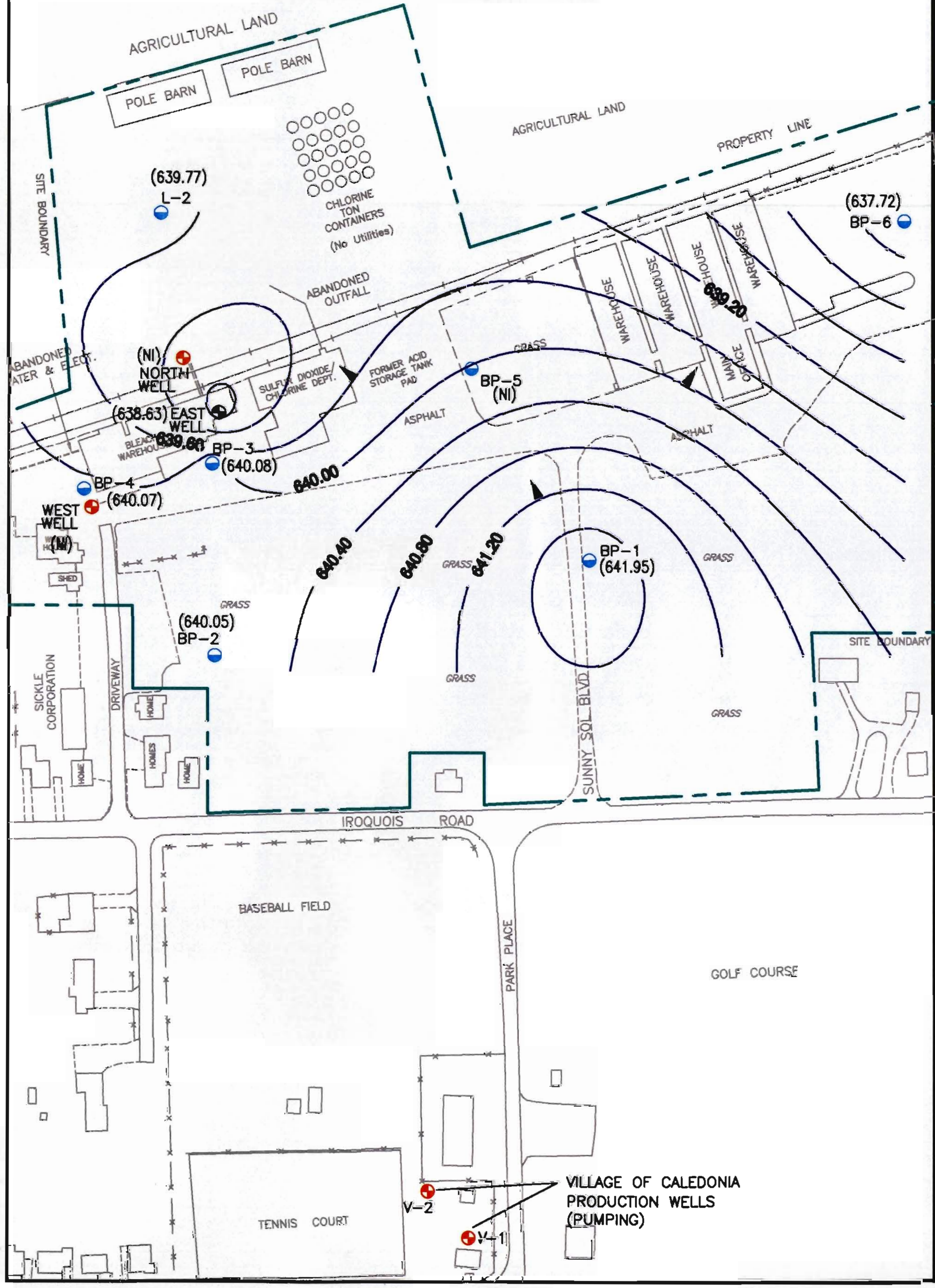
Figure 10

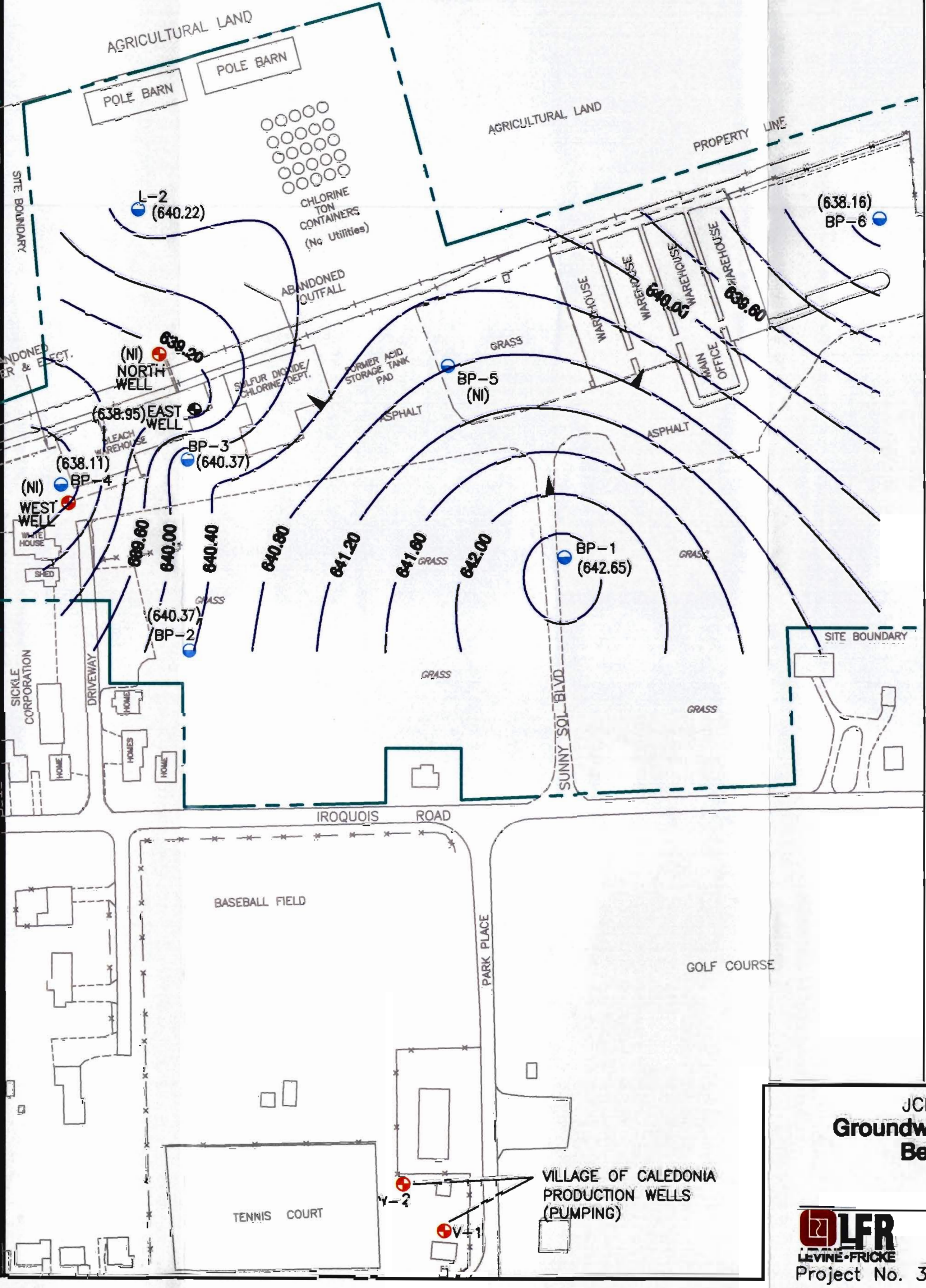
Project No. 3165.20

JONES/CALEDONI/CALSITE/WDW/02-07-00

Groundwater Elevations-Bedrock
Monitoring Wells, May 7, 1996
On-Site Production Wells: Not Pumping



Groundwater Elevations-Bedrock
Monitoring Wells, May 16, 1996
On-Site Production Wells: Pumping



N

LEGEND

◒	Monitoring well–Bedrock
⊕	Production wells North Well–Overburden West Well–Bedrock
⊕	Former production well
— — —	Site boundary Jones Chemicals, Inc.
(639.42)	Groundwater elevation (FT NGVD)
— 640.00 —	Groundwater elevation contour (FT NGVD)
(NI)	Not included
NGVD	National Geodetic Vertical Datum
►	Groundwater flow direction

0 240 FEET

JCI / Jones Chemicals, Inc

Groundwater Elevation Contour Maps,
Bedrock Monitoring Wells
May 7 and 16, 1996
Caledonia, New York

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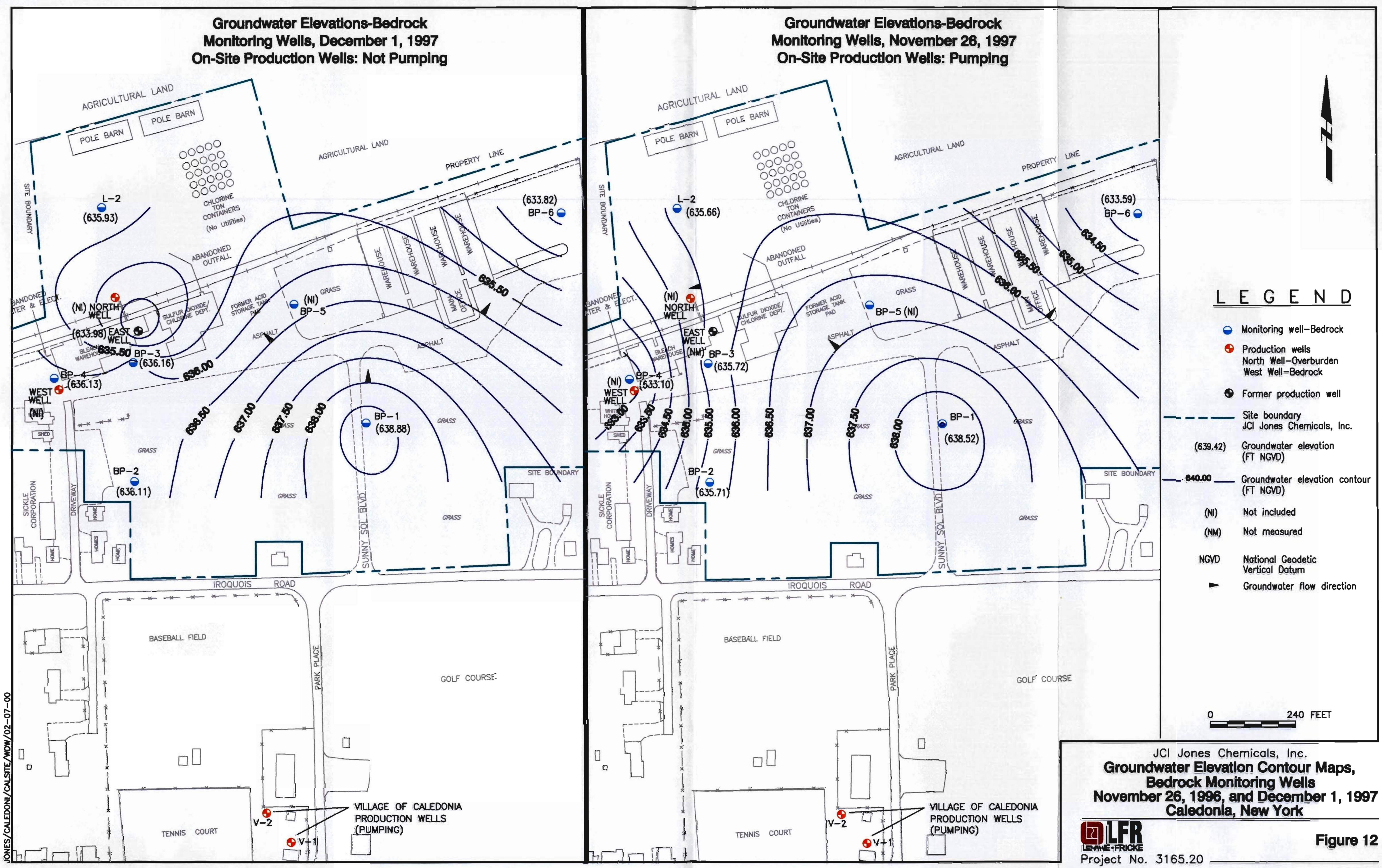
Project No. 3165.01

Figure 11

JONES/CALEDONI/CALSURF/WDW/2-17-99



Groundwater Elevations-Bedrock Monitoring Wells, December 1, 1997 On-Site Production Wells: Not Pumping

Groundwater Elevations-Bedrock Monitoring Wells, November 26, 1997 On-Site Production Wells: Pumping

JCI Jones Chemicals, Inc.

Groundwater Elevation Contour Maps, Bedrock Monitoring Wells November 26, 1996, and December 1, 1997 Caledonia, New York

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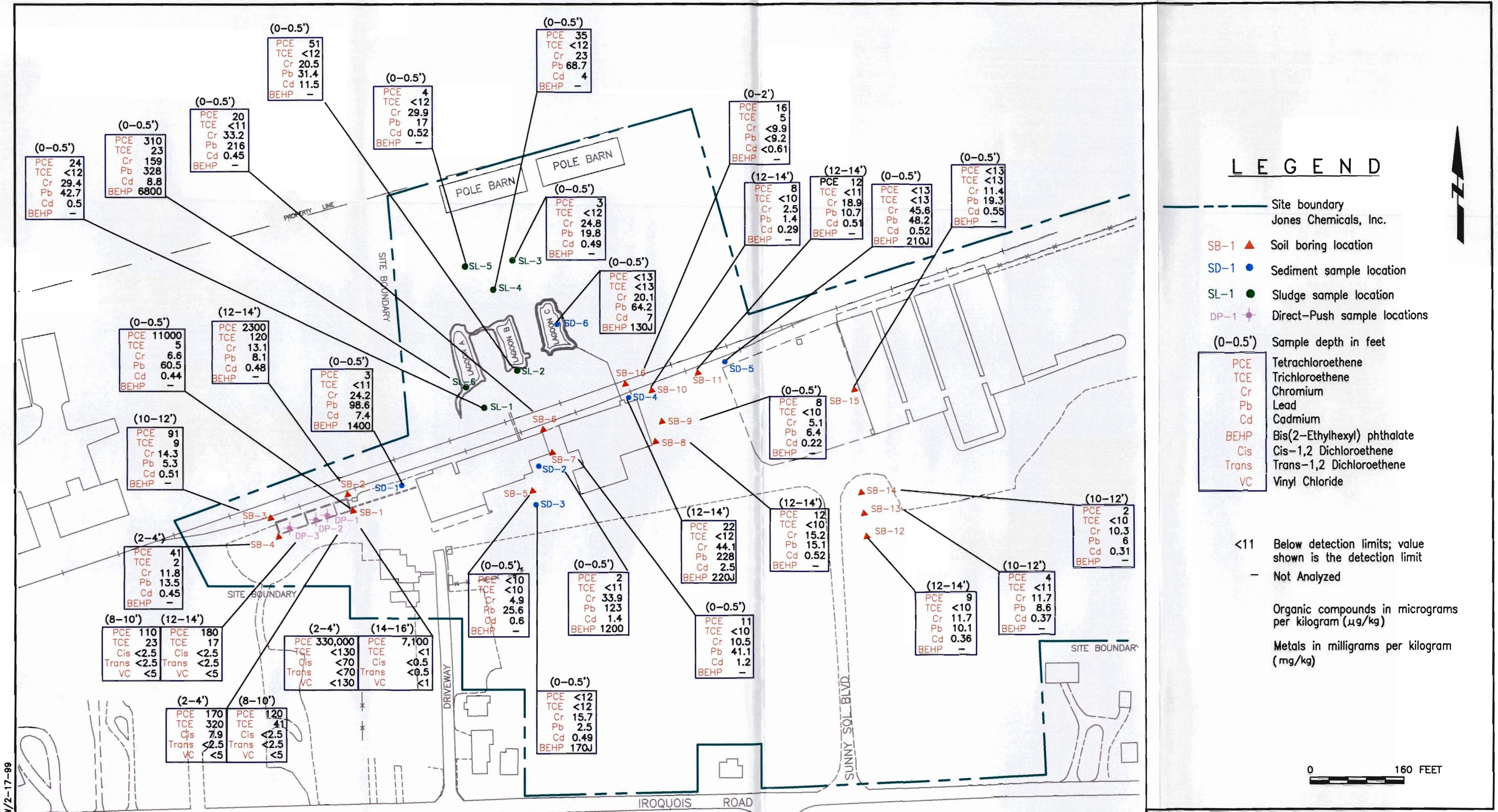
Project No. 3165.20

Figure 12



JCI / Jones Chemicals, Inc

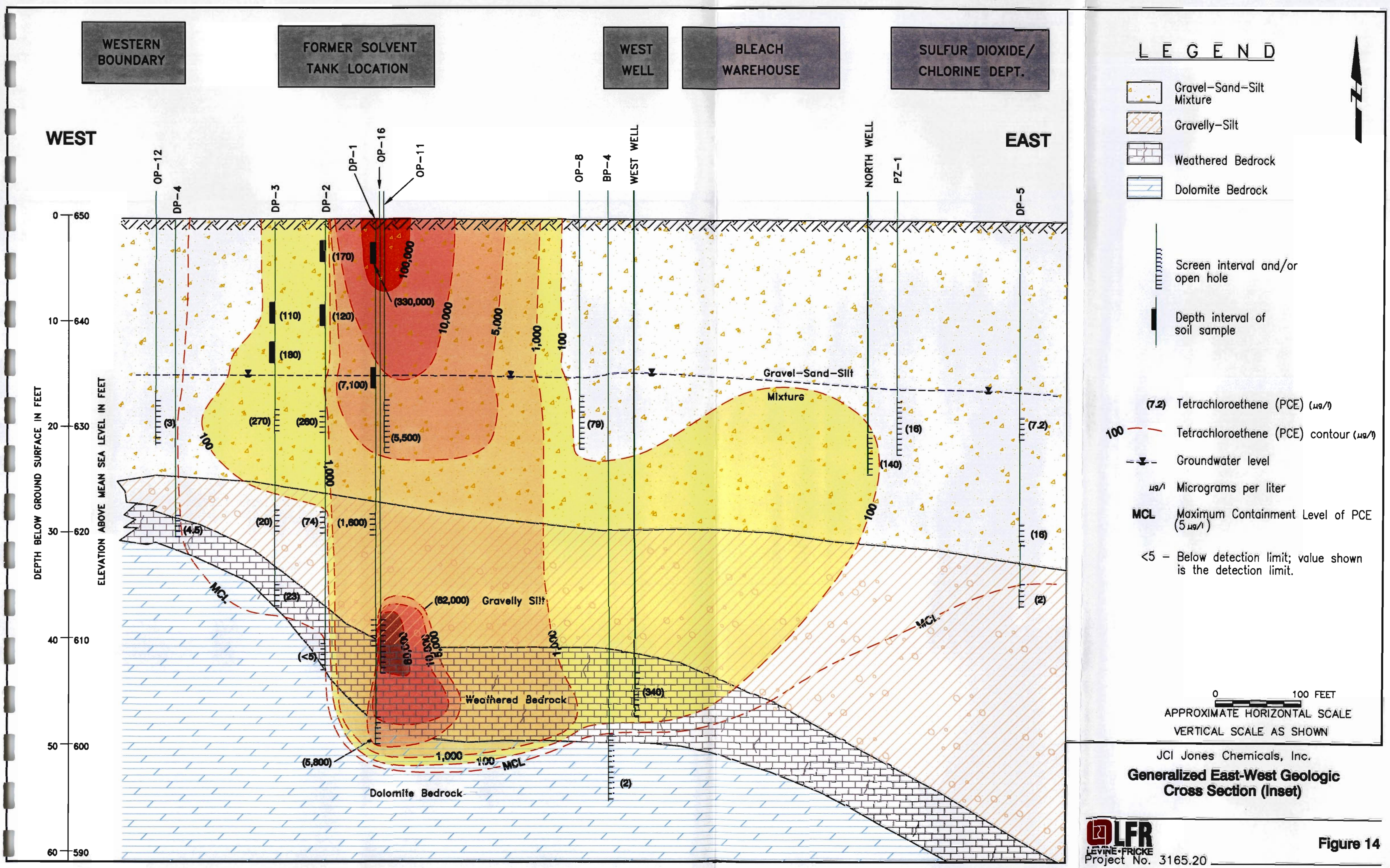
Selected Analyte Concentrations in Soil Borings, Sediment, Sludge, and Direct-push Soil Samples

LFR LEVINE·FRICKE

Project No. 3165.01

Figure 13

JONES/CALEDONI/CALSITE/WDW/2-17-99



JCI Jones Chemicals, Inc.

Generalized East-West Geologic Cross Section (Inset)

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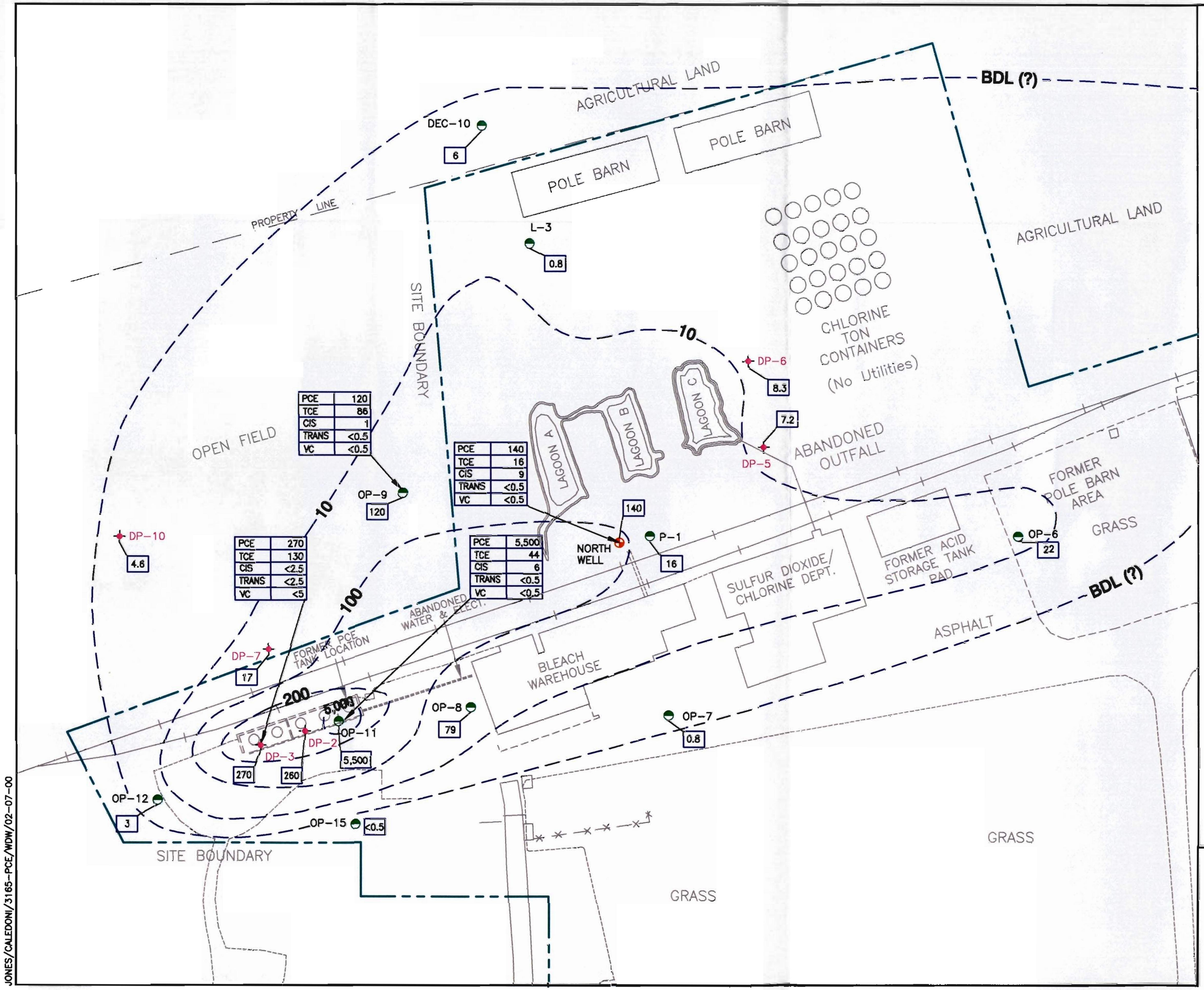
Figure 14



L E G E N D

— - —	Site boundary JCI Jones Chemicals, Inc.
◒	Monitoring well-Overburden
⊕	Production well
✦	Direct-Push sample location
PCE	Tetrachloroethene
PCE TCE CIS TRANS VC	Tetrachloroethene (µg/l) Trichloroethene (µg/l) Cis-1,2-Dichloroethene (µg/l) Trans-1,2-Dichloroethene (µg/l) Vinyl Chloride (µg/l)
22	PCE Concentration (µg/l)
10 — —	PCE inferred isoconcentration contour (µg/l)
µg/l	Micrograms per liter
BGS	Below ground surface
BDL	Below detection limit

Notes: Shallow monitoring wells are between 20 and 25 feet in total depth. Direct-push points sampled between 17 and 20 feet bgs.

0 100 FEET

JCI Jones Chemicals, Inc.

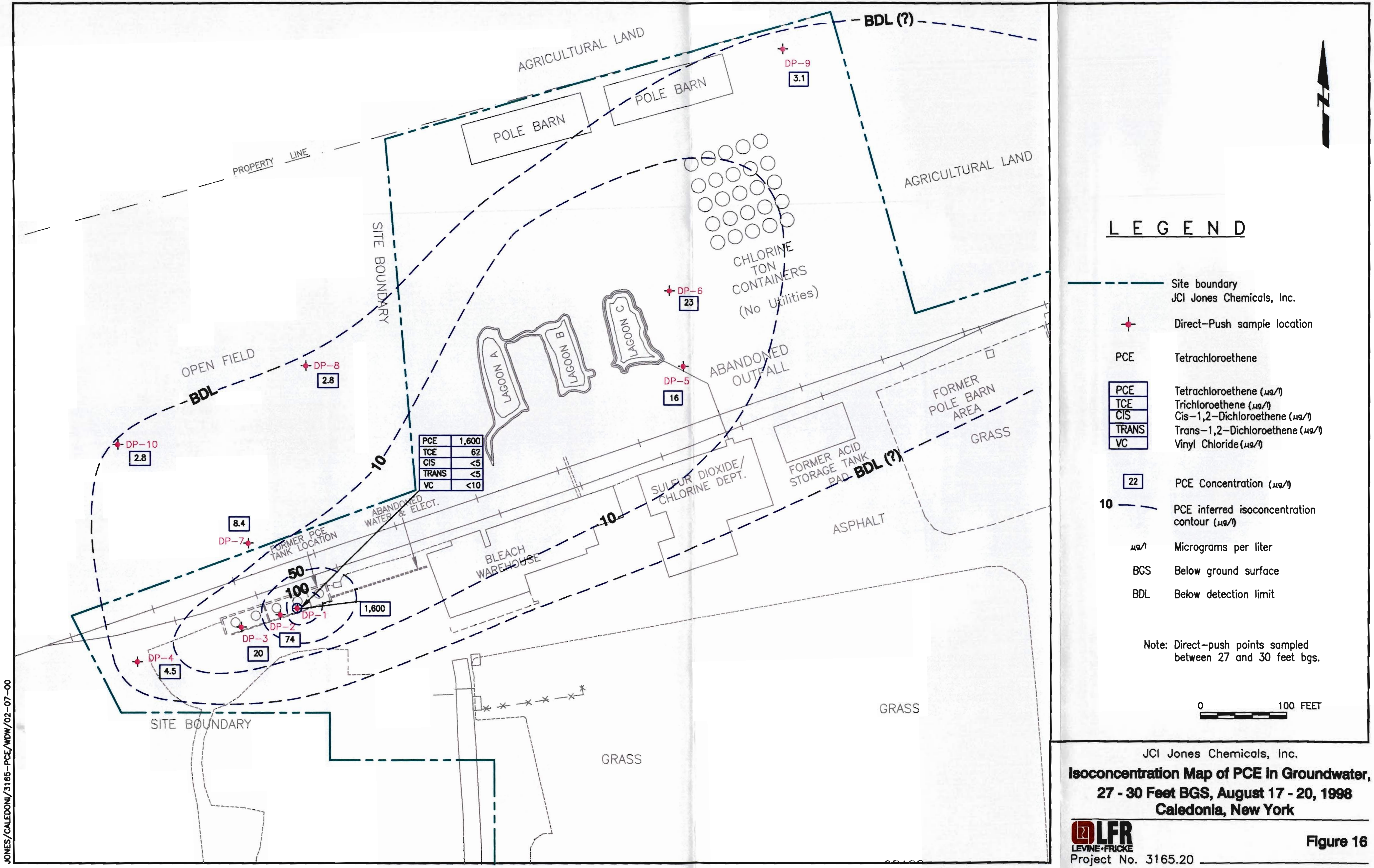
Isoconcentration Map of PCE in Groundwater, 17 - 25 Feet BGS, August 17 - 22, 1998 Caledonia, New York

LFR LEVINE·FRICKE

Project No. 3165.20

Figure 15

JONES/CALEDONI/3165-PCE/WDW/02-07-00



JCI Jones Chemicals, Inc.

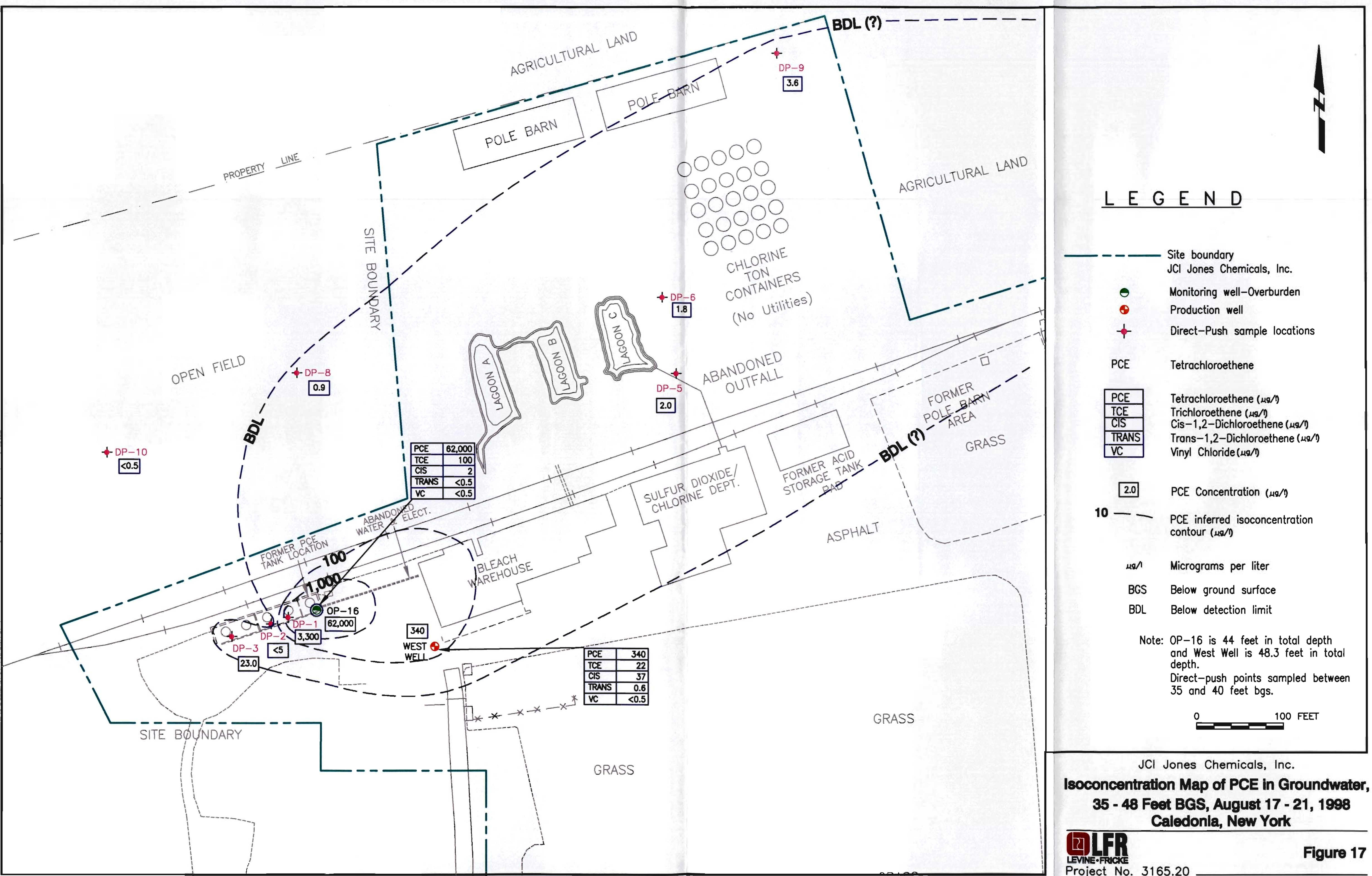
Isoconcentration Map of PCE in Groundwater, 27 - 30 Feet BGS, August 17 - 20, 1998 Caledonia, New York

LFR LEVINE•FRICKE

Project No. 3165.20

Figure 16

JONES/CALEDONI/3165-PCE/WDW/02-07-00



PCE	62,000
TCE	100
CIS	2
TRANS	<0.5
VC	<0.5

PCE	340
TCE	22
CIS	37
TRANS	0.6
VC	<0.5

Note: OP-16 is 44 feet in total depth and West Well is 48.3 feet in total depth.
Direct-push points sampled between 35 and 40 feet bgs.

JCI Jones Chemicals, Inc.

Isoconcentration Map of PCE in Groundwater, 35 - 48 Feet BGS, August 17 - 21, 1998
Caledonia, New York

LFR
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Project No. 3165.20

Figure 17

JONES/CALEDONI/3165-PCE/WDW/02-07-00

Appendix A

Cost Estimates and Technology Descriptions

APPENDIX A: TECHNOLOGY DESCRIPTIONS AND COST ESTIMATES

The technologies proposed as remedial technologies in this feasibility study are described individually from a costing standpoint in this Appendix, and summarized in Table A-1. The costs for remedial alternatives presented herein have been developed based on LFR Levine·Fricke's (LFR's) remediation experience on similar sites, LFR's direct remediation experience at this site, budgetary cost estimates obtained from remedial contractors, and cost estimates provided in the "RS Means Building Construction Cost Data 2000". The intent of these cost estimates is to provide a plus 50% to minus 30% estimate of the alternative costs. The net present value of operation, maintenance, and monitoring (OM&M) costs was calculated with the following equation.

$$(1) \qquad NPV = OMC\frac{(1+i)^n - 1}{i(1+i)^n}$$

Where NPV = the net present value
i = the discount rate
OMC = the estimated annual operation, maintenance and monitoring cost
n = the number of years

In the NPV calculations, the discount rate is assumed to be 7%, and is compounded annually. Each technology includes a description, scope of application, application assumptions, cost assumptions, and a detailed cost summary of capital, OM&M, and NPVs. These technologies have been assembled into reasonable alternatives for this site, and the costs for each of these alternatives are listed in Table A-2.

A1: No Action / No Further Action

This technology assumes that the contamination in the source zone will be left "as-is", without implementing institutional controls, containment, removal, treatment, or other mitigating action. A groundwater monitoring program would be conducted for a period of 30 years. The total NPV of this technology is $629,585.

A1-1: Direct and Indirect Capital Costs

For a "no action" on the affected soil, it is assumed that there will be no capital cost for implementation.

A1-2: Operation, Maintenance, and Monitoring

It is assumed that there will be no cost for operation and maintenance. It is assumed that groundwater samples will be collected from up to 20 groundwater monitoring wells. Costs for semiannual groundwater monitoring is presented below:

Two technicians @ $70 per hour x 60 hours each per visit x 2 visits	$16,800
Per Diem @ $125 per day x 2 people x 2 visits x 4 days per visit	$2,000
Vehicle @ $400 per week x 2 weeks per year	$800
Sampling equipment and materials @ $1,000 per visit x 2 visits	$2,000
Analysis by United States Environmental Protection Agency Method (EPA Method) 8021	
Twenty samples from monitoring wells @ $110 each x 2 visits	$4,400
Four QA/QC samples @ $110 each x 2 visits	$880
Shipping @ $200 (each visit)	$400
Annual Report	$15,000
Subtotal	$42,280
Contingency @ 20%	$8,456
TOTAL	**$50,736**

Assuming 30 years of monitoring at the Site, the net present value of monitoring for this technology is $629,585.

A2: Institutional Controls/Other Controls

These controls will include fencing around the source area and lagoons, posting warning signs on the fencing, and obtaining deed restrictions to limit groundwater use for non-potable purposes. The estimated cost of this technology is $84,820.

A2-1: Direct Capital Costs

It is assumed that this technology will have no mobilization-associated costs.

Staff Engineer @ 12 hours per day x 5 days x $85 per hour	$5,100
Per diem, lodging, and vehicle – $150 per day x 5 days	$750
Lagoon area fencing – 8-feet high, 900 linear feet x $30/linear foot	$27,000
Source area fencing – 8-feet high, 500 feet long @ $30/linear foot	$15,000
Warning signs	$2,000
Subtotal	$49,850
Contingency @ 20%	$9,970
TOTAL	**$59,820**

A2-2: Indirect Capital Costs

Engineering and project management	$10,000
Legal fees for deed restrictions	$15,000
TOTAL	**$25,000**

A2-3: Operation, Maintenance, and Monitoring Costs

It is assumed that there will be no operation or maintenance costs for this technology. It is also assumed that this technology will not be used as a stand-alone technology; therefore, it does not have any monitoring costs.

A3: Monitored Natural Attenuation

Monitored Natural Attenuation is not a "technology," per se. It generally involves monitoring a range of unaided physical and biological processes that reduce the concentration, toxicity, or mobility of contaminants. Natural attenuation makes use of natural processes to contain the spread of contamination and reduce the concentration. Monitored Natural Attenuation-also referred to as intrinsic remediation, bioattenuation, or intrinsic bioremediation-is an in situ treatment method. This means that environmental contaminants are left in place while natural attenuation works on them. Long-term monitoring is necessary to demonstrate that contaminant concentrations are continually decreasing at a rate sufficient to ensure that they will not become a health threat. This technology assumes that the affected soil and groundwater will be left "as-is" to attenuate by natural processes without implementing institutional controls, containment, removal, in situ treatment, or other mitigation actions. It is estimated that the duration of the monitored natural attenuation will be 30 years. The estimated cost for this alternative is $1,003,275.

A3-1: Capital Costs

It is assumed that there would be no direct or indirect capital costs for implementing this technology.

A3-2: Operation, Maintenance, and Monitoring Costs

It is assumed that there would be no operation or maintenance costs for this alternative. It is assumed that groundwater samples will be collected quarterly for the first 2 years and then semiannually for 28 years from up to 20 groundwater monitoring wells. It is also assumed that the most Natural Attenuation Indicative Parameters will be analyzed at a laboratory, and that no additional shipping charges will be required.

<u>Quarterly Monitoring</u>

Two technicians @ $70 per hour x 68 hours each per visit x 4 visits	$38,080
Per Diem @ $125 per day x 2 people x 4 visits x 5 days per visit	$5,000

Vehicle @ $400 per week x 4 weeks per year	$1,600
Sampling equipment and materials @ $1,800 per visit x 4 visits	$7,200
Analysis by United States Environmental Protection Agency Method (EPA Method) 8021	
Twenty samples from monitoring wells - $110 each x 4 visits	$8,800
Four QA/QC samples - $110 each x 4 visits	$1,600
Shipping - $250 per visit x 4 visits	$1,000
Analysis of Natural Attenuation Indicative Parameters	
Twenty samples from monitoring wells @ $200 each x 2 visits	$8,000
Four QA/QC samples @ $200 each x 2 visits	$1,600
Annual Report	$30,000
Quarterly subtotal	$102,880
Contingency @ 20%	$20,576
Quarterly Total	**$123,456**

Assuming 2 years of quarterly monitored natural attenuation and groundwater monitoring, the net present value of the quarterly sampling is $223,211.

Semiannual Monitoring

Two technicians @ $70 per hour x 68 hours each per visit x 2 visits	$19,040
Per Diem @ $125 per day x 2 people x 2 visits x 5 days per visit	$2,500
Vehicle @ $400 per week x 2 weeks per year	$800
Sampling equipment and materials @ $1,800 per visit x 2 visits	$3,600
Analysis by United States Environmental Protection Agency Method (EPA Method) 8021	
Twenty samples from monitoring wells @ $110 each x 2 visits	$4,400
Four QA/QC samples @ $110 each x 2 visits	$880
Shipping @ $250 (each visit)	$500
Analysis of Natural Attenuation Indicative Parameters	
Twenty samples from monitoring wells @ $200 each x 2 visits	$8,000
Four QA/QC samples @ $200 each x 2 visits	$1,600
Annual Report	$20,000
Semiannual subtotal	$61,320
Contingency @ 20%	$12,264
Semiannual total	**$73,584**

Assuming 28 years of monitoring, the net present value for semiannual monitoring is $780,064. This number is derived by calculating the semiannual NPV for 30 years and subtracting the semiannual NPV for the initial 2 years that are addressed in the quarterly monitoring section.

The total net present value for 30 years of operation, maintenance, and monitoring for this technology is $1,003,275.

A4: Soil Vapor Extraction

A soil vapor extraction (SVE) system would be installed to treat the affected soil in the vadose zone of the source area. An SVE pilot test has not been conducted; however, based on LFR's experience in designing, implementing, and operating SVE systems, and based on the information in the RI, LFR estimates that a radius of influence of approximately 25 feet can be achieved from a single extraction well at a flow rate of 75 standard cubic feet per minute (scfm). Based on the assumed radius of influence, LFR estimates that a maximum of seven SVE wells will be required to influence the affected vadose zone soil at the Site. The extracted vapors would be routed to the SVE system via a buried 6-inch diameter polyvinyl chloride (PVC) pipe. The piping trench would be 2 feet wide, 1 foot deep, and approximately 200 feet long. The SVE blower would be capable of extracting approximately 550 scfm at a vacuum of 60 inches of water column. The SVE blower would be skid-mounted and be equipped with a moisture separator, a controls system, an air filter, mufflers, and appropriate gauges and valves. The equipment would be housed in a winterized structure for year-round operation. Two 2,000-pound granular activated carbon (GAC) units would be used to treat the extracted vapors.

A4-1: Costs

It is estimated that this system will require approximately 20 working days to install, which includes the SVE wells, equipment, controls, and system startup. LFR estimates that SVE system operations will be terminated within three years. This technology is intended to address the soil contamination only, and will not be used to remediate groundwater contamination at the site. Therefore, it is assumed that there will be no groundwater monitoring costs associated directly with this technology. However, periodic groundwater monitoring is expected to occur during the implementation of one of groundwater alternatives described later in this appendix. In addition, confirmatory soil samples would likely need to be collected by direct push methods at the end of the operational life of the SVE system. The estimated net present value of direct, indirect, and OM&M for this technology is approximately $599,469.

A4-2: Direct Capital Costs

Soil Vapor Extraction Well Installation

Seven, 4-inch diameter PVC wells @ $1,000 each	$7,000
IDW disposal (as D039 code) @ $350 per drum x 10 drums	$3,500
Mobilization and demobilization	$1,000
Per Diem – 3 person crew @ $125 per day x 3 days	$1,125

Soil Vapor Extraction Piping and Vaults

Surface removal and disposal @ $2.00 per square foot (sf) x 400 sf	$800
Surface repair – $3.00 per sf x 400 sf	$1,200

Excavation, backfill, and compaction of the trench – $10 per ft x 200 linear feet (lf)	$2,000
Pipe installation and testing – $30 per foot x 200 feet	$6,000
SVE well vaults, gauges, valves, well head connections, and concrete – $1,500 per well x 7 wells	$10,500
SVE equipment installation (lump sum)	$10,000

Equipment Costs

SVE system (e.g., structure, moisture, gauges, valves controls, and mufflers)	$35,000
GAC purchase and disposal costs @ $4.50 per pound x 4,000 pounds	$18,000
Transportation	$4,000

Electrical Modifications

Lump sum	$15,000
Site restoration	$5,000

Confirmatory Direct-Push Soil Sampling

Mobilization/Demobilization	$500
Soil sampling – $200 per boring x 10 borings	$2,000
Analysis by USEPA Method 8021	
Twelve samples x $110 per sample	$1,320
Two QA/QC samples x $110 per sample	$220
Sample shipping	$150

Subtotal	$124,315
Contingency @ 20%	$24,863
TOTAL	**$149,178**

A4-3: Indirect Capital Costs

Engineering design documents	$40,000
Project management	$15,000
Air permitting	$10,000

Construction and Well Installation Oversight

Staff Engineer @ 12 hours per day x 15 days x $85 per hour	$15,300
Per diem, lodging, and vehicle – $150 per day x 15 days	$2,250
Travel to and from the site @ 20 hours x $85 per hour, plus $1,000 for airfare	$2,700

System Startup and Shakedown

Staff Engineer @ 12 hours per day x 5 days x $85 per hour	$5,100
Technician @ 12 hours per day x 5 days x $70 per hour	$4,200

Per diem, lodging, and vehicle @ $150 per day x 5 days x 2 people	$1,500
Travel to and from the site @ 20 hours x $155 per hour, plus $2,000 for airfare	$5,100
Startup equipment and sampling equipment	$1,000
Off-gas sample analysis – 12 samples x $300 per sample	$3,600
Sample shipping – three shipments @ $100 each	$300
Construction completion and startup reporting	$10,000

Confirmatory Direct Push Soil Sampling

Staff Engineer @ 12 hours per day x 2 days x $85 per hour	$2,040
Per diem, lodging, and vehicle @ $150 per day x 2 days	$300
Travel to and from the site @ 20 hours x $85 per hour, plus $1,000 for airfare	$2,700
Sampling report	$10,000
TOTAL	**$131,090**

A4-4: Operation, Maintenance, and Monitoring

For operation, maintenance, and monitoring (OM&M), it is assumed two technicians would visit the Site monthly for the operational lifetime of the SVE system. The technicians will conduct routine maintenance on the SVE system. It is also assumed that an average of two, 2,000 pound GAC units would be exhausted and replaced annually. The used GAC would be disposed of as a hazardous waste.

The annual OM&M costs for SVE system are listed below:

Monthly Visits

Two technicians @ $70 per hour x 12 hours each per visit x 12 visits	$20,160
Per diem, expendables, and field equipment – $500 per visit x 12 visits	$6,000

Sample Analysis

Influent, effluent, and duplicate samples – $250 each x 12 visits	$9,000
Shipping – $100 per event x 12 visits	$1,200

Electricity – 30 horsepower @ $800 per horsepower per year	$24,000
Annual repair costs	$6,000

GAC Replacement

Replacement and disposal of spent GAC – $4.50 per pound x 4,000 pounds	$18,000
Transportation	$2,000

Annual report	$15,000

Subtotal	$101,360
Contingency @ 20%	$20,272
TOTAL	**$121,632**

The net present value of OM&M over the anticipated three years of the SVE system operation is $319,201.

A5: Soil Excavation with Off-Site Disposal

This technology includes excavating the affected soil in the vadose zone and disposing of it off site. In this technology, soil would be excavated from ground surface to approximately 15 feet below ground surface (bgs), which is approximately the depth to groundwater. The sides of the excavation would be sloped at 1 horizontal to 1 vertical. Therefore, the excavation will have a footprint of 180 feet and 50 feet at the surface. The estimated total volume of soil to be removed is 3,300 cy. It is assumed that the excavation and construction area would be secured with the existing fencing around the facility. Temporary decontamination facilities for equipment and personnel would be installed at the Site. Contaminated water from the decontamination processes would be placed in 20,000-gallon mobile storage tanks. The water would be treated with a portable air-stripping tower prior to disposal as non-hazardous waste. It is assumed that this project would require the disposal of 40,000 gallons of non-hazardous waste water. Solid wastes generated in the decontamination process would be disposed of with the hazardous waste soil.

A mobile laboratory would be used at the Site for approximately 25 days to analyze excavated soil samples by EPA Method 8021 parameters. One soil sample would be analyzed for each 50 tons of soil excavated. Soil samples would also be collected from the side walls of the excavation to confirm that the extent of the excavation encompasses the volume of affected soil. The excavated soil would be segregated as appropriate and placed in a lined and bermed storage area. The storage area would be approximately 100 feet by 100 feet. For concentrations below ARAR levels, the soil would be backfilled in the excavation. The PCE affected soil above ARAR cleanup standards would be hauled to a licensed hazardous waste treatment faculty for disposal. As a basis for the cost estimate for this alternative, it is assumed that the affected soil would be hauled to a treatment facility in Calvert City, Kentucky, which is approximately 800 miles driving distance. For this alternative, the affected soil being disposed of would be considered a Characteristic Waste (D039). The PCE contaminated soil would be treated to appropriate levels with an incinerator and disposed of in a Subtitle D landfill.

The estimated time to complete on-site activities is 45 working days. The total estimated cost of this alternative is $3,183,996.

A5-1: Direct Capital Costs

Mobilizing construction equipment and crew (lump sum)	$30,000
Contractor permitting and specification requirements (lump sum)	$20,000
Decontamination facilities for equipment (lump sum)	$14,000
Decontamination facilities for personnel (lump sum)	$10,000

Utility clearance (lump sum)	$1,500
Safety equipment (i.e., barricades, signs, etc. [lump sum])	$5,000
Surface asphalt removal and disposal (180 ft x 50 ft = 9,000 sf) @ $2.50 per sf	$22,500
Soil excavation and segregation - 3,300 cy @ $13.75 per cy	$45,375

Soil Analysis Mobile Laboratory

Twenty-five days - $2,400 per day	$60,000
Mobilization/demobilization - $1,000 x 2 events	$2,000
Storage area - 10,000 sf @ $0.77 per sf	$7,700
Loading - $1,200 per day x 25 days	$30,000
Soil disposal - 2,500 tons @ $692 per ton	$1,730,000

Hauling

800 miles @ $3.5/mile = $2,800 per load
2,500 tons / 18 ton roll-off containers = 140 loads

140 loads x $2,800 per load	$392,000

Backfill

Make-up soil for excavation - 1,667 cy @ $14.35 per cy	$23,922
Backfill and compaction - 3,300 cy @ $ 3.35 per cy	$11,055

Surface Replacement

Six-inch pavement base @ $1.11 per sf x 9,000 sf	$9,990
Two-inch asphalt pavement @ $1.87 per sf x 9,000 sf	$16,830

Decontamination Water Treatment

Mobile air stripper rental for two months	$15,000
System set-up	$2,000
Operation	$4,000
20,000-gallon storage tank for two months	$3,500
Treated water disposal @ $0.30 per gallon x 40,000 gallons	$12,000
Confirmatory sampling	$3,000

Demobilization (lump sum)	$30,000
Site Restoration (lump sum)	$10,000

Subtotal	$2,511,372
Contingency @ 20%	$502,274
TOTAL	**$3,013,646**

A5-2: Indirect Implementation Costs

Engineering design documents	$70,000
Project management	$10,000
Air permit for mobile air stripper	$10,000

<u>Construction Oversight</u>

Staff Engineer @ 12 hours per day x 45 days x $85 per hour	$45,900
Per diem, lodging, and vehicle - $150 per day x 45 days	$6,750
Travel to and from the Site - 20 hours x $85 per hour, plus $1,000 for airfare	$2,700
Construction completion reporting	$25,000
TOTAL	**$170,350**

A5-3: Operation, Maintenance, and Monitoring Costs

It is assumed that there would be no annual operation, maintenance, or monitoring costs associated with this technology.

A6: Soil Excavation with On-Site Treatment

In this alternative, the affected soil in the vadose zone would be excavated as discussed above in section A5; however, the soil would be treated on site with a mobile low temperature thermal desorption treatment process. The process would treat approximately 15 cubic yards per hour, or up to 150 cubic yards per day. The affected soil would be treated to ARAR cleanup levels and backfilled in the excavation. The affected soil would be segregated from unaffected soil in separate piles. The affected soil would be placed in a staging area with appropriate containment. One soil sample would be collected for each 50 cubic yards of soil excavated. Soil samples would also be collected from the side walls of the excavation to confirm that the extent of the excavation encompasses the volume of affected soil. In addition, one soil sample would be collected for each 50 cubic yards of soil treated to confirm the effectiveness of the treatment system. The soil samples would be analyzed on site by EPA Method 8021 parameters by an approved mobile laboratory.

The estimated time to complete on-site activities is 45 working days. The total estimated cost of this alternative is approximately $1,094,196.

A6-1: Direct Capital Costs

Mobilizing construction equipment and crew (lump sum)	$30,000
Contractor permitting and specification requirements (lump sum)	$20,000
Decontamination facilities for equipment (lump sum)	$14,000
Decontamination facilities for personnel (lump sum)	$10,000
Utility clearance (lump sum)	$1,500
Temporary power (lump sum)	$12,000
Safety equipment (e.g., barricades, signs, etc. [lump sum])	$5,000

Surface asphalt removal and disposal – 9,000 sf @ $2.50 sf	$22,500
Soil excavation and segregation – 3,300 cy @ $13.75 per cy	$45,375

Soil Analysis Mobile Laboratory

Twenty-five days @ $2,400/day	$60,000
Mobilization/demobilization – $1,000 x 2 events	$2,000
Storage area – 10,000 sf @ $0.77/sf	$7,700

Soil Treatment System

Mobilization (lump sum)	$28,000
Soil treatment @ $125 per ton x 2,500 tons	$312,500
Loading and unloading – $1,200 per day x 25 days	$30,000
Demobilization	$28,000

Backfill

Make-up soil for excavation – 1,667 cy @ $14.35/cy	$23,922
Backfill and compaction – 3,300 cy @ $3.35/cy	$11,055

Surface Replacement

Six-inch pavement base @ $1.11/sf x 9,000 sf	$9,990
Two-inch asphalt pavement @ $1.87/sf x 9,000 sf	$16,830

Decontamination Water Treatment

Mobile air stripper rental for two months	$15,000
System set-up	$2,000
Operation	$4,000
20,000-gallon storage tank for two months	$3,500
Treated water disposal – $0.30 per gallon x 40,000 gallons	$12,000
Confirmatory sampling	$3,000

Demobilization – lump sum	$30,000
Site restoration –lump sum	$10,000

Subtotal	$769,872
Contingency @ 20%	$153,974
TOTAL	**$923,846**

A6-2: Indirect Implementation Cost

Engineering design documents	$70,000
Project management	$10,000
Air permit for mobile air stripper	$10,000

Construction Oversight

Staff Engineer – 12 hours/day x 45 days x $85/hour	$45,900
Per diem, lodging, and vehicle @ $150/day x 45 days	$6,750
Travel to and from the Site – 20 hours x $85/hr + $1,000 for airfare	$2,700
Construction completion reporting	$25,000
TOTAL	**$170,350**

A6-3: Operation, Maintenance, and Monitoring Costs

It is assumed that there will be no annual operation, maintenance or monitoring costs associated with this technology.

A7: Source Area Pump and Treat

This technology includes utilizing an existing overburden groundwater extraction well (North Well), and installing two groundwater extraction wells in the overburden zone and one groundwater recovery well in the bedrock zone. This technology also includes converting another existing overburden groundwater extraction well (West Well) to a groundwater monitoring well. The three new wells would be located on the downgradient edge of the presumed source area. The two overburden extraction wells would be 3 feet in diameter, and extend to a depth of approximately 30 feet bgs. The bedrock zone well would be 6 inches in diameter, and would extend to a depth of approximately 55 feet bgs. The total average groundwater extraction rate from the four groundwater extraction wells would be approximately 400 gpm. The estimated flow rates from each of the wells are listed on Figure B-1 in Appendix B.

Groundwater would be extracted from these wells with electrical submersible pumps. The extracted groundwater would be routed to the existing air stripping tower to remove chlorinated volatile organic compounds (VOCs). The treated groundwater would either be routed through the heat exchangers before disposal in the ponds, or disposed of directly into the ponds depending on process status at the plant. The existing air stripping tower system would be modified to include manifolding of the new piping to the influent line and automated valves for the proposed source area groundwater extraction wells. In addition, because of the higher concentrations of PCE in the recovered groundwater, the discharge stack height of the air stripping tower would be increased from 55 feet above ground surface to 70 feet above land surface. The original air-stripping tower was installed in May 1996, in conjunction with a treatability study, and has proven to be effective in reducing the concentration of dissolved PCE from 400 micrograms per liter (µg/l) to less than 1 µg/l (LFR, 1997 Treatability Study Report). The air-stripping unit is capable of treating up to 500 gpm. It is assumed that this technology will need to operate for 15 years to accomplish remediation goals. It is estimated that this technology will take approximately 45 days to install and conduct startup activities.

The total NPV of this technology is $277,466.

A7-1: Direct Capital Costs

Well Installation

Two 10-inch diameter wells to 30 feet bgs – $12,000 each	$24,000
One 6-inch diameter well to 55 feet bgs – lump sum	$10,000
IDW disposal – 40 drums @ $350 each	$14,000
Convert existing west well to a monitoring well	$1,000

Piping Trench (2 feet wide x 3.5 feet deep x 350 feet long)

Excavation – 350 feet long @ $10 per foot	$3,500
Piping – $28 per foot x 350 feet x 2 wells	$19,600
Electric conduit – $7.75 per linear foot x 350 feet x 2 wells	$5,425
Backfill and compaction – $5 per foot x 350 feet	$1,750
Surface replacement – $5 per sf x 700 sf	$3,500

Well Vaults

Installation – $1,500 each x 3	$4,500
Piping and appurtenances – $1,200 each x 3	$3,600

Extraction Pumps

Two Gravel well pumps – $2,000 each	$4,000
Bedrock zone well pump	$1,500

Air Stripping Tower Modifications

Piping – Lump sum	$6,000
Controls – Lump sum	$10,000
Discharge – Lump sum	$10,000

Surface Replacement

Six-inch pavement base @ $1.11/sf x 1,000 sf	$1,110
Two-inch asphalt pavement @ $1.87/sf x 1,000 sf	$1,870

Electrical Modifications

Lump sum	$10,000
Site restoration	$5,000

Subtotal	$140,355
Contingency @ 20%	$28,071
TOTAL	**$168,426**

A7-2: Indirect Implementation Costs

Engineering design documents	$50,000
Project management	$10,000
Air permitting (modifications to the existing air stripper)	$10,000

Construction Oversight

Staff Engineer @ 12 hours per day x 5 days x $85 per hour	$5,100
Per diem, lodging, and vehicle - $150 per day x 5 days	$750
Travel to and from the Site - 20 hours x $85 per hour, plus $1,000 for airfare	$2,700

System Startup and Shakedown

Staff Engineer - 12 hours per day x 3 days x $85 per hour	$3,060
Technician - 12 hours per day x 3 days x $70 per hour	$2,520
Per diem, lodging, and vehicle @ $250 per day x 3 days	$750
Technician travel to and from Site - 20 hours x $70 per hour, plus $1,000 for airfare	$2,400
Start-up equipment	$1,000
Influent and effluent sample analysis - 6 samples x $110 per sample	$660
Sample shipping	$100
Construction completion reporting	$20,000
TOTAL	**$109,040**

A7-3: Operation, Maintenance, and Monitoring Costs

It is assumed that JCI will use the treated groundwater for its processes at the facility. It is also assumed that JCI personnel would conduct operation, maintenance and monitoring activities as part of their existing process. No additional labor costs or expenses will be caused by this technology for operation, maintenance, and monitoring during the anticipated 15 years for this technology to achieve remediation objectives. Groundwater monitoring costs associated with this technology are addressed in Monitored Natural Attenuation, which is used in conjunction with this technology in all remedial alternatives

A8: Site Wide Pump and Treat

This technology includes installing ten groundwater extraction well in the overburden zone and six groundwater recovery wells in the bedrock zone. This technology also includes converting an existing overburden groundwater extraction well (North Well) to a groundwater monitoring well. The sixteen new wells would be located on the downgradient edge of the presumed source area. The ten overburden extraction wells would be 12 inches in diameter, and extend to a depth of approximately 30 feet bgs. The six bedrock zone wells would be 6 inches in diameter, and would extend to a depth of approximately 55 feet bgs. The total average groundwater extraction rate from the sixteen groundwater extraction wells would be approximately 1,200 gpm. The estimated flow rates from each of the wells in the overburden zone are listed on Figure B-2 in Appendix B, and the flow rates from the bedrock zone wells are listed on Figure B-3 in Appendix B.

Groundwater would be extracted from these wells with electrical submersible pumps. The extracted groundwater would be routed to either the existing air stripping tower or a new air stripping tower to remove chlorinated volatile organic compounds (VOCs). Approximately 2,400 feet of piping for the wells in the overburden zone and approximately 400 feet of piping in for the wells in the bedrock zone will need to be installed. Approximately 300 gpm of extracted groundwater will be routed to and treated by the existing air stripping tower. The treated water from the existing air stripper will either be routed through the heat exchangers before disposal in the ponds, or disposed of directly into the ponds depending on process status at the plant. The existing air stripping tower system would be modified to include piping from the new extraction well system in the influent line and automated valves.

The remaining 900 gpm of extracted groundwater will be routed to and treated by the proposed air stripping unit. The treated water from the new air stripping tower will be disposed of in the proposed infiltration gallery. The proposed infiltration gallery would be approximately 20 feet wide, 400 feet long, and be approximately 10 feet deep. The infiltration gallery will have a surface area of approximately 8,000 square feet, and be constructed of 2-foot diameter punched corrugated metal pipe surrounded with gravel. Approximately 2,963 cubic yards (cy) of soil will be excavated for the infiltration gallery. The excavation will be filled from 2 to 10 feet bgs with gravel (2,370 cy), and from 0 to 2 feet bgs native soil will be replaced (593 cy). It is estimated that this technology will take approximately 90 days to install, and conduct startup activities. It is assumed that this technology will need to operate for 15 years to accomplish remediation goals. The net present value of this technology including direct and indirect costs and OM&M for 15 years is $2,982,265.

A8-1: Direct Capital Costs

Well Installation

Ten 12-inch diameter wells to 30 feet bgs - $12,000 each	$120,000
Six 6-inch diameter well to 55 feet bgs - $10,000 each	$60,000
IDW disposal - 140 drums @ $350 each	$49,000
Convert existing North Well to a monitoring well	$1,000

Piping Trench (2 feet wide x 3.5 feet deep x 2,800 feet long)

Excavation - 2,800 feet long @ $10 per foot	$28,000
Piping - $28 per foot x 2,800 feet	$78,400
Electric conduit - $7.75 per linear foot x 5,160 feet	$39,990
Backfill and compaction - $5 per foot x 2,800 feet	$14,000
Surface replacement - $5 per sf x 5,600 sf	$28,000

Well Vaults

Installation – $1,500 each x 16	$24,000
Piping and appurtenances – $1,200 each x 16	$19,200

Extraction Pumps

Ten Gravel well pumps – $2,000 each	$20,000
Six Bedrock zone well pump – $1,500 each	$9,000

Air Stripping Tower

Equipment and tower – Lump sum	$100,000
Installation – Lump sum	$75,000
Controls and compound piping – Lump sum	$40,000

Surface Replacement

Six-inch pavement base @ $1.11/sf x 7,000 sf	$7,770
Two-inch asphalt pavement @ $1.87/sf x 7,000 sf	$13,090

Electrical Modifications

Controls to existing stripping tower, service for new stripping tower – Lump sum	$40,000

Infiltration Gallery

Excavation – 20 feet wide x 400 feet long x 10 feet deep = 80,000 cubic feet 80,000 cubic feet / 27 cubic feet per cubic yard (cy) = 2,963 cy x $2/cy	$5,926
3/8-inch gravel – 2,370 cy x $22/cy	$52,140
Hauling of excavated soil – 2,370 cy x $4/cy	$9,480
Perforated corrugated metal pipe, 2 foot diameter – 400 feet x $30/foot	$12,000
Additional piping and appurtenances	$5,000

Subtotal	$850,996
Contingency @ 20%	$170,199
TOTAL	**$1,021,195**

A8-2: Indirect Implementation Costs

Engineering design documents	$170,000
Project management	$25,000
Air permitting (for new air stripper)	$10,000

Construction Oversight

Staff Engineer @ 12 hours per day x 45 days x $85 per hour	$45,900
Per diem, lodging, and vehicle – $150 per day x 45 days	$6,750
Travel to and from Site – 20 hours x $85 per hour, plus $1,000 for airfare	$2,700

System Startup and Shakedown

Staff Engineer – 12 hours per day x 8 days x $85 per hour	$8,160
Technician – 12 hours per day x 8 days x $70 per hour	$6,720
Per diem, lodging, and vehicle @ $250 per day x 8 days	$2,000
Travel to and from the Site – 20 hours x $155 per hour, plus $2,000 for airfare	$5,100
Start-up equipment	$1,500
Influent and effluent sample analysis – 12 samples x $110 per sample	$1,320
Sample shipping– $100 per event x 4 events	$400
Construction completion reporting	$25,000
TOTAL	**$310,550**

A8-3: Operation, Maintenance, and Monitoring Costs

It is assumed that JCI personnel would conduct monitoring for the existing air stripping unit and no new or additional costs will be associated with the existing air stripping unit. It is also assumed that the new air stripping unit will need to be visited on a quarterly basis by two technicians. Quarterly influent and effluent water samples would likely be required for the assumed 15 year operation of this technology. Since this technology is not used in conjunction with other technologies that have groundwater monitoring sampling, these monitoring costs will also need to be included with this technology. Up to 20 wells will be sampled quarterly using EPA Method 8021, along with 6 QA/QC samples, for the first two years and then twice a year for the remaining 13 years. The operation, maintenance, and monitoring costs are as follows:

Operation and Maintenance of Equipment

Energy – 70 horsepower x $800 per horsepower per year	$56,000
Equipment maintenance – Lump sum per year	$30,000
Subtotal	$86,000
Contingency @ 20%	$17,200
TOTAL	**$103,200**

The NPV of costs associated with the operation and maintenance of the equipment for this technology for 15 years is $939,937.

Monitoring (by EPA Method 8021)

Quarterly Air Stripper Monitoring

Two technicians @ $70 per hour x 30 hours each per visit x 4 visits	$16,800
Per diem, expendables, and field equipment – $250 per visit x 4 visits	$1,000
Air stripper Influent and effluent samples – $110 each x 4 events per year	$880
One air stripper QA/QC sample – $110 each x 4 events per year	$440
Shipping – $50 each event x 4 events	$200
Annual report preparation	$20,000
Subtotal	$39,320
Contingency @ 20%	$7,864
TOTAL	**$47,184**

Assuming 15 years of air stripper operation, the net present value of quarterly air stripper monitoring is $429,748.

Quarterly Groundwater Monitoring

Two technicians @ $70 per hour x 30 hours each per visit x 4 visits	$16,800
Per diem, expendables, and field equipment – $450 per visit x 4 visits	$1,800
Groundwater monitoring samples – $110 each x 20 wells x 4 events per year	$8,800
Six groundwater monitoring QA/QC samples – $110 each x 4 events per year	$2,640
Shipping – $100 each event x 4 events	$400
Subtotal	$30,440
Contingency @ 20%	$6,088
TOTAL	**$36,528**

The net present value of quarterly groundwater monitoring for the assumed initial two year period of operation of this technology is $66,043.

Semiannual Groundwater Monitoring

Two technicians @ $70 per hour x 30 hours each per visit x 4 visits	$16,800
Per diem, expendables, and field equipment – $450 per visit x 4 visits	$1,800
Groundwater monitoring samples – $110 each x 20 wells x 2 events per year	$4,400
Six groundwater monitoring QA/QC samples – $110 each x 2 events per year	$1,320
Shipping – $100 each event x 2 events	$200
Subtotal	$24,520
Contingency @ 20%	$4,904
TOTAL	**$29,424**

Assuming 13 years of monitoring, the net present value for semiannual monitoring is $214,792. This number is derived by calculating the semiannual NPV for 15 years and subtracting the semiannual NPV for the initial 2 years that are addressed in the quarterly monitoring section.

The net present value of OM&M for site wide pump and treat for 15 years is $1,650,520.

A9: Potassium Permanganate Injection Cost Estimate

This technology oxidizes dissolved phase PCE, and to some extent DNAPL PCE, by using potassium permanganate ($KMnO_4$) to generate hydroxyl radicals which break the double bond in PCE. For the purposes of this cost estimate, LFR is assuming that the potential DNAPL PCE source area is 15 feet in diameter and extends to a depth of 50 feet bgs. To provide an effective spatial distribution of the $KMnO_4$ injection system, a cluster of two injection wells would be installed. The upper injection well would be screened, in overburden layer, between 10 feet and approximately 25 feet bgs. The deep injection well would be screened between approximately 40 feet and 50 feet bgs in the weathered bedrock. The injection wells would be constructed of 4-inch diameter, flush joint, schedule 40 PVC well casing with 0.01-inch slotted screen. To monitor the transport of $KMnO_4$ and destruction of PCE in each zone, two monitoring wells clusters with wells screened in the same zones as the injection wells, would be installed downgradient of the injection well cluster. For the cost estimate, LFR assumed that the $KMnO_4$ injection rate would be 3.85 grams per liter and the $KMnO_4$ would be injected quarterly.

The mixing and injection system would include a 300-gallon above ground mixing tank, a helix screw feeder, a potable water line, an injection pump and appurtenances. In general water and $KMnO_4$ (in powder form) would be metered into the mixing tank at appropriate flow rates. A transfer pump would be used to pump the $KMnO_4$ water mixture from the mixing tank to the injection well cluster. The flow rate of the mixture would be metered into each injection well with valves and flow meters at the well heads. It is estimated that this system would take approximately 5 working days to install.

$KMnO_4$ oxidation of chlorinated solvents is an emerging technology. At startup of the remedial system, LFR is recommending conducting a field testing of the proposed system at various $KMnO_4$ concentrations to determine an appropriate mass loading in each zone. Groundwater data would be collected and evaluated from the injection and monitoring wells during field testing. The field testing data would also provide an appropriate injection frequency. Also for this cost estimate, it is assumed that quarterly $KMnO_4$ injection would be performed for five years. After this five-year period, $KMnO_4$ injection should be re-evaluated. The NPV for direct and indirect costs and OM&M for five years of this technology is $257,029.

A9-1: Direct Capital Costs

Well Installations

Mobilization/Demobilization	$500
Per Diem and lodging, 2 man crew – $50 per man per day x 3 days	$300

Injection Wells

One 4-inch diameter well to 25 feet bgs	$1,000
One 4-inch diameter well to 50 feet bgs	$2,200
IDW disposal – 8 drums @ $350 each	$2,800

Monitoring Wells

Two 2-inch diameter wells to 25 feet bgs – $500 each	$1,000
Two 2-inch diameter wells to 50 feet bgs – $1,200 each	$2,400
IDW disposal – 20 drums @ $350 each	$7,000

Well Vaults and Piping

Installation, piping and appurtenances – $1,500 each x 6 wells	$9,000

Mixing System and Equipment

System and equipment – Lump sum	$10,000
System and equipment installation – Lump sum	$15,000

Subtotal	$51,200
Contingency @ 20%	$10,240
TOTAL	**$61,440**

A9-2: Indirect Implementation Costs

Engineering design documents	$10,000
Project management	$2,500
Injection permit and regulatory variance	$10,000

Construction Oversight

Staff Engineer @ 12 hours per day x 5 days x $85 per hour	$5,100
Per diem, lodging, and vehicle – $150 per day x 5 days	$750
Travel to and from Site – 20 hours x $85 per hour, plus $1,000 for airfare	$2,700

System Startup and Shakedown

Staff Engineer – 12 hours per day x 2 days x $85 per hour	$2,040
Technician – 12 hours per day x 2 days x $70 per hour	$1,680
Per diem, lodging, and vehicle @ $250 per day x 2 days	$500

Travel to and from the Site – 20 hours x $155 per hour, plus $2,000 for airfare	$5,100
Start-up equipment	$1,500
Groundwater sample analysis – 12 samples x $200 per sample	$2,400
QA/QC samples – 2 samples x $200 per sample	$400
Sample shipping– $100 per event x 2 events	$200
Construction completion reporting	$10,000
TOTAL	**$54,870**

A9-3: Operation, Maintenance, and Monitoring Costs

For OM&M, it is assumed that two technician would visit the site quarterly for five years. LFR estimates that it would take approximately 2 days per site visit to complete injection of $KMnO_4$. Groundwater samples would be collected semiannually to monitor the effects of the $KMnO_4$ injection. LFR assumes that these samples would be collected in addition to the remediation by natural attenuation monitoring and that no additional labor or analytical expenses would be incurred as a result of monitoring this technology. LFR also assumes that the annual report for this technology would be prepared in conjunction with the annual remediation by natural attenuation monitoring report and would not be a stand-alone document. The annual OM&M costs for $KMnO_4$ injection are described as follows:

Monitoring – Annual Visit

Two technicians @ $70 per hour x 10 hours each per day x 8 days	$5,600
Per diem, expendables, and field equipment ($500 per day x 8 days)	$4,000
Annual Report/ Project Management	$10,000

Operation

Annual $KMnO_4$ – purchase and transportation	$4,000
Utilities (water and electricity)	$2,000

Maintenance

Annual repair costs	$3,000
Subtotal	$28,600
Contingency @ 20%	$5,720
TOTAL	**$34,320**

For a five-year period, the NPV of OMM of $KMnO_4$ injection is $140,719.

Table A-1
Technology Cost Estimates
JCI Jones Chemicals, Inc.
Caledonia, New York

Technology	Description	Direct and Indirect Capital Costs	OM&M (Annual)	Years of OM&M	*Net Present Value - OM&M	*Net Present Value - Total
Technology 1	No Action / No Further Action	$0	$50,736	30	$629,585	$629,585
Technology 2	Institutional Controls/Other Controls	$84,820	$0	0	$0	$84,820
Technology 3	Monitored Natural Attenuation					
	Quarterly Monitoring (first 2 years)	$0	$123,456	2	$223,211	$223,211
	Semiannual Monitoring (remaining 28 years)	$0	$73,584	28	$780,064	$780,064
	Total	*Annualized*	$80,850 **	30	$1,003,275	$1,003,275
Technology 4	Soil Vapor Extraction	$280,268	$121,632	3	$319,201	$599,469
Technology 5	Excavation of PCE Affected Soils with Off-Site Disposal	$3,183,996	$0	0	$0	$3,183,996
Technology 6	Excavation of PCE Affected Soils with On-Site Treatment	$1,094,196	$0	0	$0	$1,094,196
Technology 7	Source Area Pump and Treat	$277,466	$0	15	$0	$277,466
Technology 8	Site Wide Pump and Treat	$1,331,745				$1,331,745
	Equipment Maintenance and Operation		$103,200	15	$939,937	$939,937
	Quarterly Air Stripper Monitoring		$47,184	15	$429,748	$429,748
	Quarterly Groundwater Monitoring (first 2 years)		$36,528	2	$66,043	$66,043
	Semiannual Groundwater Monitoring (remaining 13 years)		$29,424	13	$214,792	$214,792
	Total	$1,331,745	$181,221 **	15	$1,650,520	$2,982,265
Technology 9	Potassium Permanganate Injection	$116,310	$34,320	5	$140,719	$257,029

*Net present value assumes a discount rate of 7 percent.
**Represents an averaged annualized OM&M value.

Table A-2
Alternatives Cost Estimates
JCI Jones Chemicals, Inc.
Caledonia, New York

Medium	Alternative Number	Technologies	Direct and Indirect Capital Costs	OM&M (Annual)	Years of OM&M	*Net Present Value - OM&M	*Net Present Value - Total
Soil	**Alternative 1**	No Action	$0	$0	0	$0	$0
		Total:	**$0**	**$0**	**0**	**$0**	**$0**
	Alternative 2	Soil Vapor Extraction	$280,268	$121,632	3	$319,201	$599,469
		Other Controls	$84,820	$0	0	$0	$84,820
		Total:	**$365,088**	**$121,632**	**3**	**$319,201**	**$684,289**
	Alternative 3A	Excavation of PCE Affected Soils with Off-Site Disposal	$3,183,996	$0	0	$0	$3,183,996
		Other Controls	$84,820	$0	0	$0	$84,820
		Total:	**$3,268,816**	**$0**	**0**	**$0**	**$3,268,816**
	Alternative 3B	Excavation of PCE Affected Soils with On-Site Treatment	$1,069,196	$0	0	$0	$1,069,196
		Other Controls	$84,820	$0	0	$0	$84,820
		Total:	**$1,154,016**	**$0**	**0**	**$0**	**$1,154,016**
Ground-water	**Alternative 1**	No Further Action	$0	$50,736	30	$629,585	$629,585
		Total:	**$0**	**$50,736**	**30**	**$629,585**	**$629,585**
	Alternative 2	Source Area Pump and Treat	$277,466	$0	15	$0	$277,466
		Monitored Natural Attenuation	$0	$80,850 **	30	$1,003,275	$1,003,275
		Institutional Controls	$84,820	$0	0	$0	$84,820
		Total:	**$362,286**	**$80,850**	**30**	**$1,003,275**	**$1,365,561**
	Alternative 3	Site Wide Pump and Treat	$1,331,745	$181,221 **	15	$1,650,520	$2,982,265
		Institutional Controls	$84,820	$0	0	$0	$84,820
		Total:	**$1,416,565**	**$181,221**	**15**	**$1,650,520**	**$3,067,085**
	Alternative 4	Source Area Pump and Treat	$277,466	$0	15	$0	$277,466
		Monitored Natural Attenuation	$0	$80,850 **	30	$1,003,275	$1,003,275
		Potassium Permanganate Injection	$116,310	$34,320	5	$140,719	$257,029
		Institutional Controls	$84,820	$0		$0	$84,820
		Total:	**$478,596**	**$115,170**	**30**	**$1,143,993**	**$1,622,589**
	Alternative 5	Monitored Natural Attenuation	$0	$80,850	30	$1,003,275	$1,003,275
		Institutional Controls	$84,820	$0		$0	$84,820
		Total:	**$84,820**	**$80,850**	**30**	**$1,003,275**	**$1,088,095**

*assumes a discount rate of 7 percent
**averaged annualized OM&M value
OM&M = operation, maintenance, and monitoring

Appendix B

Groundwater Modeling

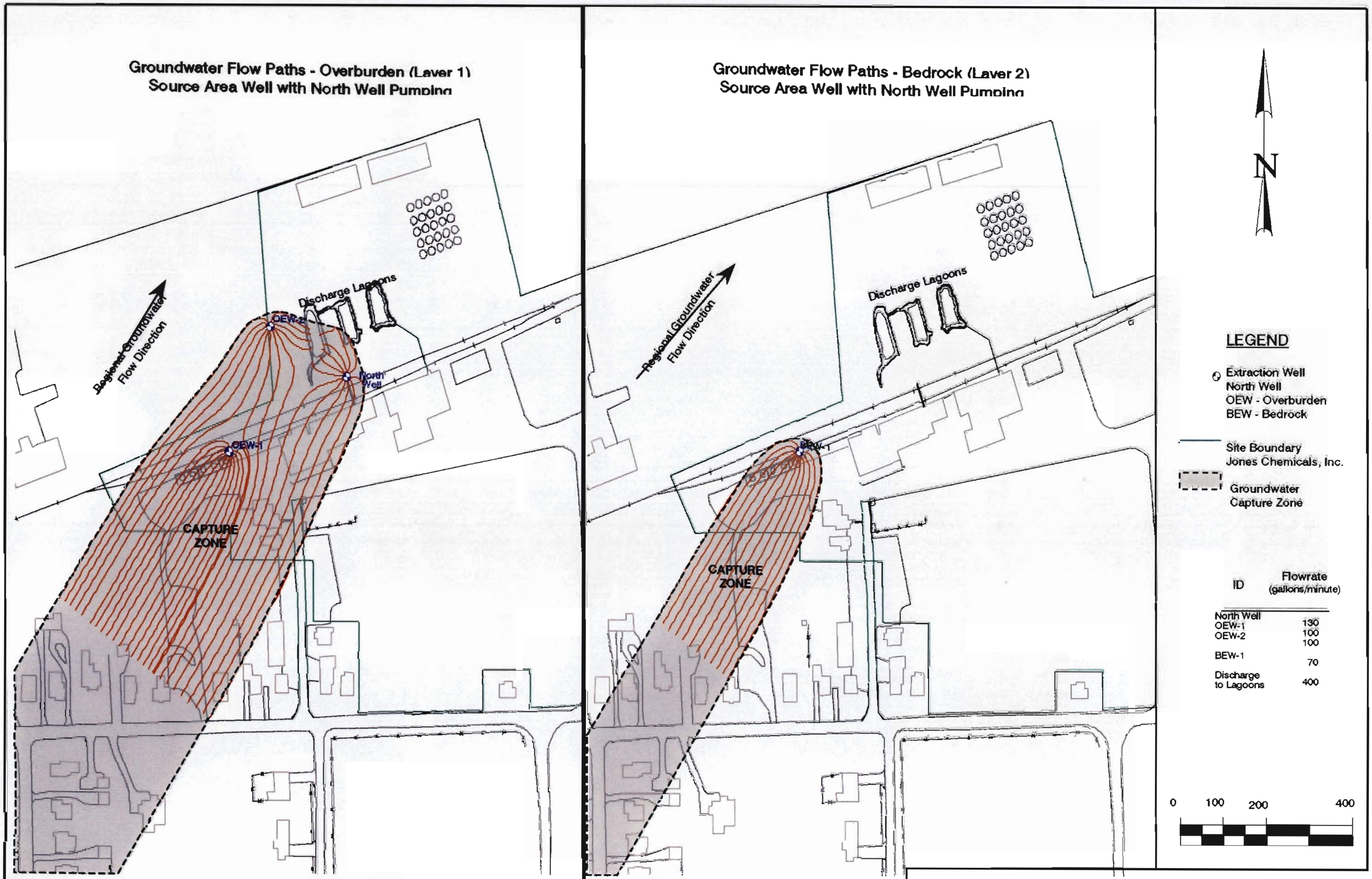
Groundwater Modeling
Jones Chemicals, Inc. Site, Caledonia, New York

Groundwater modeling of proposed source area and site-wide pump and treat systems at the JCI Jones Chemicals, Inc. site ("the Site") was conducted using the MODFLOW and MODPATH groundwater flow models within the Groundwater Modeling System pre- and post-processing program. The objective of the simulations was to estimate the location and flow rate of extraction wells required to capture tetrachloroethene (PCE)-contaminated groundwater in the source area and groundwater across the Site.

Several simplifying assumptions, including uniform hydrogeologic units and a regional hydraulic gradient, were used in the model. The model parameters were based on data collected during remedial site investigations. A preliminary calibration of the model was performed using site-specific information, including water level elevations, hydraulic gradients, and hydraulic conductivity estimates. The model was constructed with a grid spacing of 10 feet to allow delineation of site features and location of boundaries at a distance to minimize influence on results. The grid was oriented parallel with the assumed regional hydraulic gradient.

Site hydrogeological features were modeled using two layers. The upper, overburden zone consisting of a gravel-sand-silt mixture was modeled as an unconfined layer with a thickness of 30 feet and a hydraulic conductivity of 1,800 feet per day. Site lithologic logs indicate the hydraulically prolific gravel-sand-silt mixture grades with depth into a gravelly-silt unit that acts as a confining unit. A leak factor of 0.0003 feet per day was used in the unconfined layer to simulate the gravelly-silt, confining unit. The gravelly-silt confining unit directly overlies a carbonate bedrock modeled as a confined layer with a transmissivity of 8,640 square feet per day. Regional hydraulic gradients of 0.003 foot per foot for the upper layer and 0.006 foot per foot for the lower layer were used. Three lagoons at the Site covering approximately 10,000 square feet and an infiltration gallery covering 8,000 square feet were included in the model as recharge areas to the upper layer. The model assumes that all extracted groundwater is treated and discharged to the upper layer via recharge at the lagoons and the infiltration gallery.

Groundwater flow paths and capture zones were modeled for two groundwater extraction scenarios: Source Area Pump-and-Treat and Site Wide Pump-and-Treat (Figures B-1, B-2, and B-3). In the first scenario, the extraction rate from the existing North Well (currently 280 gallons per minute) was reduced to 130 gallons per minute. By adding two extraction wells in the upper layer and one extraction well in the lower layer, a total extraction rate of 400 gallons per minute captured groundwater immediately downgradient of the source area (former PCE tank location; Figure B-1). In the second scenario, the number of extraction wells and total extraction rate were increased to provide site-wide capture of PCE-affected groundwater in both layers (Figure B-2 and B-3). Since the total extraction rate was 1,200 gallons per minute, a downgradient infiltration gallery was included in the model to improve hydraulic capture and discharge treated water. Discharge rates were 300 gallons per minute (5.8 feet per day) to the lagoons and 900 gallons per minute (21.7 feet per day) to the infiltration gallery. A total of 16 extraction wells (including the two source area wells) provided hydraulic capture of the site-wide PCE plume.



ID	Flowrate (gallons/minute)
North Well	130
OEW-1	100
OEW-2	100
BEW-1	70
Discharge to Lagoons	400

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Groundwater Flow Paths
Source Area Pump-and-Treat
Caledonia, New York

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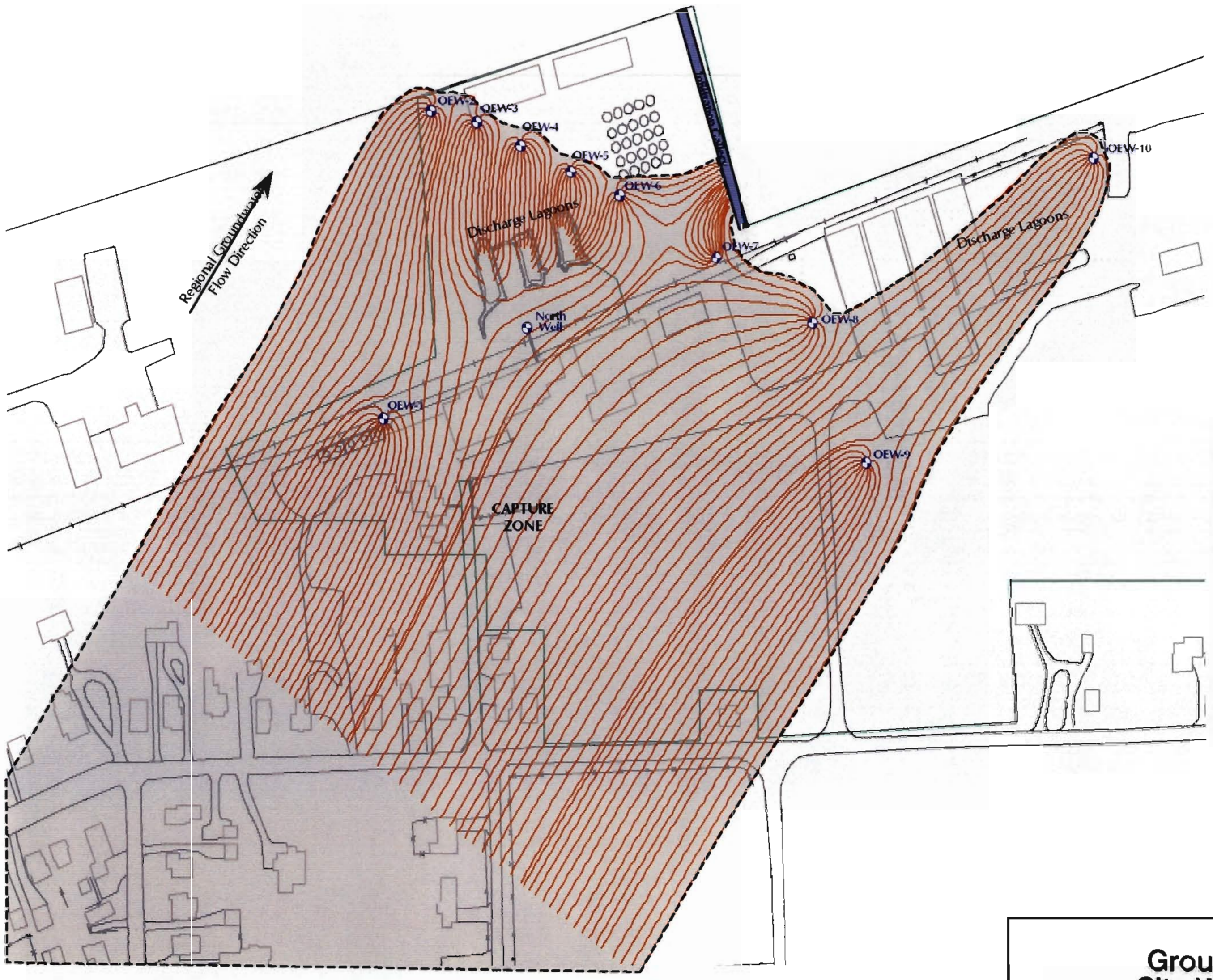
Figure B-1

Project No. 3165.20

Groundwater Flow Paths - Overburden (Layer 1)
Site Wide Pump and Treat



N

LEGEND

Extraction Well
North Well
OEW - Overburden
BEW - Bedrock

Site Boundary
Jones Chemicals, Inc.

Groundwater
Capture Zone

Infiltration Gallery

ID	Flowrate (gallons/minute)
North Well	0
OEW-1	90
OEW-2	100
OEW-3	100
OEW-4	100
OEW-5	100
OEW-6	80
OEW-7	40
OEW-8	130
OEW-9	100
OEW-10	110
Overburden Total	950
Bedrock Total	250
Discharge to Lagoons	300
Discharge to Gallery	900

0 100 200 400

Groundwater Flow Paths Site Wide Pump-and-Treat Overburden Zone Caledonia, New York

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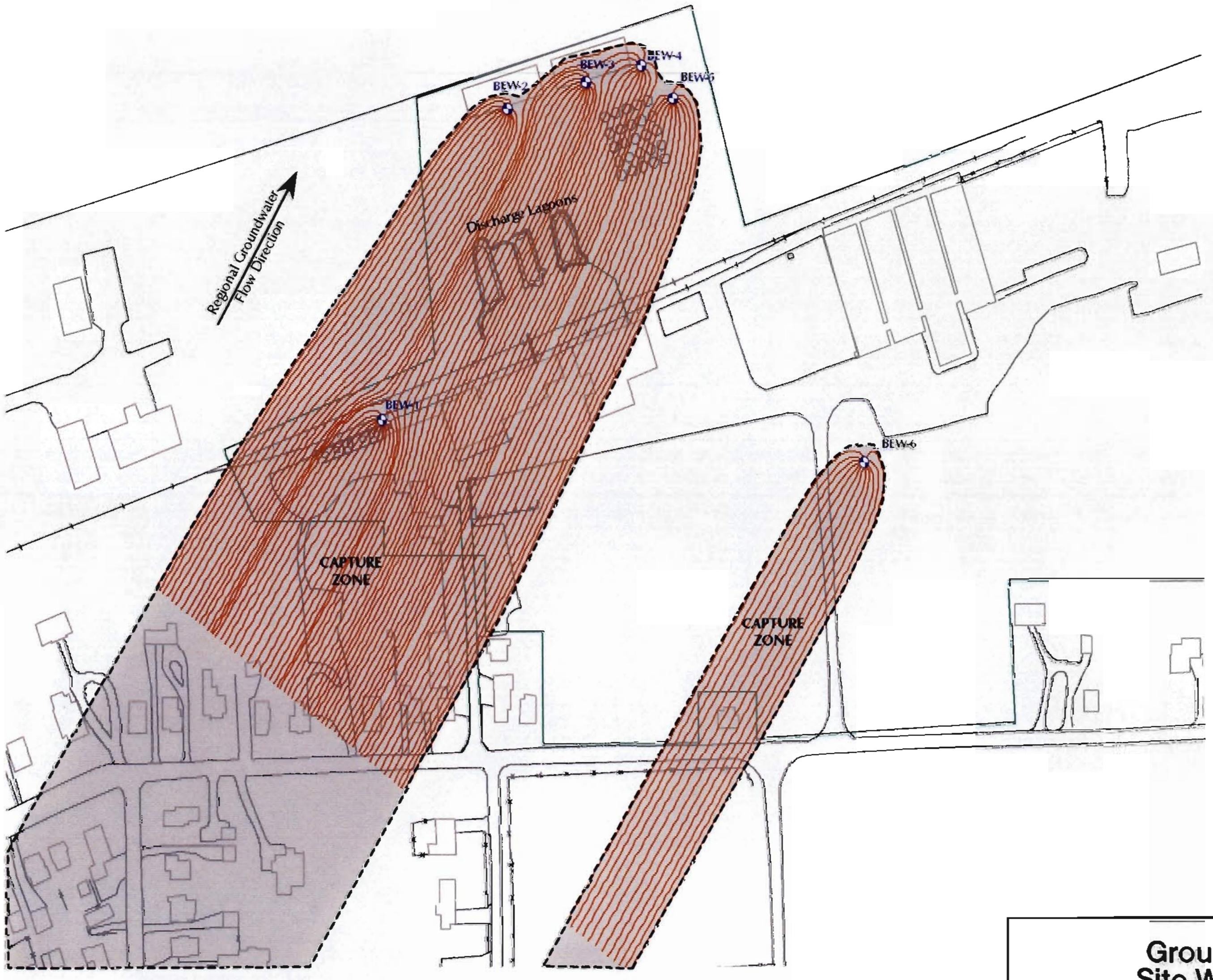
Figure B-2

Flowpath Figures.ppt 1/14/00

Groundwater Flow Paths - Bedrock (Layer 2)
Site Wide Pump and Treat



N

LEGEND

- Extraction Well
  North Well
  OEW - Overburden
  BEW - Bedrock
- Site Boundary
  Jones Chemicals, Inc.
- Groundwater
  Capture Zone

ID	Flowrate (gallons/minute)
BEW-1	50
BEW-2	40
BEW-3	35
BEW-4	35
BEW-5	40
BEW-6	50
Bedrock Total	250

0 100 200 400

Groundwater Flow Paths
Site Wide Pump-and-Treat
Bedrock Zone
Caledonia, New York

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Figure B-3

Project No. 3165.20

Flowpath Figures.ppt 1/14/00