APPENDIX 8-A

SWMUS 7 AND 46 BIOREMEDIATION SYSTEM PILOT TEST REPORT

SOLID WASTE MANAGEMENT UNITS 7 AND 46 BIOREMEDIATION SYSTEM PILOT TEST REPORT

Prepared for the

William L Bonnell Company, Inc.
Post Office Box 428
Newnan, Georgia 30264

May 9, 1997
Revised July 28, 1997

Prepared By
Thomas W. Watson, Inc.
110 Dartmouth Ave.
Avondale Estates, Georgia 30002

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SECTION 1
INTRODUCTION

1.1 INTRODUCTION

On June 14, 1995, the Georgia Environmental Protection Division (GEPD) stated that corrective action would be required of The William L Bonnell Company, Inc. (Bonnell) at several Solid Waste Management Units (SWMUs) for hazardous constituents listed in Table II of the Facility's Post-Closure Care Permit that exceed established background concentrations for the site. GEPD included SWMUs 7 and 46 in the list of units requiring remedial action. Solvent contamination from these SWMUs was discovered during previous groundwater monitoring.

1.2 BACKGROUND

On January 26, 1996, Bonnell retained Thomas W. Watson, Inc. (TW^2), to help prepare an appropriate corrective action plan (CAP) for remediation of SWMUs 7 and 46. Bonnell completed the CAP in June 1996. Bonnell proceeded immediately with the process of selecting a qualified contractor to implement the system. In December 1996, Bonnell and TW^2 requested assistance from Zimmerman Technical Service, Inc. (ZimTech) with field engineering and design of the proposed soil venting system. In January 1997, TW^2 and ZimTech conducted a pilot test as described in the June 1996 CAP. In conducting the pilot test, TW^2 and ZimTech made several observations that indicated some changes to the plan would be required to complete an effective remediation. This report describes the findings of the pilot test, and includes recommendations for revision to the June 1996 CAP.

The CAP was designed to meet the following goals:

- to protect human health and the environment,
- to comply with standards for management of wastes and contaminated media,
- to achieve media cleanup standards,
- to remediate soil contamination,
- to prevent hazardous constituents from exceeding their respective concentration limits at the compliance point by removing the hazardous constituents or treating them in place, and
- to establish a remediation and monitoring methodology with defined termination criteria.

The Bonnell site lies in the Piedmont physiographic province of Georgia, a terrain of metamorphic rock. Hydrogeologic investigation at this site has subdivided the Piedmont rock into two general monitoring zones.

The weathered zone is found from the surface to varying depths up to several tens of feet below land surface. This zone consists of residual rock weathered in-situ. Groundwater in the weathered zone moves under porous media conditions; that is, the water flows slowly between individual grains of sand, silt, and clay.

The weathered rock zone is the area of interest for the CAP. Beneath the weathered interval is the crystalline bedrock. Within the crystalline rock, groundwater flow is primarily through fractures in the rock body.

The primary rock types observed at this site are sillimanite schist, biotite quartz schist, and gneiss of various mineral compositions. Different rock types occur in a complex pattern of folding over the site. The rocks or their weathered remnants appear to occur in bands whose thicknesses range from a few inches to several hundred feet.

Water level elevations in well pairs show similar water levels in wells installed in residual soil and wells installed in bedrock. This suggests that the crystalline rock aquifer and the overlying residual aquifer are interconnected and respond as an unconfined aquifer.

To date, 85 groundwater monitoring wells have been installed on site. The predominant groundwater flow direction, as verified by ongoing potentiometric measurements, is toward streams running across the Bonnell property. A potentiometric surface map is included as Figure 1A.

1.3 DESCRIPTION OF SWMUs 7/46

The waste solvents accumulation tank (SWMU 7) had a capacity of 5,000 gallons. The tank had been used to accumulate spent solvents generated from the paint line cleaning processes since 1970.

The tank system had secondary containment since 1989. The waste xylene tank was emptied at least every 90 days by a licensed hazardous waste transportation company. Xylene, naphthalene, trimethylbenzene, and other paint solvents are constituents of concern at SWMU 7.

The solvent tank farm (SWMU 46) consisted of one 10,000 gallon tank used to store virgin xylene. This tank was previously used to store virgin toluene. A release of approximately 1000 pounds of virgin toluene occurred from this tank in July 1990.

Because of the close proximity of the two units, and because of the similarity of the constituents of concern, SWMU 7 and SWMU 46 have been addressed as one unit. Both tanks were removed from service and moved to temporary storage locations on site in November 1996. Bonnell decommissioned the tanks by emptying their contents into drums for proper disposal and then triple-rinsing the tanks to remove the residuals, which were removed for treatment and/or disposal.

A detailed discussion of the sampling protocol is included in Section 1.5. Bonnell also assessed the presence of chromium in soil since a release of chromium-containing wastewater from the upgradient paint line pit occurred in 1986. Soil pH was also evaluated as part of the RFI and test boring installation.

1.4 SAMPLING EVENTS

The RFI of SWMU 7/46 was accomplished by EMCON Southeast in July 1994 and July 1995 using soil gas probes at thirteen locations and soil borings at sixteen locations. EMCON sampled discrete soil intervals from two to twenty feet below ground surface (BGS). The RFI report for the facility was submitted to the Georgia Environmental Protection Division (GEPD) in July 1994.

1.5 SAMPLING METHODOLOGY

1.5.1 RFI Sampling

RFI sampling in the SWMU 7/46 area consisted of sixteen soil borings, advanced using a truck-mounted hollow-stem auger unit, or a hand auger. Sampling and boring equipment was decontaminated between each sampling point.

Soil samples for laboratory analysis were stored in clean glass jars appropriate for the analytical suite selected. The samples were kept on ice in coolers under standard chain-of-custody procedures. Locations of RFI soil borings relevant to definition of the total soil TEX plume are shown on Figure 3.

The RFI soil borings were used to assess the vertical distribution of volatile organic compounds (VOCs) and chromium constituents. Soil samples from the borings were collected at approximate five-foot intervals to a minimum depth of 15 feet, or until a headspace reading of less than 100 parts per million (ppm) on a photoionization detector (PID) was measured. If groundwater was encountered, the boring was terminated.

Samples from the first eight borings were analyzed for VOCs, pH, and chromium. Samples from the second set of RFI soil samples collected in March 1995 were sampled for the VOCs detected during the first round of sampling.

1.5.2 Soil Venting Pilot Test Sampling

Borings for the soil venting pilot test proposed in the June 1996 CAP were advanced into soils immediately upgradient and downgradient of the SWMUs on January 13, 1997. Four soil borings were completed using a trailer-mounted solid-stem auger rig. These borings were converted to pilot test/vapor monitoring wells.

Groundwater was encountered in each boring during initial construction. A PVC bailer was inserted into each test well on March 13, 1997, to check for the presence of light non-aqueous-phase liquids (LNAPLs).

Soil samples were collected using a decontaminated hand auger, and analyzed for the same analytes as in the RFI. Results are summarized on Figure 3. Soil boring logs and well construction diagrams, including depth to groundwater, are included in Appendix A.

In addition to the four test wells, six vapor monitoring points were installed by direct-push methods. A one and one-half inch rod was driven into the ground using a sledge hammer or the trailer-mounted rig. A one-half inch by six-inch long metal screen was attached to the drive point and installed at a depth of about five feet below grade. One-quarter-inch nylon tubing was attached to the screen and extended to the surface.

The annulus above the drive point adjacent to the screen was filled with a filter pack of fine glass beads to within two or three feet of the surface. The remaining space around the nylon tubing and above the glass beads was filled with adjacent soils. A plastic protective cover was installed at the surface.

Prior to the start of pilot testing on January 15, 1997, soil gas readings were collected from the wells and vapor monitoring points using a Landtec model GA-90 landfill gas analyzer. After a stabilization period of at least two minutes, readings for oxygen (O_2), carbon dioxide (CO_2), and total petroleum hydrocarbons (TPH, as methane) were recorded.

1.6 SAMPLING RESULTS

The RFI analytical results relevant to definition of the soil toluene-ethylbenzene-xylene (TEX) plume are summarized on Figure 3. In addition, Table 1 summarizes results of the laboratory analyses performed on the soil samples collected during the CAP pilot test. Results are presented in units of milligrams contaminant per kilogram of soil (mg/kg or ppm).

Analytical Services, Inc., (ASI) of Norcross, Georgia, performed the laboratory analyses for VOCs, pH, and aerobic heterotrophs. MicroMacro International, Inc. (MMI), of Athens, Georgia, performed the soil nutrient analyses. Certified laboratory results are included in Appendix B.

Generally, aerobic heterotrophs are oxygen-consuming bacteria utilizing organic carbon as a food source. Normally the number of colony-forming units (CFU) of bacteria per gram of soil should be at least 1000 for assurance of good native populations available for remediation using bio-stimulation. Smaller numbers in an area with known availability of an organic carbon food source would indicate the presence of some type of growth inhibitor.

Table 2 summarizes results of the soil gas survey. Soil gases in an area known to be affected by a release of organic carbon and with active bacterial colonies, as depicted in Figure 3 and Table 1, should exhibit oxygen levels depressed below about five to ten percent and carbon dioxide typically elevated above about 10 percent.

Depressed oxygen and elevated carbon dioxide were indicated only in the readings collected from vapor monitoring points VP-1 and VP-2. Both of these are located near the center of the area affected by the VOC release.

The behavior observed at point VP-1 was indicative of a possible explanation for these results. Readings initially moved quickly away from ambient as the probe and instrument purged themselves of the ambient air. However, after initially stabilizing at a moderate level, the oxygen began rising again indicating short-circuiting with the surface. After further compaction of the soils around the drive-point hole, the oxygen readings dropped to the expected low level. Additional work sealing the other vapor points prior to the next round of sampling may help to provide more reliable readings.

The unusually high oxygen readings in the test wells may be explained by the low permeability soils encountered around the well locations. The sampling pump integral with the vapor analyzing instrument lacked the vacuum power to properly purge the wells of ambient air under these conditions.

The aerobic heterotroph plate counts indicate elevated biological activity in the volume of soils affected by the VOC release near the SWMU. Soil nutrients are somewhat depressed but are not likely to become a serious concern. If asymptotic behavior of biological activity is observed prematurely during the corrective action (as indicated by the performance monitoring described in Section 4), standard landscaping fertilizer can be broadcast and irrigated into the subsurface by natural rainfall or artificial sprinklers.

1.7 NATURE AND EXTENT OF CONTAMINATION

None of the soil samples exceeded the site-specific background level for chromium (73 mg/kg) established in the Bonnell RFI Work Plan. As was discussed in the Work Plan, GEPD policy is that any value above the detection limit for volatile organic compounds is above the background concentration. Based on this standard, certain soil samples exceeded background concentrations for various constituents. The soil samples collected from the boring for test well TW-1 indicated the highest levels of TEX determined to date.

The groundwater at the hillside appears to have been minimally affected by the SWMU. Typical groundwater concentrations for the low point collector (LPC) are about 280 ug/l toluene, 50 ug/l ethylbenzene, and 20 ug/l total xylenes.

Bailer checks of groundwater in the test well installations indicated LNAPLs were present in wells TW-1 and TW-2. The bailer drawn from well TW-1 contained about one-quarter-inch LNAPL and that from well TW-2 contained about fourteen inches. The LNAPLs were dark amber in color, with a strong solvent odor. The water table was encountered about 12.0 feet below the top of casing (TOC) in well TW-1 and about 13.9 feet below TOC in well TW-2. Free product was not detected in any of the other test wells installed for the pilot test.

It has been the experience of TW^2 that the presence of an LNAPL layer in a monitor well is not an accurate indication of thickness of the LNAPL layer in the aquifer, or the total volume of LNAPL present. Given the TEX levels observed in soil samples, and the minimal involvement of groundwater described above, the LNAPL thickness is probably minimal.

The principal soil contaminants are toluene, ethylbenzene, xylenes, naphthalene, and trimethylbenzene. The waste solvent tanks contained mostly waste xylene, toluene, and other solvents; and the solvent tank farm contained virgin xylene and toluene. Xylene and toluene were the two constituents exhibiting the highest concentrations.

The horizontal and vertical extent of the soil contamination has been defined during the site assessments completed to date. Horizontal extent was discussed in the RFI. The vertical extent of soil contamination extends to the groundwater table as indicated by previous groundwater sampling.

Samples collected closer to the tanks are more thoroughly affected vertically than soil samples collected further away. Near the limits of the plume, as shown in Figure 3, the soils appear to be most affected at depth. However, the samples collected from boring SO-7/46-8 appear to be uniformly affected vertically. This is probably due to the significantly lower topographic elevation of the boring nearer the LPC.

Surface spills, such as occurred near the SWMU, move essentially vertically down through the vadose zone until encountering a water table. Then they tend to travel downgradient with the groundwater flow in a floating lens, affecting mostly the soils near the water table.

Soils above the lens are affected by seasonal changes in the water table, creating a so-called "smear zone," and by upward vapor migration. The vadose zone becomes thinner as the topography falls toward the LPC, increasing these effects.

1.8 CURRENT REMEDIATION EFFORTS

Recovery of contaminated groundwater at the Bonnell site is being accomplished by a series of seven groundwater recovery wells. Additionally, a groundwater collection sump is located downgradient of SWMU 7/46. The recovered groundwater is piped to one of two of the plant's waste water treatment systems. The treated effluent is then discharged to Bonnell's NPDES-permitted outfall.

The groundwater extraction and treatment system has been in place at the Bonnell Plant since August of 1993. A total of 37 million gallons of contaminated groundwater from the hillside area has been treated by the system through January 1997. This CAP proposes no additional groundwater treatment.

Bonnell has implemented LNAPL removal from wells TW-1 and TW-2. They are using a hand bailer to remove a mixture of LNAPL and water until only a sheen or less is visible inside the bailer. The removed LNAPL and groundwater are disposed of in the plant wastewater treatment system.

1.9 CONCLUSIONS REGARDING SWMUs 7 & 46

The two tanks in SWMU 7/46 previously used to store solvents used in the plant process and waste solvents have recently been removed from service. The RFI and additional remedial investigation for the pilot test indicate soils surrounding these tanks have been affected by the VOC release to a depth of up to 20 feet BGS.

The CAP addresses residual VOC-affected soils in this area. A soil venting system can be effective as a corrective action. Soil venting for enhanced biodegradation is a proven cost-effective technology for this type of release (USEPA, 1995).

The technology, commonly called bioventing, is the process of aerating soils to stimulate in- situ biological activity and promote bioremediation. It typically is applied in-situ to the vadose zone and is applicable to any chemical that can be aerobically biodegraded.

Although bioventing is related to the process of soil vapor extraction (SVE), these processes have different primary objectives. SVE is designed and operated to maximize the volatilization of low-molecular-weight compounds, with some biodegradation occurring. In contrast, bioventing is designed to maximize biodegradation of aerobically biodegradable compounds, regardless of their molecular weight, with some volatilization.

Through the efforts of the U. S. Air Force Bioventing Initiative, bioventing has been implemented at over 150 sites and has emerged as one of the most cost-effective, efficient technologies currently available for vadose zone remediation of VOC-contaminated sites. In its simplest terms, bioremediation involves mechanical aeration, which increases oxygen levels in the vadose zone, allowing the naturally occurring soil bacteria to enhance microbial activity and promote biodegradation of contaminants. The main advantages of bioventing are its use of smaller, less-expensive blowers and related systems, and lack of volatile off-gasses that must be treated (USEPA, 1975).

As can be seen from Figure 4, venting for enhanced biodegradation results in a lower required flow rate, for a given hydrocarbon mass removal rate, than venting for physical stripping by volatilization. Biodegradation results in the complete destruction of contaminants instead of merely transferring them to other media which must be further treated.

In most cases, if safe and feasible, pressure venting is the preferred method for full-scale operations. Generally, air can be supplied at flow rates low enough to avoid surface emissions. Figure 5 illustrates typical system operations.

In such a system, some VOC vapors will migrate into surrounding soils where they can biodegrade. This has the advantage of creating an expanded in-situ bioreactor, destroying the contaminants in place by means of biological processes. The greatest vapor-phase degradation occurs in the shallow root-zone soils (USEPA, 1995).

Results from full-scale operations at multiple sites in the USAF Bioventing Initiative indicate the majority of hydrocarbon mass mineralization occurred in the expanded bioreactor outside the main area affected by the VOC releases. Total mass removal rates (kilograms/day) were often double that occurring inside the main area. The concept is analogous to an in-situ biofilter; a proven technology for off-gas treatment (USEPA, 1995). The size and extent of the expanded in-situ bioreactor is difficult to predict, and depends on the permeability of the local soil. It is estimated that the extent of the expanded in-situ bioreactor is 10% to 50% larger than the originally impacted area.

Besides creating an expanded bioreactor, pressure venting will expose a significant portion of capillary-fringe contaminated soil to treatment due to water table depression, a result of the positive pressure created in the vadose zone. The positive pressure also causes an increase in the temperature of the supplied air, resulting in enhanced rates of biological activity.

At many sites, the capillary fringe is the most contaminated zone, and lowering the water table allows for its more effective treatment. In addition, this dewatering effect frequently results in an increased radius of influence and greater soil gas permeability (USEPA, 1995).

The pilot testing and additional remedial investigation performed as part of the implementation of this corrective action plan have been used to improve on the design efficiency of the proposed remedial system. Subsequent sections will describe the conceptual design based upon these results.

SECTION 2
SOIL VENTING PILOT TEST

2.1 OBJECTIVE

The objective of this corrective action plan is to enhance the rate of soil clean-up that can be achieved. This objective will be met by supplementing the current groundwater recovery system with a soil venting system. The venting system will work in conjunction with the existing groundwater recovery system to remediate soil and help remediate groundwater contamination downgradient of SWMU 7/46.

2.2 PILOT TEST FIELD INVESTIGATION

To develop site specific data for conceptual design of the proposed soil venting system, four test wells were installed on January 13, 1997. The test wells were constructed in a manner similar to a groundwater monitoring wells, with 10 feet of two-inch PVC 0.010-slot screen. Well construction diagrams are included in Appendix A and their locations are indicated on Figure 2.

The RFI results indicated that groundwater would be encountered at about 20 feet BGS. However, actual groundwater depths ranged from slightly more than 10 feet to 15 feet BGS. At least five feet of overburden above the sand pack should generally be maintained to prevent short-circuit air flow from the surface. Consequently, the screen bottoms were set a few feet below the water table to provide for sufficient overburden thickness and to accommodate a water rise due to applied vacuum during the test.

A pressure venting test in higher permeability soils could result in uncontrolled vapor migration concerns. Therefore, a vacuum venting test was planned since soil permeability and utility locations near the proposed test well locations were not certain at the time of the work plan preparation and Bonnell did not want to risk an occurrence of contaminant migration.

For the pilot test, a 2.5 horsepower regenerative blower was used to apply a vacuum to test well TW-1. Magnahelic gages reading vacuum/pressure in inches of water were used to monitor test results. A gage with a range of 0 to 100 inches at the moisture separator inlet was used to measure applied vacuum.

Lower range gages of 0 to 0.25 and 0 to 1.0 inches were installed at test wells TW-2, TW-3, and TW-4. After three hours of applying 80 inches water vacuum to well TW-1 there was no indication of vacuum at any of the test wells.

Air extraction creates a partial vacuum in the soil, resulting in a water table and capillary-fringe rise or upwelling. This upwelling increases soil moisture in the fringe, thereby reducing soil gas permeability and radius of influence. USAF Bioventing Initiative site experience indicates upwelling can reduce permeability by one-half and radius of influence by one-third (USEPA, 1995).

From the well construction diagram, it can be seen the top of the screen for well TW-1 is 4.5 feet BGS and the water table is at 12.3 feet, providing about 7.8 feet (94 inches) of screen above the water. With an applied vacuum of 80 inches, only 14 inches of screen was potentially open for venting.

In low-permeability soils, the radius of influence may approach the length of the screened interval open to soil. Sufficient screen between the required overburden and a shallow groundwater table may not be available to prevent short-circuit airflow in such soils.

Screening the vent wells up to the existing grade and covering surface soils with an impermeable seal, such as geotextile vapor barrier, may not be a cost-effective option at this site. The steep grades would likely make such emplacement an expensive technical challenge. Groundwater pumping to lower the water table also would not likely be cost-effective compared to other options such as pressure venting.

Based upon the foregoing, the decision was made to switch the blower configuration to pressure venting at well TW-1 and run the pilot test again. Given the low soil permeability apparent after the initial test, uncontrolled vapor migration was not considered to be a serious concern.

After one hour of venting, 0.03 inches of water pressure was measured at well TW-2 and 0.02 inches at TW-3. These wells are located at radii of 15 and 30 feet from well TW-1, respectively. Further testing was not attempted because of time limitations.

SECTION 3
SYSTEM CONCEPTUAL DESIGN

3.1 DESIGN PARAMETERS

The proposed technology will increase the rate of site remediation by increasing the VOC removal rate from the soil at SWMU 7/46. Soil venting increases the removal rate of all four phases of VOCs from the vadose zone: gas vapors in the soil, gases adsorbed to the solids, gases dissolved in pore water, and NAPL residuals trapped in the soil pore spaces. The technology has been successfully applied at various sites in different soil types (USEPA, 1995).

Based on conditions observed during the pilot test at the Bonnell facility, it is anticipated that contaminant removal will occur in an acceptable time frame. Rather than trying to predict or quantify removal capabilities at this time, Bonnell will demonstrate the performance of the technology through actual site remediation.

Once full-scale pilot operations have begun, actual system performance can be measured and evaluated to predict the time to closure. In-situ testing including the use of a tracer gas study will be employed to evaluate system function. In-situ testing and adequate monitoring of the peripheral areas of the plume will determine if the contaminant is being remediated or merely pushed around by air pressure. If the technology fails to provide suitable removal capabilities, alternative remedial measures can be evaluated.

The planned system will consist of two four-horsepower regenerative blowers working in series to pressurize ten vent wells. The existing test wells will be completed by grouting to the surface and then used for soil gas monitoring. The screened intervals of existing wells are presently isolated from the surface with bentonite pellets, and then backfilled with soil cuttings.

Four additional vapor monitoring points will be installed at a depth of 10 feet BGS to assist with system performance monitoring and optimization. The existing monitoring point drive rod holes will be better sealed to improve performance. The locations of the proposed vent wells and monitoring points are shown on Figure 6.

Bonnell will collect soil samples from the soil borings drilled for vent well construction. Samples will also be collected from groundwater in existing test wells and from the vent wells, if encountered. The samples will be handled and analyzed according to the site sampling and analysis plan in Section E of the Part B Permit Application. In addition, several undisturbed soil samples will be collected for geotechnical analyses of grain size, porosity, bulk density, and permeability. At present, the intrinsic permeability of soils at the unit is estimated empirically to be between 10^{-8} to 10^{-9} cm^2 (Freeze and Cherry, 1979, page 27). Intrinsic permeability is derived through calculations based on soil conditions, or empirically derived. Intrinsic permeability cannot be measured directly by laboratory methods. Soil moisture content at the Tank Farm Unit will vary depending on rainfall and depth below land surface. In previous studies (USEPA, 1995) soil moisture has been found to directly limit biodegradation rates only where bioventing has been implemented in very dry desert environments. A strong correlation between soil moisture and oxygen utilization rates has not been identified, and in fact, a primary limiting factor to bioremediation is too much moisture. Soil moisture in the Tank Farm Unit can be controlled and adjusted easily through surface irrigation.

Results of the sample collection and analyses will be used to provide additional data for corrective action planning and system performance monitoring. By correlating groundwater and soil analyses for samples collected from the same borehole, along with the geotechnical parameters, the fraction of NAPL residuals present in unit volumes of vadose zone soils can be calculated. The geotechnical and soil VOC results will also be important for calculating biodegradation rates during system performance monitoring.

The vent wells will be constructed using four-inch schedule 40 PVC screens with 0.020-inch slots as detailed in the June 1996 CAP. The screen bottoms will be placed at a depth of 20 feet BGS (the normal seasonal low water table) with tops at 10 feet BGS.

This overburden thickness should contain 130 inches of applied water pressure without pressure leakage. This applied pressure will be capable of depressing the seasonal high water table down to the seasonal low elevation, uncovering the "smear zone" created by seasonal water level fluctuations, and allow for more effective remediation of residual VOCs. The depression will cause the residual VOCs to become trapped in the soil pore spaces and exposed to oxygenation. Bioremediation will then become effective in causing their removal by mineralization. Mechanical removal by hand bailer will continue on a weekly basis as long as LNAPLs in excess of 1/8 inch are detectable in the bailer. The recovered liquid is being disposed of through the Bonnell facility groundwater treatment system.

The result of the pilot test data reduction and linearization is a radius of influence of about 20 feet. If the applied pressure is increased to 130 inches (the maximum allowed by a ten-foot overburden) and the well diameter is increased to four inches, a radius of influence of 30 feet should be achieved. The calculations are included in Appendix C.

The area of the TEX-affected soils shown in Figure 3, as measured by electronic digital planimeter, is approximately 14,000 square feet. Assuming an average depth of contamination of 20 feet, the volume of contaminated soils is approximately 280,000 cubic feet. Using equation 2-1 in Volume II of USEPA (1995), an assumed oxygen utilization rate of 0.25 percent/hr, and soil porosity of 36 percent (both based upon similar sites in the southeast), the required total venting flow rate is 26 cubic feet per minute (cfm), or about 2.6 cfm per well.

Locating the wells approximately as shown in Figure 5, will result in the radius of influence of the recovery wells overlapping somewhat. Individual wells may be phased out of the system based on observations of the operating system.

The two four-horsepower regenerative blowers plumbed in series will produce the required 130 inches of pressure at a minimum flow of 128 cfm. The flow exceeding the required 26 cfm can be bypassed through a gate valve and muffler. The excess will also be available for adjusting the system to meet actual demands.

The blowers will be attached to a nearby manifold from which individual pipes will run to the wells. Gages and valves can be incorporated into the manifold to allow system balancing from a central location.

Inlet air will be protected by an appropriate filter and equipped with fittings to allow some wells to be converted to vacuum venting operations. Conversion of some wells to vacuum points may be desirable to control subsurface pressure gradients or for performance testing purposes. Control of pressure gradients may be necessary if unwanted migration of the contaminants in the subsurface is detected. Provisions for incorporating a moisture separator into the inlet side of the system (as depicted in the June 1996 CAP) will be made for use during vacuum operations.

As discussed earlier, off-gas treatment in the proposed system will be by in-situ biodegradation. In the event some wells are converted to vacuum operations, the system can be configured to recirculate the extracted off-gasses for continued in-situ treatment. Such a system has proven effective at several sites (USEPA, 1995) and is illustrated in Figure 7. Leak detection during vacuum operations will be accomplished by using a flame ionization detector (FID) to monitor piping runs.

3.2 FULL SCALE SYSTEM TESTING

The full-scale system will be pilot tested for a period of 1 to 2 months to develop operating parameters and to verify the system design. Monthly soil gas monitoring will be conducted during the first year of operation to ensure the site is well oxygenated, and to determine if the contaminant plume is being driven by air pressure. Because of the simplicity of the system, frequent soil gas monitoring should not be required once the initial testing period has been completed.

Once full aeration has been achieved, system operations can be optimized. After the initial testing period, soil gas monitoring will be conducted semi-annually for the first year, during the summer and winter months to observe potential significant variations caused by seasonal temperature changes. If no significant seasonal variation is detected, soil gas monitoring will be conducted annually thereafter. If a significant seasonal variation is detected, semi-annual monitoring will be considered.

According to USEPA (1995), surface VOC emissions sampling is not necessary at most soil venting sites. Out of 125 sites documented during the USAF Bioventing Initiative, none exceeded local air emissions standards. Testing for surface emissions will be conducted at this facility, particularly during the first year of operation.

From Figure 6, it can be seen there are two sewer lines (one sanitary and one storm) running through the center of the soils area affected by the release of VOCs. Bonnell is not aware of any vapor accumulation issues associated with these utilities. However, any soil venting operation will modify the subsurface pressure gradients and could result in changes to the existing stable situation. Therefore, vapor monitoring of the 60-inch storm sewer pipe and sanitary sewer manhole will be conducted concurrent with the soil gas sampling.

If hazardous vapor accumulations are detected, some of the vent wells can be converted to vacuum operations.

All vapor monitoring points and wells will be checked under static conditions, prior to starting system operations, to ensure that proper readings can be obtained. The full-scale system test will then be monitored on a weekly basis, unless otherwise specified, and will include the following:

1. With the system temporarily turned off, soil gas monitoring points and wells will be tested for oxygen and carbon dioxide levels using a landfill gas analyzer. A FID calibrated to toluene will be used to read soil gas VOC concentrations.

Results will be evaluated to ensure the soils affected by VOC releases are thoroughly oxygenated. The test wells will also be checked with a hand bailer for the presence of LNAPLs.

2. The system will be re-started and equipment flows, pressures, vacuums and other pertinent data used to control the process will be recorded. These will be read from the control manifold and from soil monitoring points and wells. System monitoring will be reported on a per-well and system-wide basis; and will include vacuum/pressure readings in inches of water; air flow in standard cubic feet per minute (SCFM); soil gas readings in percent O_2 and CO_2, and VOCs in ppm for each sampling location; estimated radius of influence; and total hours of operation.

3. Surficial air monitoring using an FID.

The results of the periodic monitoring during the initial system test will be reported to the Georgia EPD on a monthly basis.

3.3 OPERATION AND MAINTENANCE OF THE SYSTEM

Soil venting systems are very simple, with minimal mechanical and electrical parts. If the system is operated in the pressure mode, a simple visual system check would be required to ensure that the blowers are operating within their intended flow rate and pressure range. Weekly system checks are desirable.

If a recirculation system is in operation, an additional check of condensate accumulations in the moisture separation drum will be necessary. Accumulations can be drained into containers and added to the groundwater treatment system.

Equipment operation and maintenance will be performed as specified by equipment manufacturers. The operation and maintenance (O&M) will be performed by Bonnell personnel unless otherwise required by the manufacturer.

A standard operating practice (SOP) manual will be prepared. A copy of the SOP manual will be provided to EPD. The manual will contain the normal operation and maintenance of each major piece of equipment.

A check list summarizing each component and a schedule for maintenance will be included in the SOP. The SOP will also provide data sheets to record pertinent operational information necessary to calibrate, control, and report the system performance.

The system will be monitored continually for the first week of operation, or until routine operation has been established, whichever is longer. Once the system is operating as intended, monitoring will take place on a weekly basis. Weekly monitoring will include recording pressure/vacuum and air flow for all points, and recording total hours of operation and hours per vent well

SECTION 4
PERFORMANCE MONITORING

4.1 IN-SITU RESPIRATION TESTING

In-situ respiration testing will be conducted periodically as a means of monitoring progress of site remediation. As the site remediation progresses and VOC concentrations decrease in the soils affected by the release, in-situ respiration rates should approach those measured in unaffected soils.

The in-situ respiration test is performed by adding 1 to 2% helium to the injection air. The helium is used as an inert tracer gas to assess the extent of diffusion of soil gases within the aerated zone. The gas used as a tracer will be 99% or greater purity, and is available from welding supply stores. Helium in the soil gas will be measured with a Marks Helium Detector Model 9821 (or equivalent) with a minimum sensitivity of 0.01%. Typically, helium is injected into the ground for a period of at least 24 hours prior to testing. Following helium injection, concentrations of oxygen, carbon dioxide, helium, and total hydrocarbons are measured with the system running. The system is then turned off and soil gas monitoring is conducted every few hours to record oxygen disappearance, carbon dioxide production, levels of hydrocarbons, and helium levels. Typically, the system is sampled at 2, 4, 6, and 8 hour intervals and then every 4 to 12 hours depending on the rate of oxygen utilization. Field judgement will be required to determine the sampling frequency. The biodegradation rate is then calculated using the procedures in USEPA (1995).

The procedures involve first plotting the time rate of change of the percent oxygen. The slope of the resulting linear relationship is equal to the oxygen utilization rate. Using this slope, the soil porosity and density, and a table of oxygen density versus temperature, the biodegradation rate can then be calculated with equation 1-2 from Volume II of USEPA (1995).

Using the calculated biodegradation rate and an estimate of the initial mass of VOC, the time to completion of contaminant removal can be estimated. This calculation will provide a reasonable "ballpark" estimate. However, the calculation tends to underestimate the required treatment time because the degradation rate decreases over time. At the same time, the calculation method overestimates treatment time because it does not consider the improved efficiency resulting from the expanded subsurface bioreactor created by the pressure venting process. Also, the rate varies with the season. Therefore, the calculation of time to closure must be coupled with process monitoring to provide field-based evidence the site is actually progressing as estimated.

If LNAPL thickness in excess of 1/8 inch remains detectable in hand bailer check samples from the test wells after the system has been in operation for several months, Bonnell will modify the corrective action to further enhance the rate of biodegradation. The primary enhancement will be to introduce naturally-occurring bacterial enzymes into the LNAPLs existing at the water table. These enzymes are natural products of bacterial metabolism and will accelerate the rate of biodegradation by improving the energy efficiency of the process (Meaders, 1994). Bacterial enzymes can be introduced in two ways. First, they can be injected into the subsurface via the ventilation wells. If this method is used, a one-time underground injection permit will first be obtained. Injection through a well or wells has the drawback of creating biofouling in the immediate vicinity of the well. Because of biofouling, the enzyme introduction will likely be done by the second method, surface application. Further enhancement of the remediation system would involve the installation of passive skimmers in wells with LNAPLs.

4.2 SYSTEM SHUTDOWN CRITERIA

As discussed earlier, the measured in-situ respiration rates will approach background as remediation progresses. Respiration rates in the VOC release area that are similar to rates measured in unaffected soils are indications that remediation is complete and confirmation soil sampling should be performed. Therefore, Bonnell will collect confirmation samples when soils affected by the VOC release indicate biodegradation rates within 95 percent of those measured in unaffected soils.

Two soil confirmation samples will then be collected adjacent to each vent well. Two soil confirmation samples will also be collected from the saturated zone in an area furthest from the injection wells, or in areas anticipated to present a worst case scenario for contaminant potential. The specific depths of the samples and the sampling method are described in the following section (4.3 Verification Soil Sampling Plan). Concentrations of contaminant in the soil samples will be compared to background levels to determine successful remediation levels.

4.3 VERIFICATION SOIL SAMPLING PLAN

Verification soil samples will be collected at seven locations at depths of five feet, ten feet, and at the water table, to determine VOC concentrations in soils after system shut-down. The soil sample locations will be in the vicinity of the vent wells, and in areas furthest from the oxygen sources, in areas directly affected by SWMUs 7/46.

Each soil verification sample will be collected by driving a 2-inch O. D. sampling tube with a stainless steel liner into the soil. After retrieving the sample, the ends of the sample tube will be covered with TFE-fluorocarbon sheets and plastic caps. The caps will be sealed in place with sealing tape. This method will limit escape of VOCs by handling.

All soil samples will be labeled and placed immediately into an ice-filled cooler. Soils will be tested using EPA Test Method 8260.

SECTION 5
CORRECTIVE ACTION REPORTING

5.1 SYSTEM REPORT CATEGORIES

System reports will be divided into two categories. First, following installation, a corrective action system installation report will be submitted to GEPD. The installation report will document findings and data obtained during the system installation and start-up.

Second, performance monitoring reports will be submitted on a regular basis as discussed below. The reports will include data regularly collected from the system, plus any problems encountered and applied solutions.

5.2 SYSTEM INSTALLATION REPORTING

A system installation report will be prepared and submitted to the Georgia EPD upon completion of the full-scale system pilot test. The report will include a system map and at least two cross sections showing locations of vent wells, areas of influence of each well, contaminant concentrations (isopleths), and soil types in the area. It will also include, but not be limited to, the following:

- a summary of work performed and adjustments made to the system;

- construction drawings and specifications; and
- air flow rates, total pounds of contaminant removed (based upon biodegradation rate calculations), and other pertinent operational data.

5.3 PERFORMANCE MONITORING REPORTING

Bonnell will submit performance monitoring results on a semi-annual basis in the corrective action effectiveness reports. These reports will include, but not be limited to, the following:

- pressure/vacuum data for individual wells and the overall system;
- recorded soil gas results at all monitoring points;
- total operation hours per well and for the system;
- calculations of total contaminant removed;
- amount of water generated by the system, if any; and,
- system down time.

SECTION 6
SCHEDULE

6.1 TIME LINE

The time line for the implementation of the CAP is shown Table 3. The time line includes the design of the system; the procurement of supplies, equipment, and construction materials; the construction and installation of the system; the operation of the system performance and process development test; the monthly reporting to the Georgia EPD; and the development and submittal of the Corrective Action System Installation Report.

It is anticipated that this entire process will require approximately four months to complete. The time periods presented in the schedule are approximate.

SECTION 7
BIBLIOGRAPHY

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Meaders, R.H., 1994, "Enzyme-Enhanced Bioremediation," in *Applied Biotechnology for Site Remediation*, edited by R.E. Hinchee, et al, Lewis Publishers, Boca Raton, FL, pp. 410-416

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USEPA, 1995, *Manual: Bioventing Principles and Practice*, U.S. Environmental Protection Agency, Office of Research and Development, Document EPA/540/R-95/534a, Center for Research Information, Cincinnati, Ohio.

TABLES

table 1-1.rev

TABLE 1.

SUMMARY OF LABORATORY ANALYTICAL RESULTS (mg/kg)

The William L Bonnell Co.
Newnan, Georgia
January 1997

PARAMETER	RESULTS at INDICATED DEPTH												
	TW-1 (5)	TW-1 (10)	TW-2 (5)	TW-2 (10)	TW-2 (15)	TW-3 (5)	TW-3 (10)	TW-3 (15)	TW-4 (5)	TW-4 (10)	TW-4 (15)	VP-7 (5)	REF. CONC.
pH	6.05	5.55	6.32	5.95	6.56	6.00	7.16	6.67	7.20	7.23	7.24	5.48	NA
Total Chromium	24	30	16	28	25	31	58	16	24	27	25	30	background
Aerobic Heterotrophs[3]	NA	3.5×10^5	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.0×10^5	NA
Ethylbenzene	860	920	130	740	490	<0.005	5.3	590	<0.005	0.940	51	<0.005	0.005[2]
Tetrachloroethene	<10	<10	<10	<10	<10	<0.005	<2	<10	<0.005	<0.500	<2	<0.005	0.005[2]
Toluene	1300	1100	19	1800	1200	0.020	58	5700	<0.005	1.400	<2	<0.005	0.005[2]
Trichloroethene	<10	<10	<10	<10	<10	<0.005	<2	<10	<0.005	<0.500	<2	<0.005	0.005[2]
Xylenes (total)	4200	4700	680	3600	2400	0.044	27	2900	<0.005	7.800	36	<0.005	0.005[2]

NOTES:

1. Site-specific background level based on lower detection limits
2. Concentration protective of groundwater based upon state/federal MCLs and simple contaminant leaching model using worst-case assumptions
3. Units of colonies/gram

NA - Not Analyzed or Not Applicable
REF. CONC. = Reference Concentration

TABLE 2.
SUMMARY OF SOIL GAS READINGS
The William L Bonnell Co.
Newnan, Georgia
January 1997

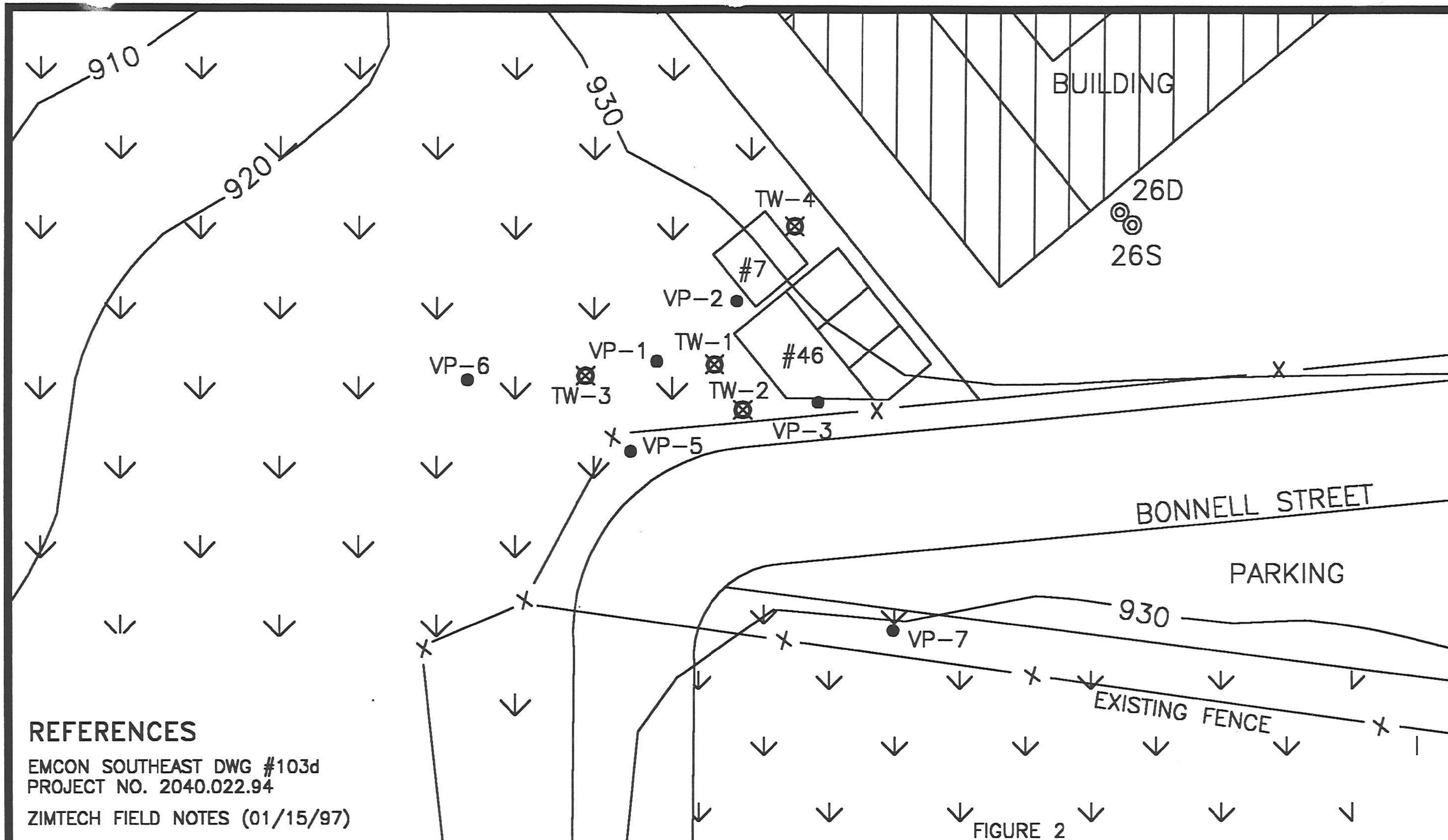
PARAMETER	RESULTS										
	VP-1	VP-2	VP-3	VP-5	VP-6	VP-7	TW-1	TW-2	TW-3	TW-4	AMBIENT
Oxygen (%)	1.5	7.1	18.5	20.0	16.8	17.3	11.7	13.8	15.2	8.9	20.7
Carbon Dioxide (%)	10.9	5.5	1.1	0.3	3.4	2.6	6.2	4.2	2.8	5.3	0.0
TPH as Methane (%)	3.9	9.1	0.6	0.1	0.0	0.0	14.9	4.5	15.5	0.8	0.8

TABLE 3. CORRECTIVE ACTION IMPLEMENTATION SCHEDULE

	MONTH														
Task	May 97	June 97	July 97	Aug 97	Sept 97	1*	2	3	4	5	6	7	8	9	10
Complete Pilot Test Report	**														
Prepare Preliminary Design/Calculations	**	***													
Prepare Construction Plans & Specifications			****	****											
Select Contractors & Vendors						**									
Order Materials and Schedule Construction Activity						***									
Construct Full Scale Pilot System						**** O	**** N	**** D	**** J	**** F	**** M				
Start-up and Optimize Full - Scale System									****	****	****	**** A			
On-Going Operations											****	****	****	****	****

* Numbers denote months after final Epd approval

FIGURES



REFERENCES

EMCON SOUTHEAST DWG #103d
PROJECT NO. 2040.022.94

ZIMTECH FIELD NOTES (01/15/97)

BONNELL DWG #F-N-0000305-95 RF
(06-02-87)

LEGEND

SWMU #7	ACCUMULATION TANK WASTE SOLVENT
SWMU #46	SOLVENT TANK FARM AREA
●	VAPOR POINT LOCATION (VP-)
⊠	TEST WELL LOCATION (TW-)

GRAPHIC SCALE

40 20 0 20 40

(IN FEET)

1 inch = 40 ft.

SITE FEATURES ARE APPROXIMATE

FIGURE 2

TEST WELL & VAPOR POINT LOCATIONS
The William L Bonnell Company
25 Bonnell Street
Newnan, Georgia 30264

© ZIMMERMAN TECHNICAL SERVICES, INC

02/23/97	96011102	
DRAWN BY: ATZ	CHECKED BY: ATZ	APPROVED:

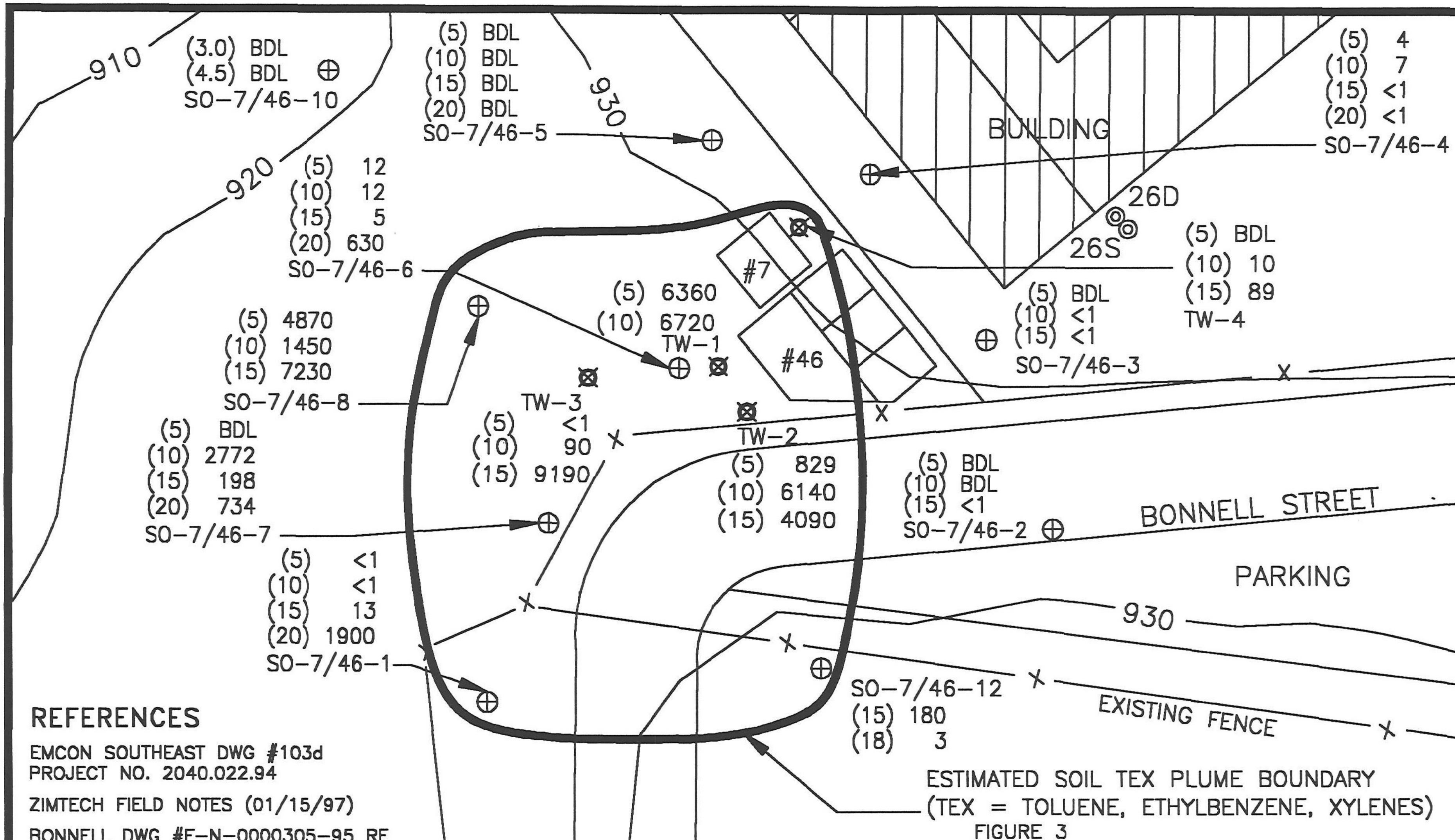


FIGURE 3

REFERENCES

EMCON SOUTHEAST DWG #103d
PROJECT NO. 2040.022.94

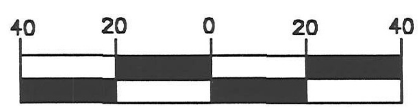
ZIMTECH FIELD NOTES (01/15/97)

BONNELL DWG #F-N-0000305-95 RF
(06-02-87)

LEGEND

SWMU #7	ACCUMULATION TANK WASTE SOLVENT
SWMU #46	SOLVENT TANK FARM AREA
⊕	SOIL BORING LOCATION
⊠	TEST WELL LOCATION (TW)
(15) 9190	(DEPTH BGS) TOTAL TEX, PPM

GRAPHIC SCALE



(IN FEET)

1 inch = 40 ft.

SITE FEATURES ARE APPROXIMATE

SOIL TEX PLUME BOUNDARY The William L Bonnell Company 25 Bonnell Street Newnan, Georgia 30264		
© ZIMMERMAN TECHNICAL SERVICES, INC		
02/23/97	96011103	
DRAWN BY: ATZ	CHECKED BY: ATZ	APPROVED:

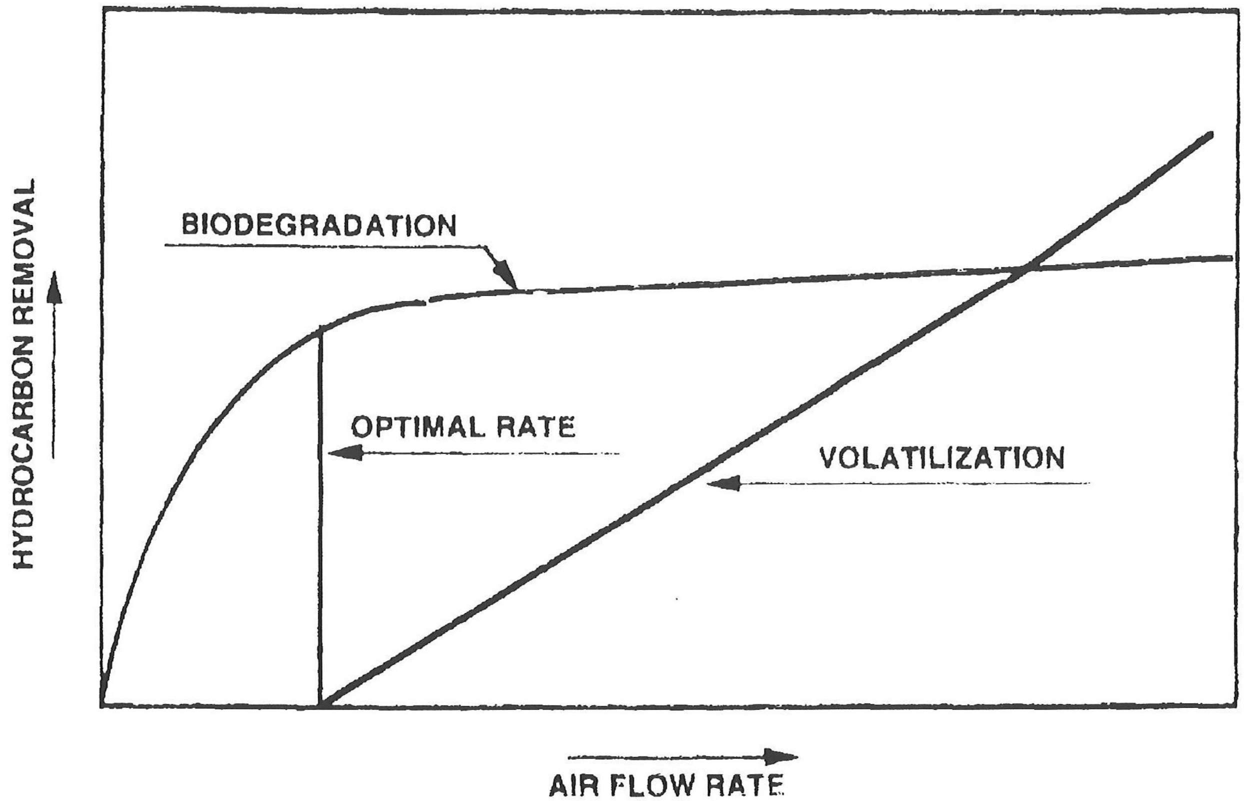


FIGURE 4. Effect of pressure venting flow rate on hydrocarbon removal for biodegradation versus volatilization (USEPA, 1995)

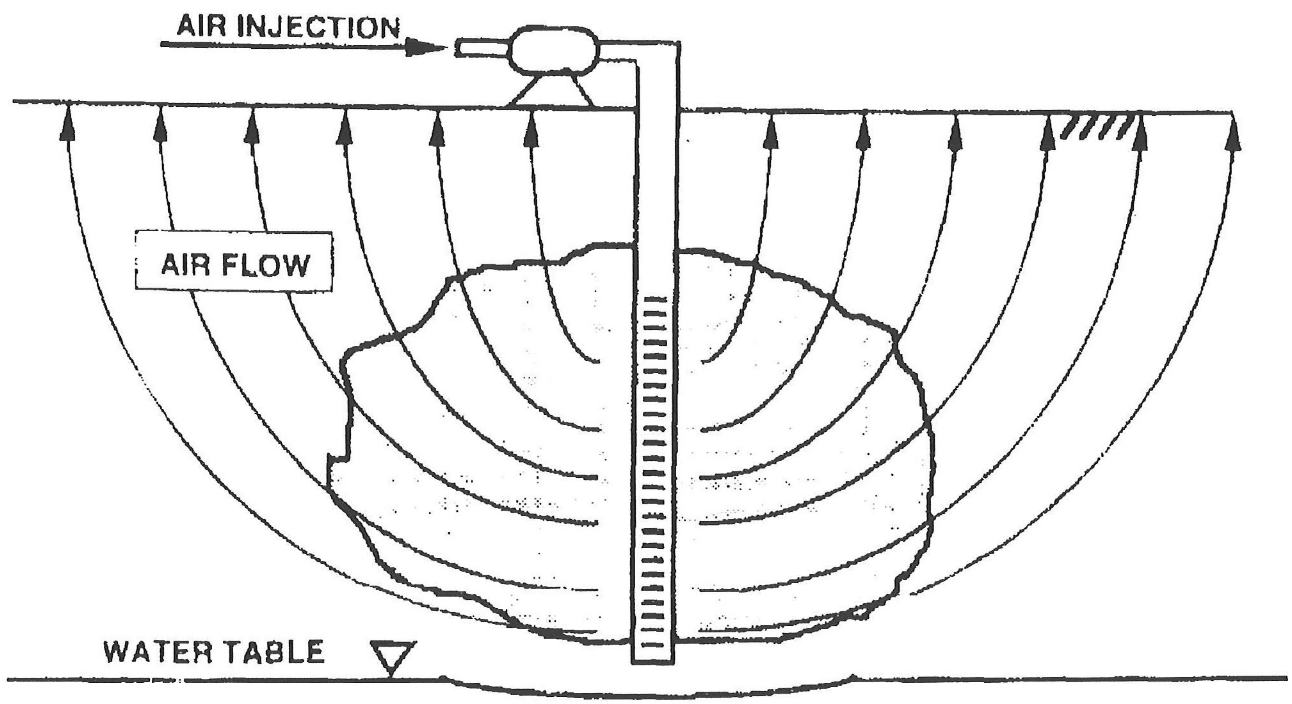
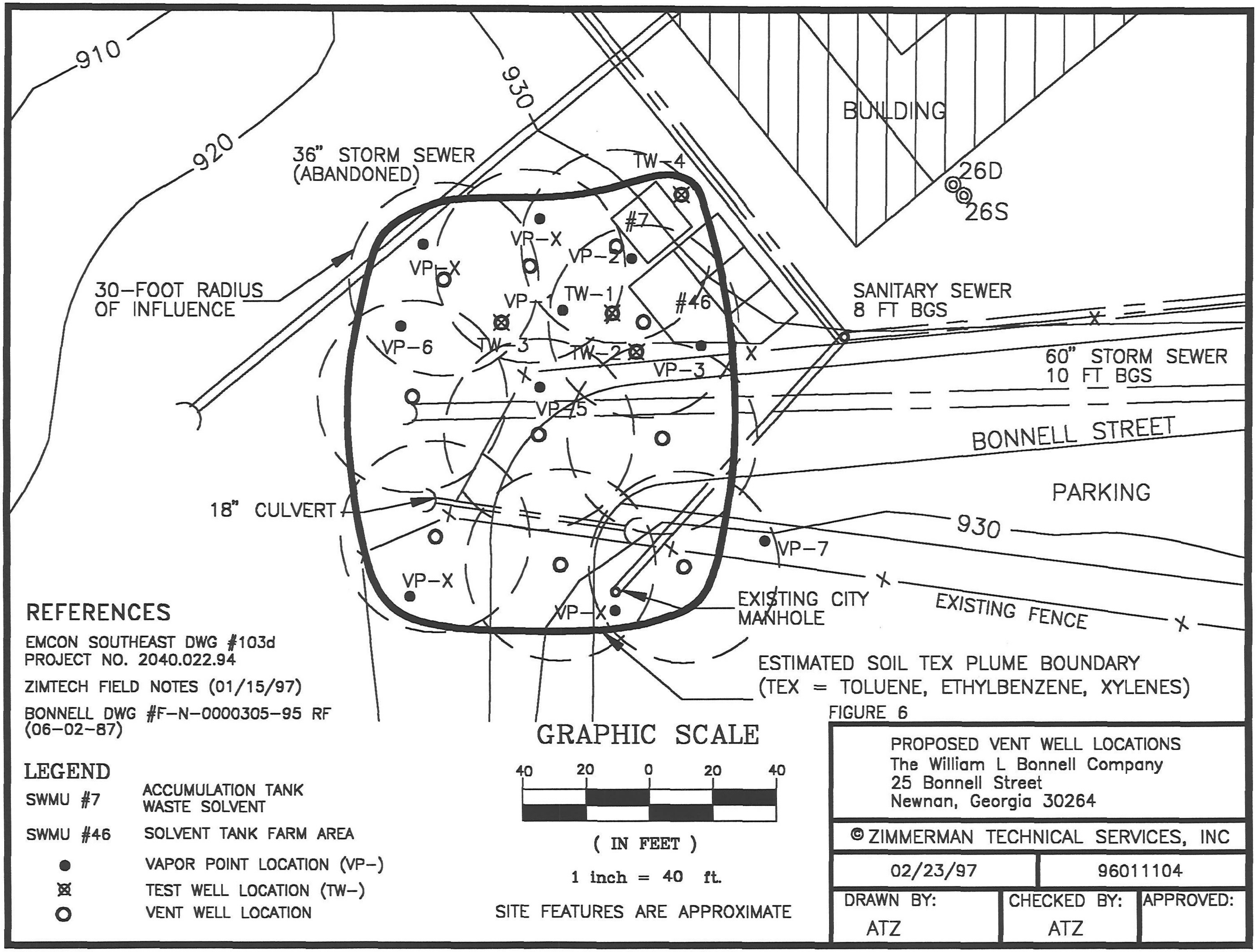


FIGURE 5. Providing atmospheric oxygen by pressure venting to create expanded bioreactor, depress the water table and reduce emissions of VOCs (Cookson, 1995)


910
920
930
36" STORM SEWER (ABANDONED)
BUILDING
26D
26S
TW-4
#7
VR-X
VP-2
VP-X
30-FOOT RADIUS OF INFLUENCE
VP-1
TW-1
#46
SANITARY SEWER 8 FT BGS
VP-6
TW-3
TW-2
VP-3
60" STORM SEWER 10 FT BGS
VP-5
BONNELL STREET
PARKING
18" CULVERT
VP-7
VP-X
VP-X
EXISTING CITY MANHOLE
EXISTING FENCE
ESTIMATED SOIL TEX PLUME BOUNDARY
(TEX = TOLUENE, ETHYLBENZENE, XYLENES)
FIGURE 6
REFERENCES
EMCON SOUTHEAST DWG #103d
PROJECT NO. 2040.022.94
ZIMTECH FIELD NOTES (01/15/97)
BONNELL DWG #F-N-0000305-95 RF
(06-02-87)
LEGEND
SWMU #7 ACCUMULATION TANK WASTE SOLVENT
SWMU #46 SOLVENT TANK FARM AREA
VAPOR POINT LOCATION (VP-)
TEST WELL LOCATION (TW-)
VENT WELL LOCATION
GRAPHIC SCALE
40 20 0 20 40
(IN FEET)
1 inch = 40 ft.
SITE FEATURES ARE APPROXIMATE
PROPOSED VENT WELL LOCATIONS
The William L Bonnell Company
25 Bonnell Street
Newnan, Georgia 30264
© ZIMMERMAN TECHNICAL SERVICES, INC
02/23/97
96011104
DRAWN BY: ATZ
CHECKED BY: ATZ
APPROVED:

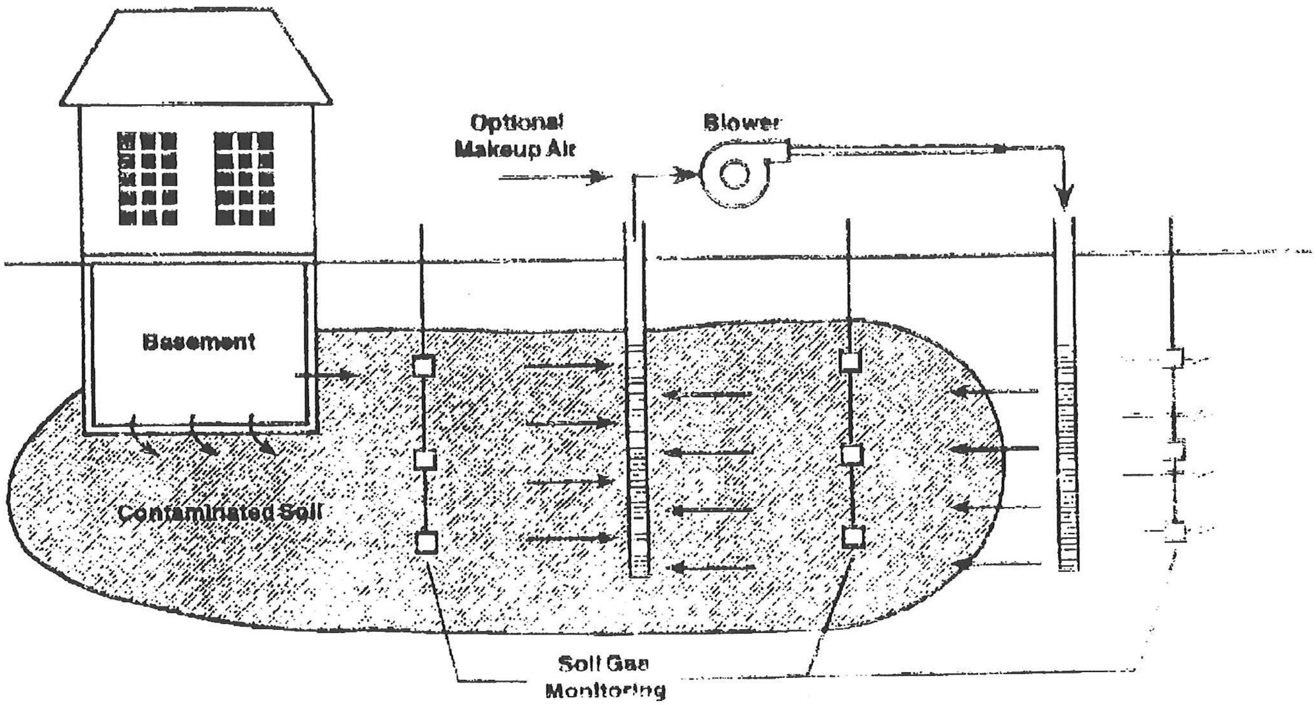


FIGURE 7. Schematic of soil venting recirculation for in-situ treatment of off-gas vapors (USEPA, 1995)

APPENDIX A

SOIL BORING LOGS AND TEST WELL CONSTRUCTION DIAGRAMS

TEST BORING FIELD REPORT

Project Name: The William L Bonnell Co.
Field Supervisor: A.T. Zimmerman, P.E.
Date: January 13, 1997
Ground Surface Elevation: ca. 930 ft. MSL
Water Level: none
Drilling Method: 3-inch hand auger

Project No.: 96-0111
Boring No.: VP-7
Weather: partly sunny, (30's)

DEPTH (ft)		SOIL STRATA DESCRIPTION AND REMARKS	LAB SAMPLE TIME
FROM	TO		
4.5	5.0	Orange-brown, silty, f-m SAND	NS
		Boring Terminated	NS
NS - not sampled MSL - elevation above mean sea level - referenced to 1929 National Geodetic Vertical Datum (NGVD)			

TEST BORING FIELD REPORT

Project Name: The William L Bonnell Co.
Field Supervisor: A.T. Zimmerman, P.E.
Date: January 13, 1997
Ground Surface Elevation: ca. 927 ft. MSL
Water Level: 12.3 ft BGS after 48 hours
Drilling Method: 4.25-inch OD continuous-flight solid-stem auger

Project No.: 96-0111
Boring No.: TW-1
Weather: partly sunny, (30's)

DEPTH (ft)		SOIL STRATA DESCRIPTION AND REMARKS	SOIL SAMPLE TIME
FROM	TO		
4.5	5.0	Brown fill, f. sandy SILT. Strong VOC odor	1210
9.5	10.0	Dark-gray, micaceous saprolite, f. sandy SILT. Strong VOC odor; degraded	1220
13.0	13.0	Water table at time of boring	1230
13.0	15.0	Below water table - no sample recovery for VOCs. Sample collected for plate counts and nutrients from lead auger. Dark-gray, f. sandy SILT. Strong VOC odor.	1240
		Boring Terminated	
NS - not sampled BGS - below ground surface MSL - elevation above mean sea level - referenced to 1929 National Geodetic Vertical Datum (NGVD)			

TEST BORING FIELD REPORT

Project Name: The William L Bonnell Co.
Field Supervisor: A.T. Zimmerman, P.E.
Date: January 13, 1997
Ground Surface Elevation: ca. 928 ft. MSL
Water Level: 13.4 ft BGS after 48 hours
Drilling Method: 4.25-inch OD continuous-flight solid-stem auger

Project No.: 96-0111
Boring No.: TW-2
Weather: partly sunny, (30's)

DEPTH (ft)		SOIL STRATA DESCRIPTION AND REMARKS	SOIL SAMPLE TIME
FROM	TO		
4.5	5.0	Brown-orange fill, f. sandy SILT with clay. VOC odor.	1445
9.5	10.0	Brown-orange fill, f. sandy SILT and clay, with f.-m. gravel. VOC odor.	1515
14.5	15.0	Saturated, dark-gray and orange, micaceous f. sandy SILT. Strong VOC odor.	1530
		Auger Refusal	
NS - not sampled BGS - below ground surface MSL - elevation above mean sea level - referenced to 1929 National Geodetic Vertical Datum (NGVD)			

TEST BORING FIELD REPORT

Project Name: The William L Bonnell Co.
Field Supervisor: A.T. Zimmerman, P.E.
Date: January 13, 1997
Ground Surface Elevation: ca. 924 ft. MSL
Water Level: 11.4 ft BGS after 48 hours
Drilling Method: 4.25-inch OD continuous-flight solid-stem auger

Project No.: 96-0111
Boring No.: TW-3
Weather: partly sunny, (30's)

DEPTH (ft)		SOIL STRATA DESCRIPTION AND REMARKS	SOIL SAMPLE TIME
FROM	TO		
4.5	5.0	Brown fill, f. sandy SILT.	0850
9.5	10.0	Brown fill, f. sandy SILT. Sewage odor.	0915
13.0	13.0	Water table at time of boring	1000
13.0	15.0	Saturated, dark-gray, silty f.-m. SAND. Strong VOC odor.	1010
		Boring Terminated	
NS - not sampled BGS - below ground surface MSL - elevation above mean sea level - referenced to 1929 National Geodetic Vertical Datum (NGVD)			

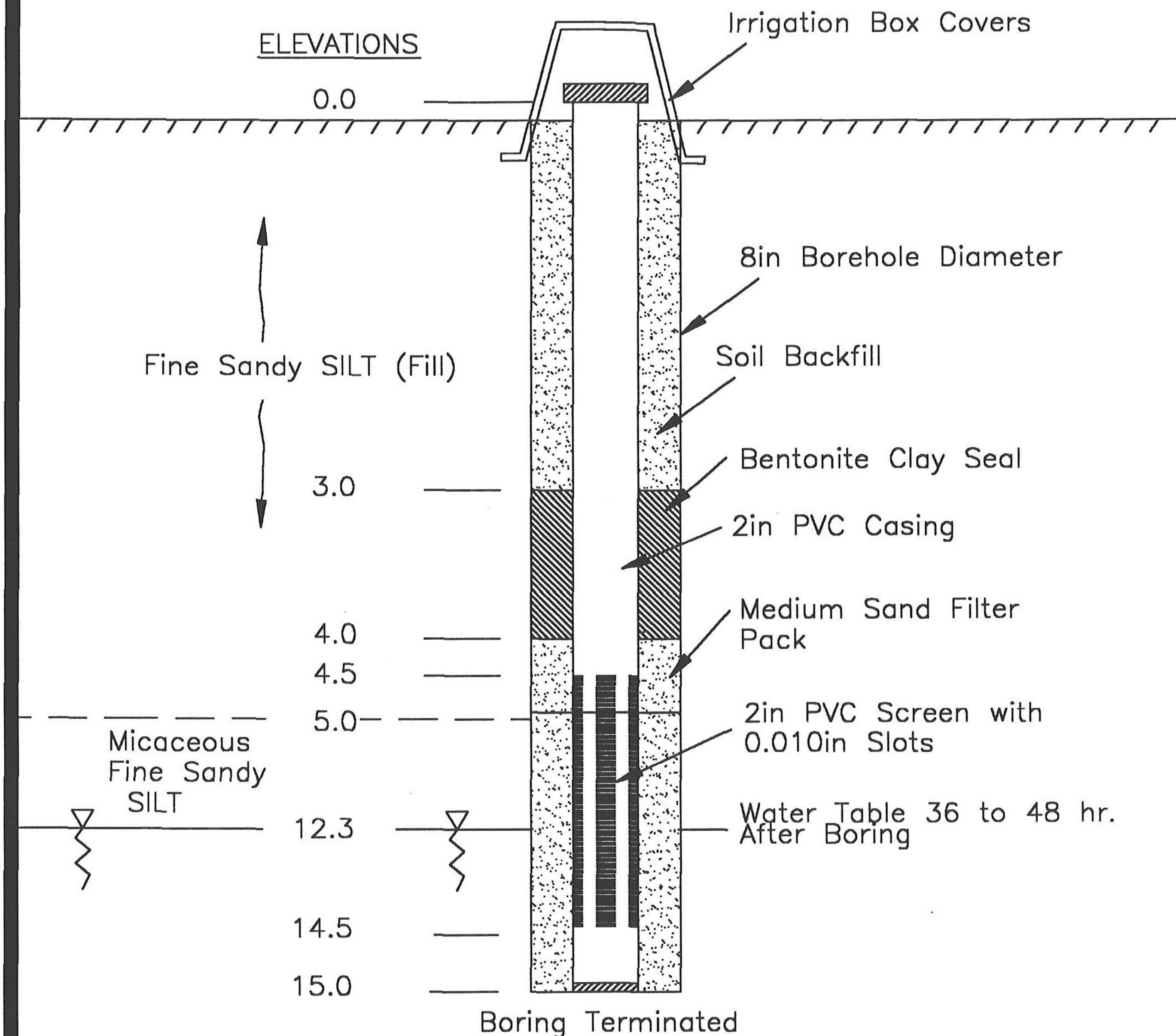
TEST BORING FIELD REPORT

Project Name: The William L Bonnell Co. | Project No.: 96-0111
Field Supervisor: A.T. Zimmerman, P.E. | Boring No.: TW-4
Date: January 13, 1997 | Weather: partly sunny, (30's)
Ground Surface Elevation: ca. 931 ft. MSL
Water Level: 15.0 ft BGS after 48 hours
Drilling Method: 4.25-inch OD continuous-flight solid-stem auger

DEPTH (ft)		SOIL STRATA DESCRIPTION AND REMARKS	SOIL SAMPLE TIME
FROM	TO		
4.5	5.0	Brown-orange fill, f. sandy SILT	1650
9.5	10.0	Brown-orange and dark-gray fill, f. sandy SILT. VOC odor.	1705
14.5	15.0	Saturated, dark-gray/black and orange, micaceous f. sandy SILT with fibrous material and metal shavings. degraded organics odor.	1720
		Boring Terminated	
NS - not sampled BGS - below ground surface MSL - elevation above mean sea level - referenced to 1929 National Geodetic Vertical Datum (NGVD)			

TEST WELL, TW–1
Constructed 01/13/97
A.T. Zimmerman, P.E. – Engineer

THE WILLIAM L BONNELL COMPANY
25 Bonnell Street
Newnan, Georgia 30264



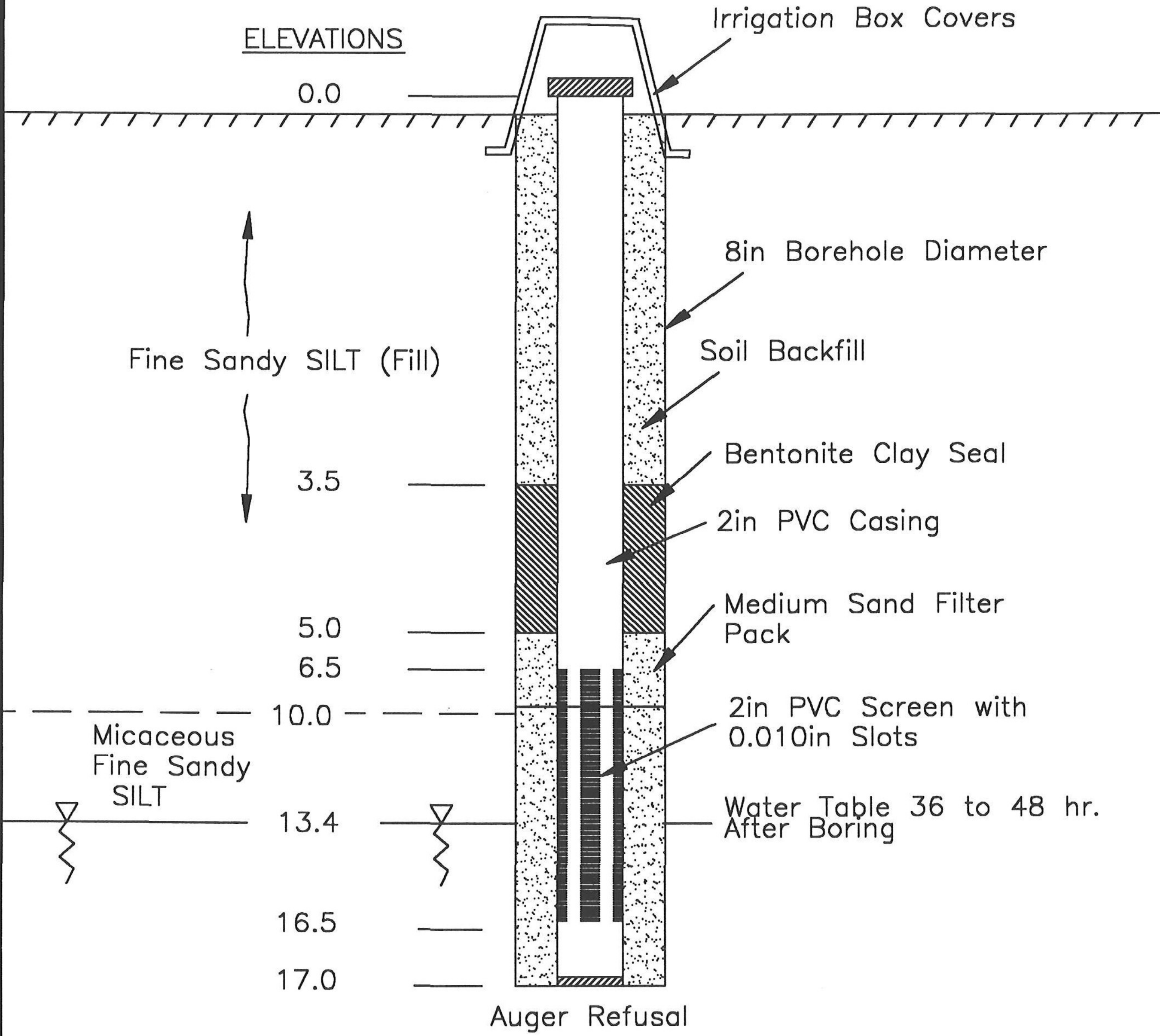
ZIMMERMAN TECHNICAL SERVICES, Inc.		
02/14/97	96011105	
Drawn: ATZ	Checked: ATZ	Approved:

DRAWING NOT TO SCALE

Elevations relative to ground surface (BGS)

TEST WELL, TW-2
Constructed 01/13/97
A.T. Zimmerman, P.E. – Engineer

THE WILLIAM L BONNELL COMPANY
25 Bonnell Street
Newnan, Georgia 30264



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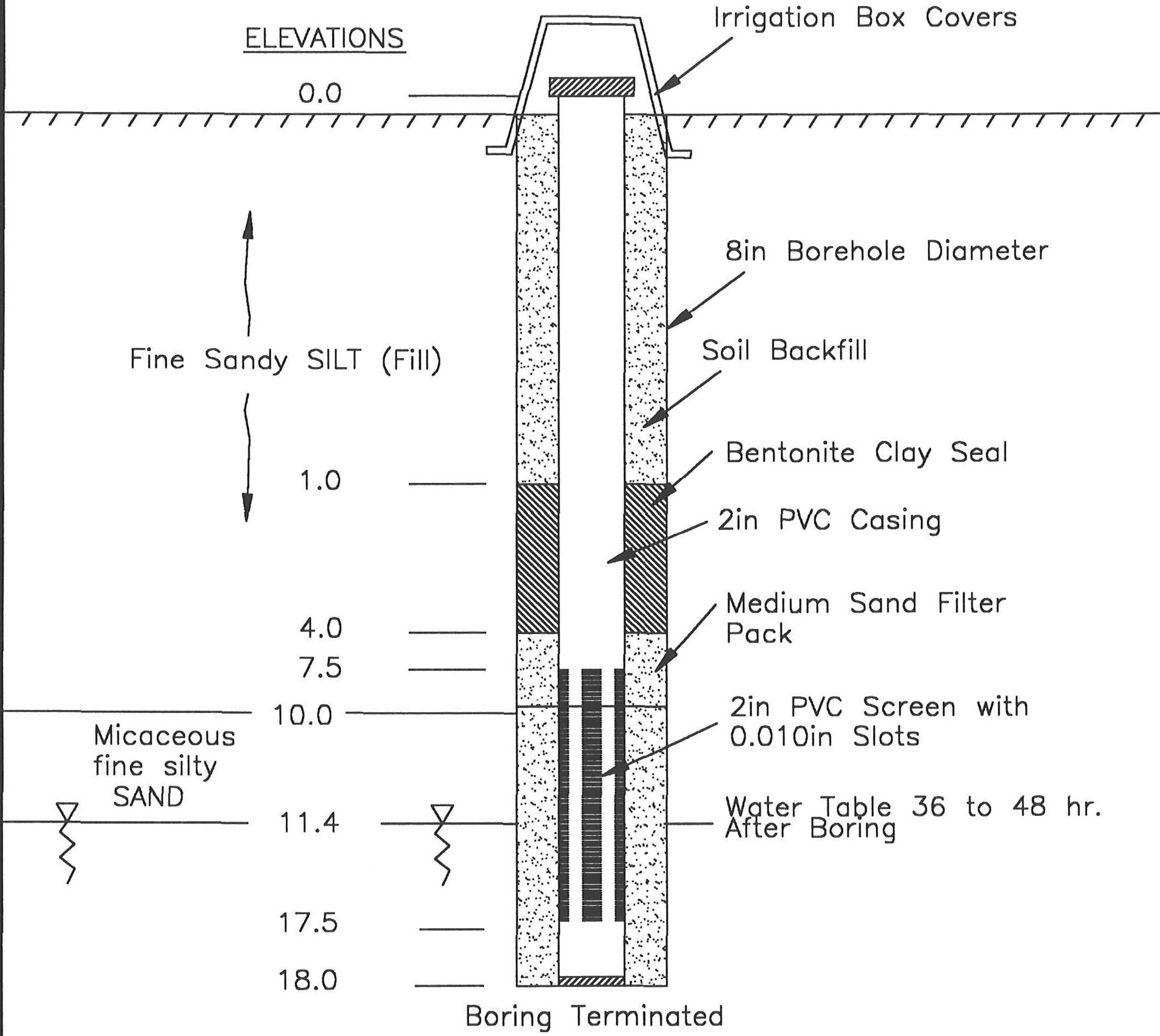
02/14/97	96011106	
Drawn: ATZ	Checked: ATZ	Approved:

DRAWING NOT TO SCALE

Elevations relative to ground surface (BGS)

TEST WELL, TW-3
Constructed 01/13/97
A.T. Zimmerman, P.E. – Engineer

THE WILLIAM L BONNELL COMPANY
25 Bonnell Street
Newnan, Georgia 30264



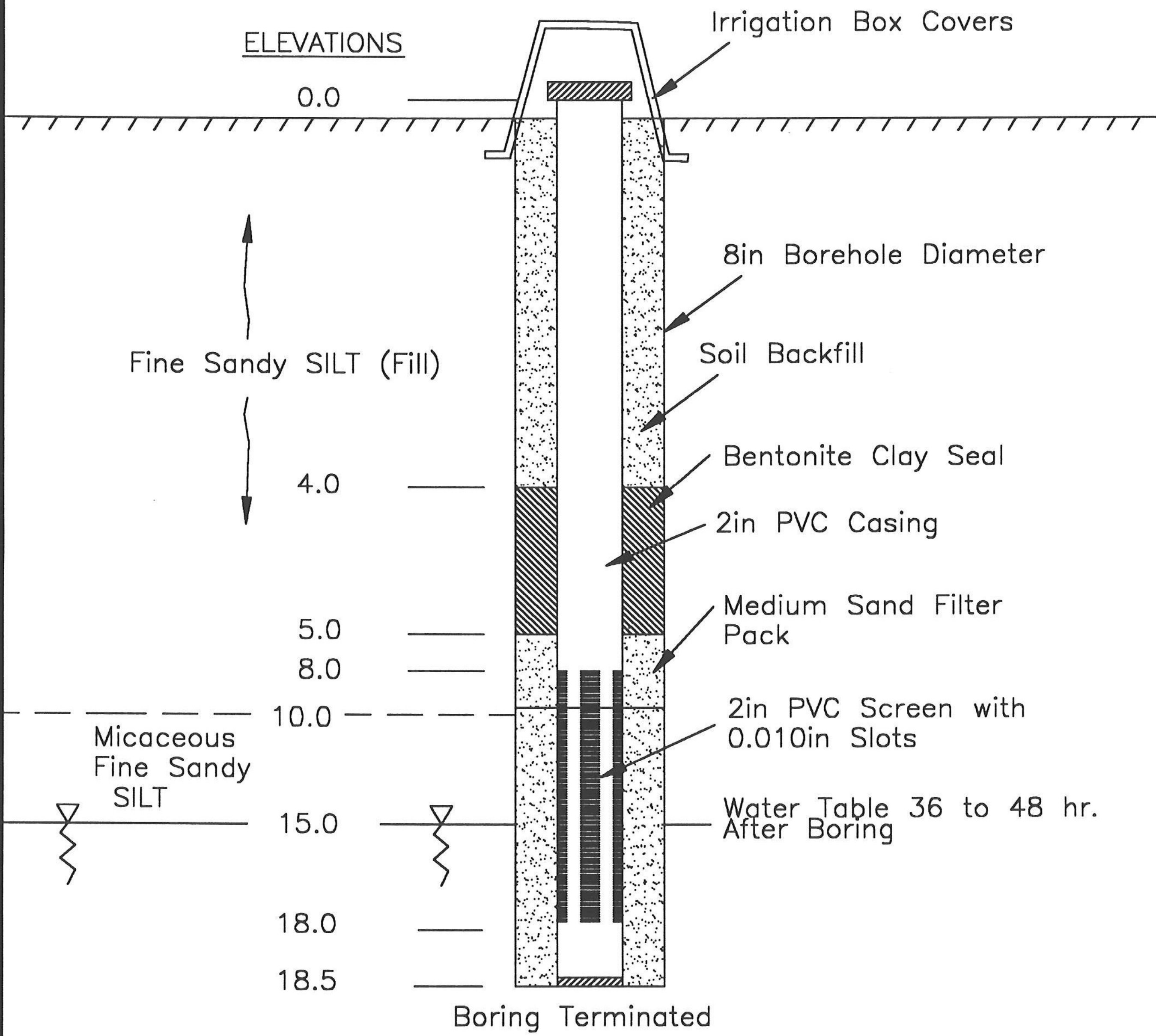
ZIMMERMAN TECHNICAL SERVICES, Inc.		
02/14/97	96011107	
Drawn: ATZ	Checked: ATZ	Approved:

DRAWING NOT TO SCALE

Elevations relative to ground surface (BGS)

TEST WELL, TW-4
Constructed 01/13/97
A.T. Zimmerman, P.E. - Engineer

THE WILLIAM L BONNELL COMPANY
25 Bonnell Street
Newnan, Georgia 30264



ZIMMERMAN TECHNICAL SERVICES, Inc.		
02/14/97	96011108	
Drawn: ATZ	Checked: ATZ	Approved:

DRAWING NOT TO SCALE

Elevations relative to ground surface (BGS)

APPENDIX B
CERTIFIED LABORATORY RESULTS

ASI

ANALYTICAL SERVICES, INC.

ENVIRONMENTAL MONITORING & LABORATORY ANALYSIS

110 TECHNOLOGY PARKWAY • NORCROSS, GA 30092
(770) 734-4200 • FAX (770) 734-4201

LABORATORY REPORT

William L. Bonnell Co. Inc.
PO Box 428
Newnan, GA 30264

January 29, 1997

P.O. No. 226868-OP

Attention: Mr. Terry Snell

Report No. 79303-4

Sample Description

Soil, grab, Bonnell, Project #96-0111, TW-1-5, 01/13/97, 12:10, received 01/14/97

RESULTS

	Result	Detection Limit
pH (laboratory)(EPA 9045)	6.05	-
Metals	(mg/kg)	(mg/kg)
Total Chromium (Cr)(EPA 6010)	24	1.0
Volatile Organics (EPA 8260)	(ug/kg)	(ug/kg)
Ethylbenzene	860000	10000
Tetrachloroethene	BDL	10000
Toluene	1300000	10000
Trichloroethene	BDL	10000
Xylenes (total)	4200000	10000

BDL - Below Detection Limit

Respectfully submitted,

Project Manager

Adrian Turk

Quality Assurance

cc: Mr. Andy Zimmerman

ASI

ANALYTICAL SERVICES, INC.

ENVIRONMENTAL MONITORING & LABORATORY ANALYSIS

110 TECHNOLOGY PARKWAY • NORCROSS, GA 30092
(770) 734-4200 • FAX (770) 734-4201

LABORATORY REPORT

William L. Bonnell Co. Inc.
PO Box 428
Newnan, GA 30264

January 29, 1997

P.O. No. 226868-OP

Attention: Mr. Terry Snell

Report No. 79303-5

Sample Description

Soil, grab, Bonnell, Project #96-0111, TW-1-10, 01/13/97, 12:20, received 01/14/97

RESULTS

	Result	Detection Limit
pH (laboratory)(EPA 9045)	5.55	-
Heterotrophic Plate Count (no/gm)(SM 9215 B)	350000	100
Metals	(mg/kg)	(mg/kg)
Total Chromium (Cr)(EPA 6010)	30	1.0
Volatile Organics (EPA 8260)	(ug/kg)	(ug/kg)
Ethylbenzene	920000	10000
Tetrachloroethene	BDL	10000
Toluene	1100000	10000
Trichloroethene	BDL	10000
Xylenes (total)	4700000	10000

BDL - Below Detection Limit

cc: Mr. Andy Zimmerman

Respectfully submitted,

Project Manager

Adrian Trik

Quality Assurance

ASI

ANALYTICAL SERVICES, INC.

ENVIRONMENTAL MONITORING & LABORATORY ANALYSIS

110 TECHNOLOGY PARKWAY • NORCROSS, GA 30092
(770) 734-4200 • FAX (770) 734-4201

LABORATORY REPORT

William L. Bonnell Co. Inc.
PO Box 428
Newnan, GA 30264

January 29, 1997

P.O. No. 226868-OP

Attention: Mr. Terry Snell

Report No. 79303-6

Sample Description

Soil, grab, Bonnell, Project #96-0111, TW-1-15, 01/13/97, 12:40, received 01/14/97

RESULTS

	Result	Detection Limit
Heterotrophic Plate Count (no/gm)(SM 9215 B).	350000	100

Respectfully submitted,

cc: Mr. Andy Zimmerman

Project Manager

Quality Assurance

ASI

ANALYTICAL SERVICES, INC.

ENVIRONMENTAL MONITORING & LABORATORY ANALYSIS

110 TECHNOLOGY PARKWAY • NORCROSS, GA 30092
(770) 734-4200 • FAX (770) 734-4201

LABORATORY REPORT

William L. Bonnell Co. Inc.
PO Box 428
Newnan, GA 30264

January 29, 1997

P.O. No. 226868-OP

Attention: Mr. Terry Snell

Report No. 79303-7

Sample Description

Soil, grab, Bonnell, Project #96-0111, TW-2-5, 01/13/97, 14:45, received 01/14/97

RESULTS

	Result	Detection Limit
pH (laboratory)(EPA 9045)	6.32	-
Metals	(mg/kg)	(mg/kg)
Total Chromium (Cr)(EPA 6010)	16	1.0
Volatile Organics (EPA 8260)	(ug/kg)	(ug/kg)
Ethylbenzene	130000	10000
Tetrachloroethene	BDL	10000
Toluene	19000	10000
Trichloroethene	BDL	10000
Xylenes (total)	680000	10000

BDL - Below Detection Limit

Respectfully submitted,

cc: Mr. Andy Zimmerman

Project Manager

Adrea N Turk

Quality Assurance

ASI

ANALYTICAL SERVICES, INC.

ENVIRONMENTAL MONITORING & LABORATORY ANALYSIS

110 TECHNOLOGY PARKWAY • NORCROSS, GA 30092
(770) 734-4200 • FAX (770) 734-4201

LABORATORY REPORT

William L. Bonnell Co. Inc.
PO Box 428
Newnan, GA 30264

January 29, 1997

P.O. No. 226868-OP

Attention: Mr. Terry Snell

Report No. 79303-8

Sample Description

Soil, grab, Bonnell, Project #96-0111, TW-2-10, 01/13/97, 15:15, received 01/14/97

RESULTS

	Result	Detection Limit
pH (laboratory)(EPA 9045)	5.95	-
Metals	(mg/kg)	(mg/kg)
Total Chromium (Cr)(EPA 6010)	28	1.0
Volatile Organics (EPA 8260)	(ug/kg)	(ug/kg)
Ethylbenzene	740000	10000
Tetrachloroethene	BDL	10000
Toluene	1800000	10000
Trichloroethene	BDL	10000
Xylenes (total)	3600000	10000

BDL - Below Detection Limit

Respectfully submitted,

cc: Mr. Andy Zimmerman

Project Manager

Quality Assurance

ASI

ANALYTICAL SERVICES, INC.

ENVIRONMENTAL MONITORING & LABORATORY ANALYSIS

110 TECHNOLOGY PARKWAY • NORCROSS, GA 30092
(770) 734-4200 • FAX (770) 734-4201

LABORATORY REPORT

William L. Bonnell Co. Inc.
PO Box 428
Newnan, GA 30264

January 29, 1997

P.O. No. 226868-OP

Attention: Mr. Terry Snell

Report No. 79303-9

Sample Description

Soil, grab, Bonnell, Project #96-0111, TW-2-15, 01/13/97, 15:30, received 01/14/97

RESULTS

	Result	Detection Limit
pH (laboratory)(EPA 9045)	6.56	-
Metals	(mg/kg)	(mg/kg)
Total Chromium (Cr)(EPA 6010)	25	1.0
Volatile Organics (EPA 8260)	(ug/kg)	(ug/kg)
Ethylbenzene	490000	10000
Tetrachloroethene	BDL	10000
Toluene	1200000	10000
Trichloroethene	BDL	10000
Xylenes (total)	2400000	10000

BDL - Below Detection Limit

Respectfully submitted,

cc: Mr. Andy Zimmerman

Project Manager

Adrea N Tuck

Quality Assurance

ASI

ANALYTICAL SERVICES, INC.

ENVIRONMENTAL MONITORING & LABORATORY ANALYSIS

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(770) 734-4200 • FAX (770) 734-4201

LABORATORY REPORT

William L. Bonnell Co. Inc.
PO Box 428
Newnan, GA 30264

January 29, 1997

P.O. No. 226868-OP

Attention: Mr. Terry Snell

Report No. 79303-1

Sample Description

Soil, grab, Bonnell, Project #96-0111, TW-3-5, 01/13/97, 08:50, received 01/14/97

RESULTS

	Result	Detection Limit
pH (laboratory)(EPA 9045)	6.00	
Metals	(mg/kg)	(mg/kg)
Total Chromium (Cr)(EPA 6010)	31	1.0
Volatile Organics (EPA 8260)	(ug/kg)	(ug/kg)
Ethylbenzene	BDL	5
Tetrachloroethene	BDL	5
Toluene	20	5
Trichloroethene	BDL	5
Xylenes (total)	44	5

BDL - Below Detection Limit

Respectfully submitted,

cc: Mr. Andy Zimmerman

Project Manager

Adrea N. Tuck
Quality Assurance

ASI

ANALYTICAL SERVICES, INC.

ENVIRONMENTAL MONITORING & LABORATORY ANALYSIS

110 TECHNOLOGY PARKWAY • NORCROSS, GA 30092
(770) 734-4200 • FAX (770) 734-4201

LABORATORY REPORT

William L. Bonnell Co. Inc.
PO Box 428
Newnan, GA 30264

January 29, 1997

P.O. No. 226868-OP

Attention: Mr. Terry Snell

Report No. 79303-2

Sample Description

Soil, grab, Bonnell, Project #96-0111, TW-3-10, 01/13/97, 09:15, received 01/14/97

RESULTS

	Result	Detection Limit
pH (laboratory)(EPA 9045)	7.16	-
Metals	(mg/kg)	(mg/kg)
Total Chromium (Cr)(EPA 6010)	58	1.0
Volatile Organics (EPA 8260)	(ug/kg)	(ug/kg)
Ethylbenzene	5300	2000
Tetrachloroethene	BDL	2000
Toluene	58000	2000
Trichloroethene	BDL	2000
Xylenes (total)	27000	2000

BDL - Below Detection Limit

Respectfully submitted,

cc: Mr. Andy Zimmerman

Project Manager

Quality Assurance

ASI

ANALYTICAL SERVICES, INC.

ENVIRONMENTAL MONITORING & LABORATORY ANALYSIS

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(770) 734-4200 • FAX (770) 734-4201

LABORATORY REPORT

William L. Bonnell Co. Inc.
PO Box 428
Newnan, GA 30264

January 29, 1997

P.O. No. 226868-OP

Attention: Mr. Terry Snell

Report No. 79303-3

Sample Description

Soil, grab, Bonnell, Project #96-0111, TW-3-15, 01/13/97, 10:10, received 01/14/97

RESULTS

	Result	Detection Limit
pH (laboratory)(EPA 9045)	6.67	-
Metals	(mg/kg)	(mg/kg)
Total Chromium (Cr)(EPA 6010)	16	1.0
Volatile Organics (EPA 8260)	(ug/kg)	(ug/kg)
Ethylbenzene	590000	10000
Tetrachloroethene	BDL	10000
Toluene	5700000	10000
Trichloroethene	BDL	10000
Xylenes (total)	2900000	10000

BDL - Below Detection Limit

Respectfully submitted,

cc: Mr. Andy Zimmerman

Project Manager

Adrean Tuck

Quality Assurance

ASI

ANALYTICAL SERVICES, INC.

ENVIRONMENTAL MONITORING & LABORATORY ANALYSIS

110 TECHNOLOGY PARKWAY • NORCROSS, GA 30092
(770) 734-4200 • FAX (770) 734-4201

LABORATORY REPORT

William L. Bonnell Co. Inc.
PO Box 428
Newnan, GA 30264

January 29, 1997

P.O. No. 226868-OP

Attention: Mr. Terry Snell

Report No. 79303-10

Sample Description

Soil, grab, Bonnell, Project #96-0111, TW-4-5, 01/13/97, 16:50, received 01/14/97

RESULTS

	Result	Detection Limit
pH (laboratory)(EPA 9045)	7.20	-
Metals	(mg/kg)	(mg/kg)
Total Chromium (Cr)(EPA 6010)	24	1.0
Volatile Organics (EPA 8260)	(ug/kg)	(ug/kg)
Ethylbenzene	BDL	5
Tetrachloroethene	BDL	5
Toluene	BDL	5
Trichloroethene	BDL	5
Xylenes (total)	BDL	5

BDL - Below Detection Limit

Respectfully submitted,

cc: Mr. Andy Zimmerman

Project Manager

Andrea N. Tuck

Quality Assurance

ASI

ANALYTICAL SERVICES, INC.

ENVIRONMENTAL MONITORING & LABORATORY ANALYSIS

110 TECHNOLOGY PARKWAY • NORCROSS, GA 30092
(770) 734-4200 • FAX (770) 734-4201

LABORATORY REPORT

William L. Bonnell Co. Inc.
PO Box 428
Newnan, GA 30264

January 29, 1997

P.O. No. 226868-OP

Attention: Mr. Terry Snell

Report No. 79303-11

Sample Description

Soil, grab, Bonnell, Project #96-0111, TW-4-10, 01/13/97, 17:05, received 01/14/97

RESULTS

	Result	Detection Limit
pH (laboratory) (EPA 9045)	7.23	-
Metals	(mg/kg)	(mg/kg)
Total Chromium (Cr) (EPA 6010)	27	1.0
Volatile Organics (EPA 8260)	(ug/kg)	(ug/kg)
Ethylbenzene	940	500
Tetrachloroethene	BDL	500
Toluene	1400	500
Trichloroethene	BDL	500
Xylenes (total)	7800	500

BDL - Below Detection Limit

Respectfully submitted,

cc: Mr. Andy Zimmerman

Project Manager

Adrea N Turk

Quality Assurance

ASI

ANALYTICAL SERVICES, INC.

ENVIRONMENTAL MONITORING & LABORATORY ANALYSIS

110 TECHNOLOGY PARKWAY • NORCROSS, GA 30092
(770) 734-4200 • FAX (770) 734-4201

LABORATORY REPORT

William L. Bonnell Co. Inc.
PO Box 428
Newnan, GA 30264

January 29, 1997

P.O. No. 226868-OP

Attention: Mr. Terry Snell

Report No. 79303-12

Sample Description

Soil, grab, Bonnell, Project #96-0111, TW-4-15, 01/13/97, 17:20, received 01/14/97

RESULTS

	Result	Detection Limit
pH (laboratory)(EPA 9045)	7.24	-
Metals	(mg/kg)	(mg/kg)
Total Chromium (Cr)(EPA 6010)	25	1.0
Volatile Organics (EPA 8260)	(ug/kg)	(ug/kg)
Ethylbenzene	51000	2000
Tetrachloroethene	BDL	2000
Toluene	BDL	2000
Trichloroethene	BDL	2000
Xylenes (total)	36000	2000

BDL - Below Detection Limit

Respectfully submitted,

cc: Mr. Andy Zimmerman

Project Manager

Quality Assurance

ASI

ANALYTICAL SERVICES, INC.

ENVIRONMENTAL MONITORING & LABORATORY ANALYSIS

110 TECHNOLOGY PARKWAY • NORCROSS, GA 30092
(770) 734-4200 • FAX (770) 734-4201

LABORATORY REPORT

William L. Bonnell Co. Inc.
PO Box 428
Newnan, GA 30264

January 29, 1997

P.O. No. 226868-OP

Attention: Mr. Terry Snell

Report No. 79303-13

Sample Description

Soil, grab, Bonnell, Project #96-0111, VP-7-5, 01/13/97, 18:00, received 01/14/97

RESULTS

	Result	Detection Limit
pH (laboratory)(EPA 9045)	5.48	-
Heterotrophic Plate Count (no/gm)(SM 9215 B)	100000	100
Metals	(mg/kg)	(mg/kg)
Total Chromium (Cr)(EPA 6010)	30	1.0
Volatile Organics (EPA 8260)	(ug/kg)	(ug/kg)
Ethylbenzene	BDL	5
Tetrachloroethene	BDL	5
Toluene	BDL	5
Trichloroethene	BDL	5
Xylenes (total)	BDL	5

BDL - Below Detection Limit

cc: Mr. Andy Zimmerman

Respectfully submitted,

Project Manager

Quality Assurance

MicroMacro
Analytical Laboratories

Micro Macro International, Inc
[illegible] Blvd Suite 108 Athens GA [illegible] USA
Telephone [illegible] Fax 706 / 548 4891

SOIL ANALYSIS

ZimTech
Andy Zimmerman
3595 Canton Rd Ste A9-271
Marietta, GA 30066

Date Received: 01/15/97
Date Completed: 01/21/97

Phone: 770-516-5902
Fax: 770-516-1097

Lab ID:70068 3

Sample Description: VP-7-5 BACKGROUND SOIL

	ppm	Low	Medium	High	Sufficiency Ranges		
Nitrate (NO3-N)	0.62	X			8.00	-	100.00
Ammonium (NH4-N)	0.00	X			5.00	-	35.00
Phosphorus (P)	0.00	X			30.00	-	100.00
Potassium (K)	68.99	X			150.00	-	350.00
Calcium (Ca)	20.91	X			400.00	-	2000.00
Magnesium (Mg)	115.69		X		100.00	-	300.00
Iron (Fe)	228.04			X	5.00	-	50.00
Manganese (Mn)	4.03	X			8.00	-	50.00
Boron (B)	0.17	X			0.50	-	1.00
Copper (Cu)	0.11	X			1.00	-	12.00
Zinc (Zn)	0.56	X			3.00	-	20.00
Molybdenum (Mo)	0.00	X			0.20	-	50.00
Sodium (Na)	15.84		X		1.00	-	60.00
Aluminum (Al)	737.98			X	5.00	-	20.00
pH	3.90	X			5.00	-	7.00

NO3-N, NH4-N, and pH based on a 1:1 0.01M CaCl2 extract, unless otherwise requested.

MicroMacro
Analytical Laboratories

Micro Macro International, Inc
[illegible] Blvd Suite 108 Athens GA 30602 USA
Telephone [illegible] Fax 706 548 4891

SOIL ANALYSIS

ZimTech
Andy Zimmerman
3595 Canton Rd Ste A9-271
Marietta, GA 30066

Date Received: 01/15/97
Date Completed: 01/21/97

Phone: 770-516-5902
Fax: 770-516-1097

Lab ID:70068 2

Sample Description: TW-1-15 SOIL CONTAMINATED W/SOLVENT

	ppm	Low	Medium	High	Sufficiency Ranges
Nitrate (NO3-N)	0.36	X			8.00 - 100.00
Ammonium (NH4-N)	0.00	X			5.00 - 35.00
Phosphorus (P)	10.20	X			30.00 - 100.00
Potassium (K)	85.19	X			150.00 - 350.00
Calcium (Ca)	145.26	X			400.00 - 2000.00
Magnesium (Mg)	52.33	X			100.00 - 300.00
Iron (Fe)	265.19			X	5.00 - 50.00
Manganese (Mn)	88.56			X	8.00 - 50.00
Boron (B)	0.51		X		0.50 - 1.00
Copper (Cu)	0.91	X			1.00 - 12.00
Zinc (Zn)	3.05		X		3.00 - 20.00
Molybdenum (Mo)	0.00	X			0.20 - 50.00
Sodium (Na)	28.94		X		1.00 - 60.00
Aluminum (Al)	844.70			X	5.00 - 20.00
pH	5.30		X		5.00 - 7.00

NO3-N, NH4-N, and pH based on a 1:1 0.01M CaCl2 extract, unless otherwise requested.

MicroMacro
Analytical Laboratories

Micro Macro International, I
[illegible]
[illegible]

SOIL ANALYSIS

ZimTech
Andy Zimmerman
3595 Canton Rd Ste A9-271
Marietta, GA 30066

Date Received: 01/15/97
Date Completed: 01/21/97

Phone: 770-516-5902
Fax: 770-516-1097

Lab ID:70068 1

Sample Description: TW-1-10 SOIL CONTAMINATED W/SOLVENT

	ppm	Low	Medium	High	Sufficiency Ranges
Nitrate (NO3-N)	0.31	X			8.00 - 100.00
Ammonium (NH4-N)	0.00	X			5.00 - 35.00
Phosphorus (P)	0.47	X			30.00 - 100.00
Potassium (K)	69.84	X			150.00 - 350.00
Calcium (Ca)	340.15	X			400.00 - 2000.00
Magnesium (Mg)	54.15	X			100.00 - 300.00
Iron (Fe)	29.09		X		5.00 - 50.00
Manganese (Mn)	76.72			X	8.00 - 50.00
Boron (B)	3.26			X	0.50 - 1.00
Copper (Cu)	0.39	X			1.00 - 12.00
Zinc (Zn)	0.61	X			3.00 - 20.00
Molybdenum (Mo)	0.00	X			0.20 - 50.00
Sodium (Na)	13.25		X		1.00 - 60.00
Aluminum (Al)	615.59			X	5.00 - 20.00
pH	5.20		X		5.00 - 7.00

NO3-N, NH4-N, and pH based on a 1:1 0.01M CaCl2 extract, unless otherwise requested.

APPENDIX C

RADIUS OF INFLUENCE CALCULATIONS AND GRAPHS

PILOT TEST RADIUS OF INFLUENCE
THE WILLIAM L. BONNELL COMPANY, INC.
25 BONNELL STREET
NEWNAN, GEORGIA 30264
February 19, 1997

FIELD DATA

PRESSURE (in-H2O)	LOG-P (in-H2O)	DISTANCE (feet)	ROI INTERCEPT
90	1.954243	0	-1
0.03	-1.52288	15	-1
0.02	-1.69897	30	-1

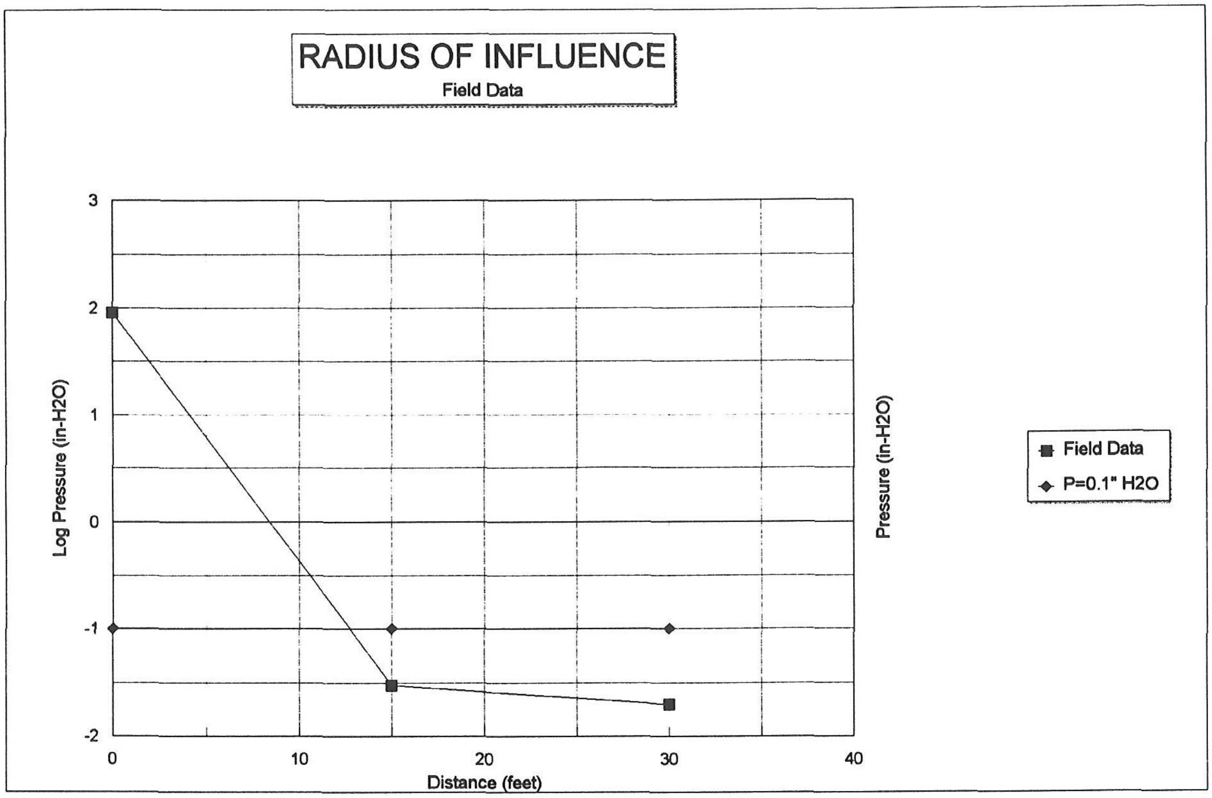
Regression Output:

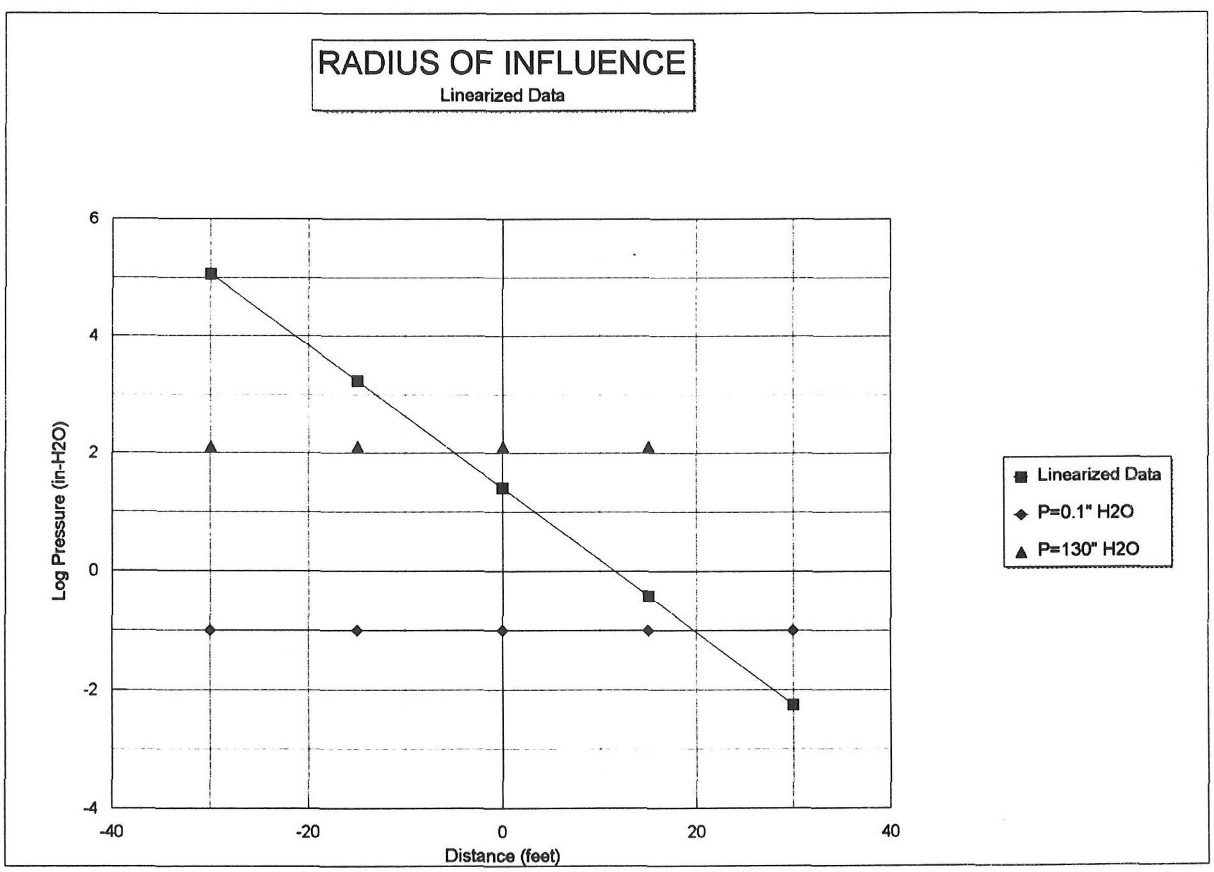
Constant		1.4040708
Std Err of Y Est		1.3476399
R Squared		0.7860633
No. of Observations		3
Degrees of Freedom		1
X Coefficient(s)	-0.12177	
Std Err of Coef.	0.063528	

LINEAR REGRESSION ANALYSES

PRESSURE (in-H2O)	LOG-P (in-H2O)	DISTANCE (feet)	ROI INTERCEPT	P=LOG(130) (in-H2O)
114069.9	5.057171	-30	-1	2.113943
1700.674	3.230621	-15	-1	2.113943
25.35543	1.404071	0	-1	2.113943
0.378025	-0.42248	15	-1	2.113943
0.005636	-2.24903	30	-1	2.113943

Log P = -0.12177 X + 1.404071


RADIUS OF INFLUENCE
Field Data
Log Pressure (in-H2O)
Pressure (in-H2O)
Distance (feet)
3
2
1
0
-1
-2
0
10
20
30
40
Field Data
P=0.1" H2O


RADIUS OF INFLUENCE
Linearized Data
Log Pressure (in-H2O)
Distance (feet)
6
4
2
0
-2
-4
-40
-20
0
20
40
Linearized Data
P=0.1" H2O
P=130" H2O