AIR SPARGING AND SOIL VAPOR EXTRACTION TO REMEDIATE GROUND WATER

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ABSTRACT

An Air Sparging and Soil Vapor Extraction System was chosen to remediate petroleum impacted ground water over traditional remedial alternatives, such as "pump and treat", to expedite site closure. Field pilot testing, computer modeling and cost benefit analyses were performed for several alternatives. Air Sparging and Soil Vapor Extraction pilot studies proved this technology to be the most effective with respect to remedial and economic concerns.

Underground Storage Tanks (UST's) were closed at the facility located in North Eastern North Carolina in August of 1992. During UST closure, petroleum impacted ground water and soils were encountered. ATEC performed a Comprehensive Site assessment to delineate the impacted soil and ground water plume. Following completion of the site assessment, a Corrective Action Plan was prepared. As part of the Corrective action Plan preparation, field pilot testing was performed to evaluate remedial alternatives and provide information for full scale design. The full scale treatment system was installed and started in January 1994.

This effective Remedial System was selected over other options due to successful pilot testing results with site closure petitioning scheduled within 12 to 14 months after start up. The Air Sparging System, properly applied, is an effective and "quick" remedial option with no generation of ground water for disposal and permitting.

This paper concentrates on the Air Sparging application applied at this North Carolina site. Although Vapor extraction was also implemented, this presentation does not elaborate on vapor extraction design or implementation and only discusses vapor extraction where it is directly related to the Air Sparging System.

BACKGROUND

The site is located in northeastern North Carolina. In July, 1992 three underground storage tanks (UST's) were removed from the site. These UST's contained gasoline products. Upon removal of the UST's ATEC performed a soil and ground water assessment. This assessment concluded the following:

- Both soil and ground water were impacted on-site;
- Ground water sampled from two monitoring wells on-site MW-3 (vertical extent well) and MW-6 (shallow well) in October, 1993 indicated levels of benzene ranging from 4,850 parts per billion (ppb) to 24,900 ppb respectively.
- No separated phase product was detected in any of the wells on-site;
- The ground water plume on-site extended approximately 90 feet from the UST pit horizontally, and approximately 30 feet vertically;
- Soils on site are comprised of sandy silts to silty sands;
- Ground water at the site has a seasonal fluctuation from a depth of one foot below grade in January, to seven feet below grade in August.

Upon completion of the assessment, an air sparging and soil venting pilot study were performed on-site. Based upon the results of this pilot study, which will be discussed in more detail later in this report, a Corrective Action Plan (CAP) was prepared, presenting air sparging and soil venting as the best available technology to remediate ground water and soil at the site. The North Carolina Department of Environmental Management (NCDEM) accepted this remediation plan. In January, 1994 an air sparging and soil venting remediation system was installed on-site.

The existing site conditions are summarized in the following table:

Avg. Depth to Ground water:	1 foot to 7 feet (seasonal)
Geological Strata:	Clayey silt to sandy silt
Hydraulic permeability:	0.13 ft/day
Transmissivity:	6.5 ft^2/day
Ground Water Velocity	0.0024 ft/day
Porosity:	0.30
Gradient:	0.0055 ft/ft

Air Sparging is most effective when applied to remediate volatile and easily biodegradable organics, such as gasoline components. Air sparging can be thought of as "In-Situ Air-Stripping" where the soils are the surface media and where the induced air produces the mass transfer of volatiles from the dissolved (in ground water) and adsorbed (on soil) phases to the gaseous phase. The volatile laden air then rises to the Vadose Zone for collection by a Vapor Extraction System.

The application of air sparging to unconsolidated soil formations in the saturated zone accomplishes three things:

1) Volatilizes contaminants adsorbed to soils;
2) Strips contaminants from the dissolved ground water plume; and
3) Enhances biodegradation of both the dissolved and adsorbed phases by increasing the dissolved oxygen levels which induce higher natural bacterial activity.

TYPICAL DESIGN PARAMETERS

As shown in, Figure 1, the areal extent of the impacted ground water is approximately 90 feet in diameter and over 30 feet below grade. Ground water ranges in depth from one to seven feet below grade. With the knowledge that the strata was predominantly sandy and clayey silts, we proceeded to design and plan an air sparging and soil vapor extraction pilot test.

Design criteria required for an effective full scale remedial application include:

- Depth of injection of air
- Injection Point Design
- Injection Pressure
- Air Injection Flow Rate
- Cone of Influence of Injected Air

The point of air injection should be placed immediately below (one to two feet) the deepest point of contamination. If the injection point is to be placed deeper than 30 to 40 feet below the water table than the installation of multiple points set at varying depths (nesting) should be installed to avoid channelling.

There are several types of well injection points which can be installed. A typical monitoring well that is one or two-inches in diameter with a six inch to two foot screen length may be installed, or cast iron well points of three quarters to one-half a inch in diameter may be utilized. In either case, a standard sand pack, and bentonite and grout should be set around the screen and a well placed grout immediately above the screen for several feet to avoid short-circuiting of induced air.

The application air pressure is essentially comprised of three factors; 1) the depth of the water column above the screen, 2) frictional losses in the system and 3) the formation release pressure, which is the capillary resistance to displace pore water. The application pressure required to overcome the depth of water column is equal to 1 psi for every 2.3 ft of water column depth above the injection screen. To allow for frictional losses and the formation release pressure add approximately 1 psi for every 3 ft of water column in a sandy formation and approximately 1 psi for every 5 feet of water column in a gravely formation. These values will rise in "tighter" formations reach as clayey or silty sands.

The air injection flow rate may vary from 2 to 10 cfm per injection point. If the water column above the injection screen is greater than 15 ft or more the injection air flow rate will be higher.

The zone of influence of the injected air will vary depending upon the geological formation. The angle of influence will vary from 15° in coarse gravel to a high of 60° in silty sands. The heterogeneity of the geological formation must also be considered as injected air may short circuit or move laterally under confining layers and then upward.

Other considerations in the feasibility stages of air sparging applications are heterogeneity of the soils as discussed above, plume and free phased product movement and the impact vapors may have on nearby structures.

If the site of concern appears amenable to air sparging after evaluation of these typical design parameters, than the next step in the design process is to perform an in field pilot test.

PILOT TEST

During the site assessment phase, ATEC installed a "deep well" to determine the vertical extent of contamination. This 2 in. diameter PVC well was screened from 23 to 28 ft below grade. The depth of water above the screen was approximately 18 ft. This well was chosen for use as the air injection point for the pilot test.

Figure 1 shows the location of the monitoring wells. MW-3 is the vertical extent well which was utilized as the pilot test sparging point. Nearby wells, MW-6 (10 feet away from MW-3 horizontally) and MW-2 (45 feet away from MW-3 horizontally) were utilized to monitor the air sparging influence. We also installed two temporary wells at distances from MW-3 of 15 ft and 20 ft respectively. All permanent and temporary monitoring wells were 2 in. diameter PVC with the screens straddling the water table.

Parameters measured during the pilot test were:

- Ground Water Levels
- Dissolved Oxygen
- pH
- Conductivity
- Organic Vapor Levels

The equipment utilized for the pilot test included, an air compressor, water level indicator, pH/conductivity meter, organic vapor analyzer (OVA) and a dissolved oxygen (DO) meter. The air compressor was a portable gas driven unit capable of sustaining up to 15 cfm at a pressure of 20 psi. The air compressor discharge line was fitted with a rotometer, gate valve and a pressure regulator. Dedicated well bailers were also used to retrieve well water for pH and conductivity measurements.

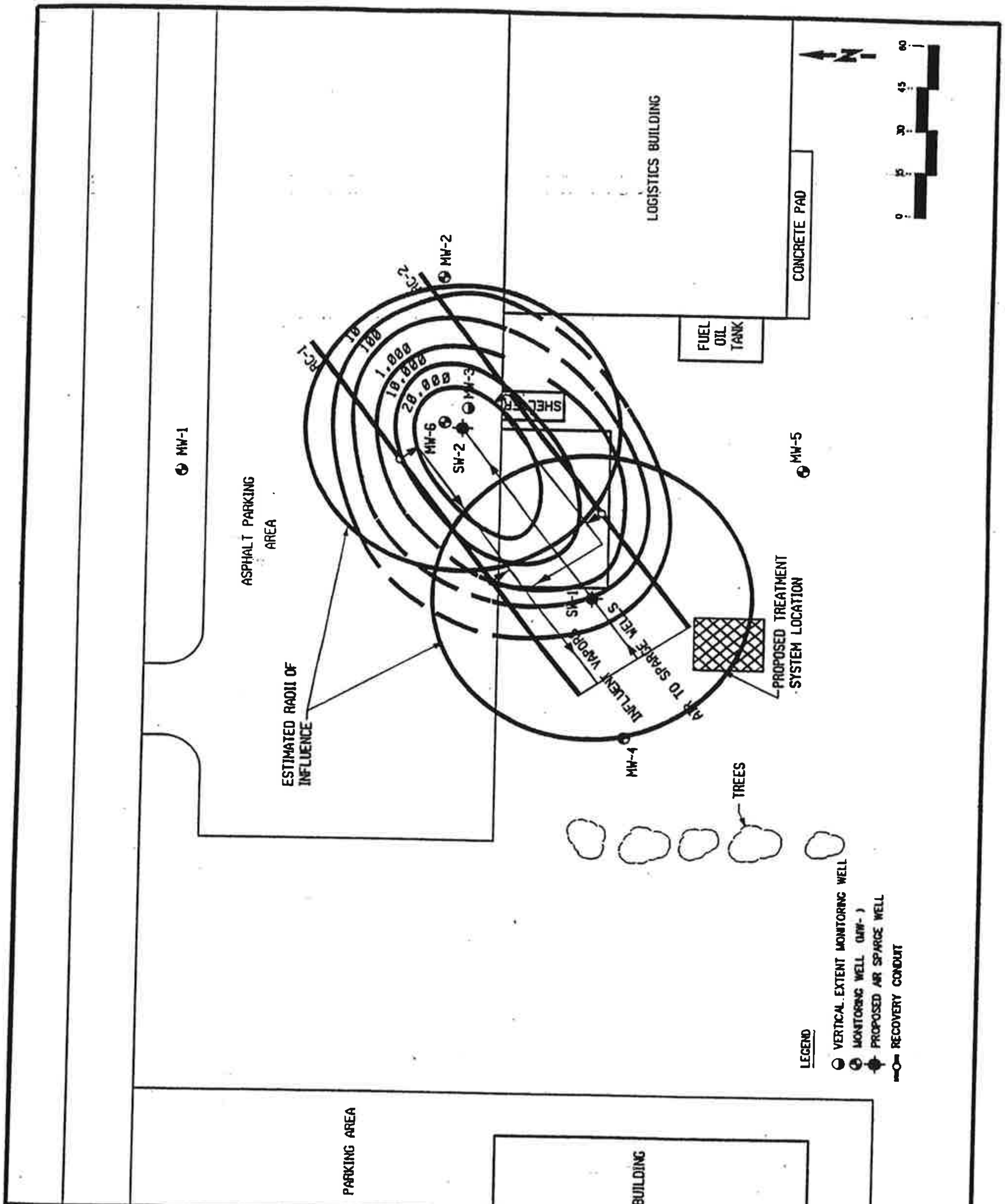

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FIGURE 1
REMEDIAL SYSTEM PLAN VIEW

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PILOT TEST RESULTS

The test was operated in steps. Initially air was injected at 5 cfm. The next step was 10 cfm and the final step was operated at 15 cfm. The most dramatic parameter change noted was the organic vapor readings from the monitoring point head spaces. Presented below is a summary of the pilot test results:

- Step One - 5 cfm

Measurement/Monitoring Point Distance				
Feet	10	15	20	45
OVA (ppm)	>1,000	220	290	0
DO (ppm)	0.6	NA	1.6	0.8
pH	6.22	NA	6.53	6.13
Conductivity (μmhos)	689	NA	545	871
Depth to Water (ft)	8.03	8.34	9.06	7.68

- Step Two - 10 cfm

Measurement/Monitoring Point Distance				
Feet	10	15	20	45
OVA (ppm)	>1,000	>1,000	>1,000	0
DO (ppm)	0.8	1.0	0.8	0.8
pH	6.26	NA	6.38	6.23
Conductivity (μmhos)	738	NA	572	588
Depth to Water (ft)	8.42	8.34	9.20	7.95

- Step Three - 15 cfm

Measurement/Monitoring Point Distance				
Feet	10	15	20	45
OVA (ppm)	>1,000	>1,000	>1,000	0
DO (ppm)	0.9	1.2	1.2	0.8
pH	6.32	NA	6.40	6.26
Conductivity (μmhos)	8.37	NA	538	722
Depth to Water (ft)	8.87	8.34	9.39	8.43

The evaluation of the data quickly shows that a radius of influence of greater than 20 ft. was achieved. Due to changes in pH and conductivity at the 45 ft. distant well it may also be implied that the sparging system influenced ground water at this distance. When evaluating the parameter results of the sparging test we are looking at changes. Some parameters may rise or fall. Due to unknown factors of the inherent geochemistry, but the key is to look for changes.

As presented in the design parameters above, the zo[illegible] influence can be calculated to be 15 to 20 feet based upon [illegible]e 18 ft. depth to ground water and angle of the zone of influence at 45° to 60°. Therefore it is safe to present the zone of influence conservatively at 20 to 30 ft. based upon the pilot test results for the shallow sparge point. The application pressure was measured at the well head at 15 to 18 psi. The air flow rate of 5 to 10 cfm appears to be adequate to affect the target area.

REMEDIAL SYSTEM DESIGN

The zone of influence of the full scale sparging wells was designed at approximately 45 ft. in radius. This additional radius of influence versus the pilot test is attributable to the additional depth of the sparging points which are set at 37 to 38 ft. below grade. This depth was chosen to allow for introduction of air below the deepest zone of contamination. Figure 1 shows the location of the installed air sparging points with the zones of influence overlying the impacted ground water plume.

The two sparging points were constructed of 2 inch diameter PVC with one foot of 0.010 in. screen at the bottom of each point.

An air compressor was selected to provide up to 30 psi of air pressure at a continuous air flow rate of 20 cfm. Up to 10 cfm of injected air per well point may be introduced.

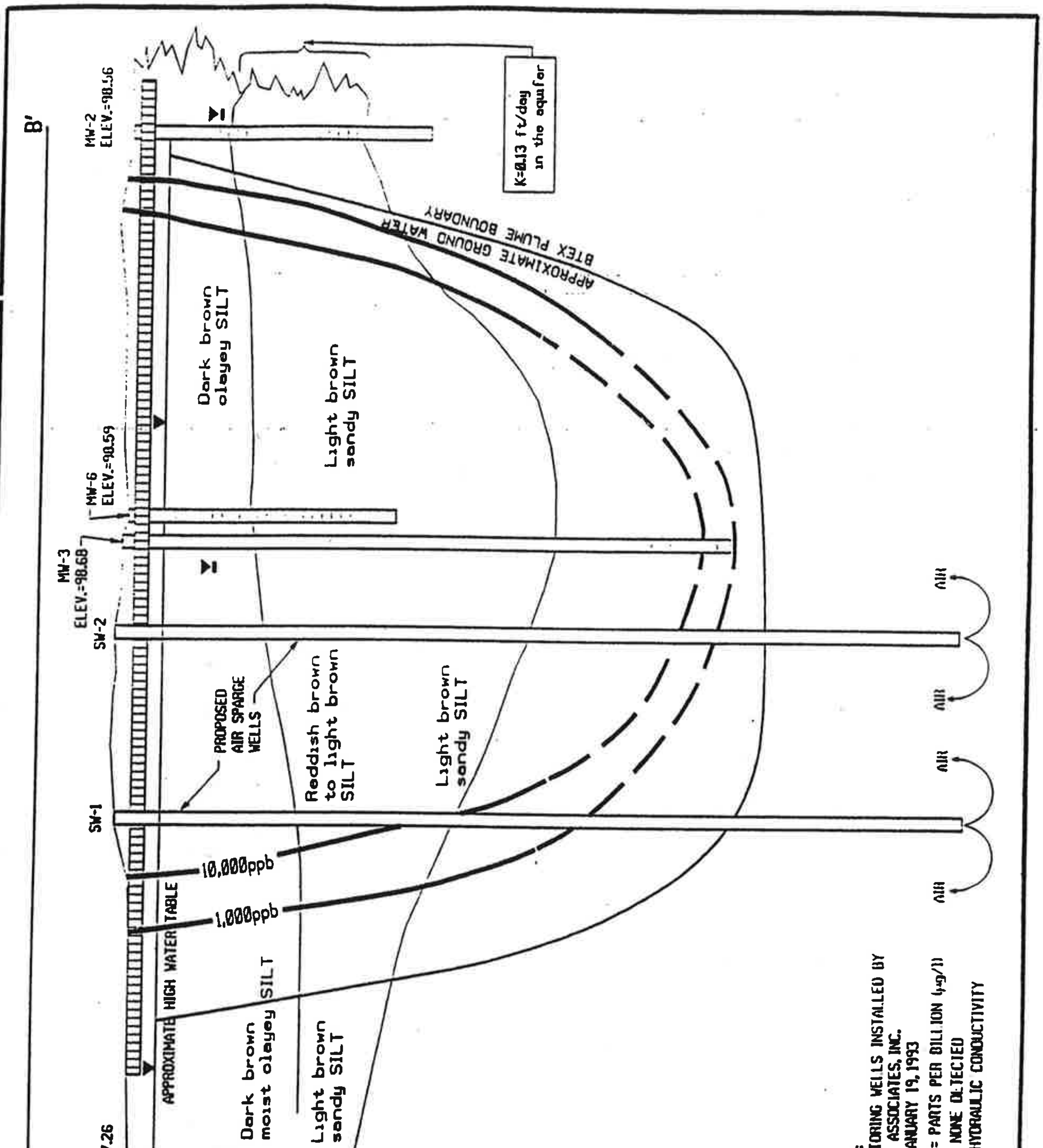

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FIGURE 2
CROSS-SECTION OF INSTALLED RECOVERY SYSTEM

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A soil vapor collection system was also designed based upon field pilot testing, to collect the vapors generated. Horizontal vapor collection conduits were installed as shown in Figure 1. The blower selected for the vapor collection process was sized to collect up to 100 cfm at a vacuum of up to 5.5 in of mercury. It is suggested that a minimum vapor collection volume to volume of air injection volume ratio be maintained at greater than 3 to 1. At this site, a paved parking lot and an adjacent building provided migration and collection points for generated vapors if not collected by a vapor recovery system.

Other control and safety features added to the installed remedial system include:

- High pressure shut-off for the air sparging compressor.
- Low vacuum shut-off for the vapor extraction system.
- Automatic shut-off of the air sparging compressor should the vapor extraction blower go down.
- High water system shut-off in the vapor extraction water drop out tank.

Figures 2 and 3 present the system cross sectional view and schematic layout.

SYSTEM PERFORMANCE

ATEC commenced operation of the full scale system in January 1994. The monitoring wells were sampled prior to start-up and again on February 17, 1994. The short term results are indicated below:

C	MW-1		MW-2		MW-3*	
	10/93	2/94	10/93	2/94	10/93	2/94
B	ND	ND	1	ND	4850	170
T	ND	ND	1	2	156	240
E	ND	ND	ND	ND	311	60
X	ND	ND	ND	ND	284	ND
MTBE	ND	ND	17	ND	1960	194

*Type III Vertical extent well

C	MW-4		MW-5		MW-6	
	10/93	2/94	10/93	2/94	10/93	2/94
B	ND	ND	ND	ND	2490	950
T	ND	ND	ND	ND	4000	289
E	ND	ND	ND	ND	2520	240
X	ND	ND	ND	ND	1170	125
MTBE	ND	ND	ND	ND	5660	162

As can be seen from the analytical data, the remediation system appears to be volatilizing the aromatics in MW-3 and MW-6. Several other important parameters to monitor aside from contaminant levels in ground water in the area of the plume at this site include:

- Contaminant levels in ground water of out lying wells.
- Water levels and subsequently ground water flow direction and gradient.
- Off gas contaminant levels from the vapor collection system.
- Contaminant vapor concentrations in monitoring well head spaces.

Monitoring of these parameters on a regular basis is important to determine if the induced air is causing the plume to migrate, if the levels of vapors driven off are varying and if vapors in the monitoring area are not fully being collected. Adjustments to the system can be made to correct these conditions if problems arise. Induced air flows can be reduced and vapor collection rates can be increased for example. ATEC also installed two shallow monitoring points near the on-site building to monitor for vapor migration toward the building. During the first couple of months the site has been "Under Control".

SITE CLOSURE GOALS

Closure criteria for sites in North Carolina include:

- Risk assessment based on contaminants remaining in the ground water;
- A curve representing the contaminant reduction which should have an asymptotic slope with a ratio of less than 1:40 over one year;
- Contaminants cannot migrate onto adjacent properties;
- Contaminants cannot impact surface waters in concentrations above state standards; and

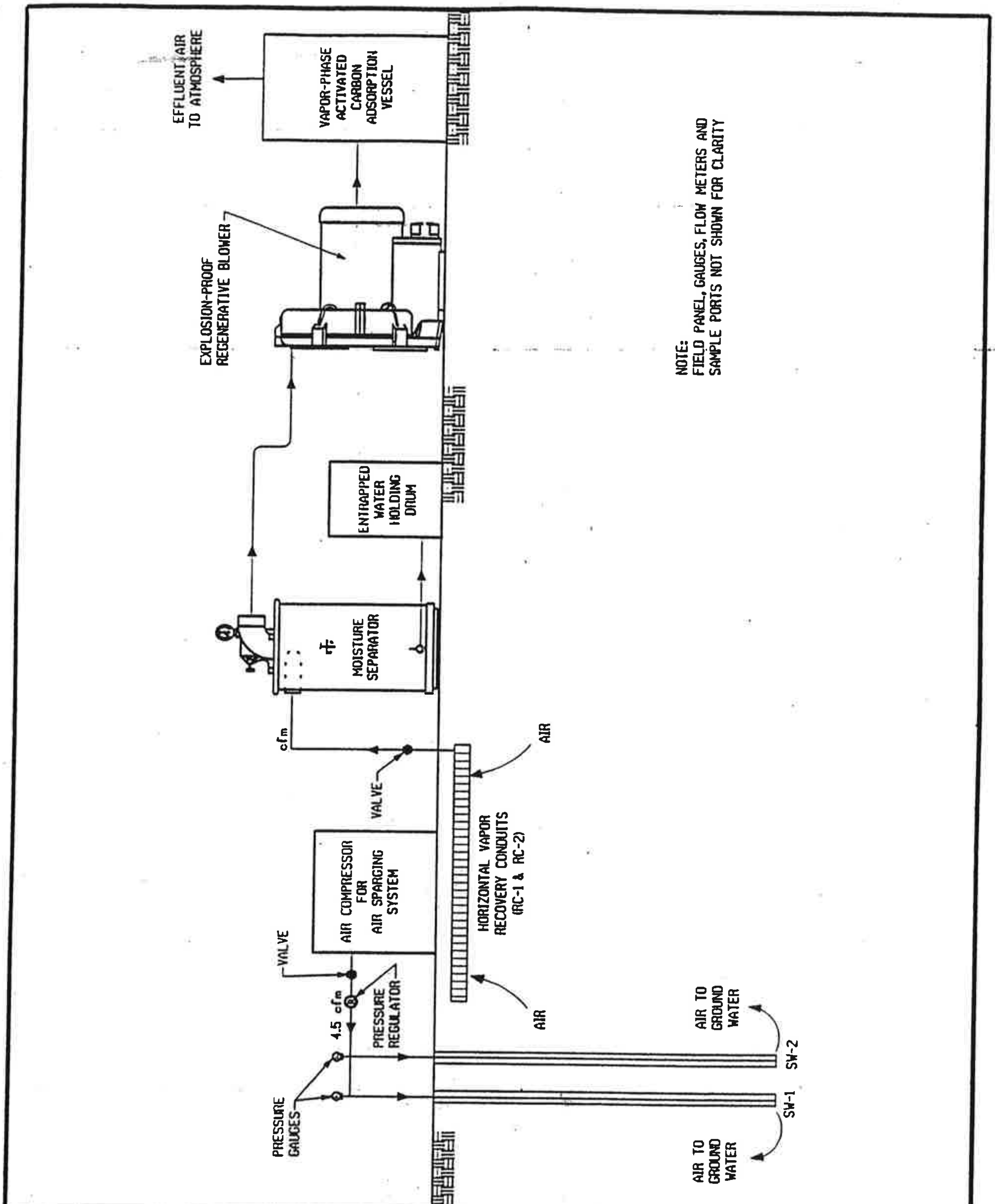

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FIGURE 3 INSTALLED TREATMENT SYSTEM SCHEMATIC				ATEC Environmental Consultants
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- Contaminants cannot impact foreseeable receptors in one years travel time of the contaminant plume.

Based upon the closure criteria, and the current remediation system operation, we expect to apply for site closure in 9 to 12 months. The state will then require one year of monitoring to ensure that contaminant levels do not return to above ground water quality standards. The site will then formally be closed.

REFERENCES

Article:
Nyer, Evank. and Suthersan, Suthan S., Air Sparging: Savoir of Groundwater Remediations or just Blowing Bubbles in the Bath Tub?, Groundwater Monitoring & Remediation, pp 87-91, Fall 1993.