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Dear Eva,

Here are copies of the remediation proposed by Woodward Clyde & OHM.

I very much like the Dual Phase (or Vapor) Extraction & would like to get my 3 bids on that technology.

Please give me your opinion.

Sincerely,

Rita

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THIS IS INFORMATION FROM WOODWARD CLYDE ON DUAL-PHASE (OR VAPOR) EXTRACTION

3.0 DUAL-PHASE EXTRACTION

Conventional groundwater extraction by pump-and-treat technology depends on gravity drainage of water to the pumping well (Figure 2). Extraction of groundwater alone will directly influence removal of the dissolved-phase mass, while the sorbed-phase mass and NAPLs will continue to provide a source of contaminants for recharge into the aquifer. Contaminant mass sorbed to the aquifer media in contact with the plume may be on the same order or greater than the dissolved phase mass (Mackay, 1989). Low permeability formations, such as clays, may provide a significant source of sorbed-phase contaminants as the porosity of such soils may be as great as the adjacent aquifer material. Consequently, this would facilitate initial diffusion of contaminants into the clays with subsequent diffusion back to the groundwater as contaminant concentrations drop in response to biodegradation, or pump-and-treat cleanup efforts.

Dual-phase extraction (DPE), a form of vacuum-enhanced groundwater extraction, was developed as a result of observations of vapor extraction effectiveness on contaminant removal in unsaturated soil. Vapor extraction takes advantage of the volatile nature of hydrocarbons, halogenated hydrocarbons, and other VOCs, by inducing air flow through the soils. Vapor-phase contaminants are entrained in the extracted air and removed from the subsurface. As the contaminant mass is removed in the vapor phase, mass which is sorbed onto the soil matrix is desorbed and entrained in the extracted air flow.

DPE takes the theory of vapor extraction and extends it to groundwater extraction. It was developed as an alternative to conventional pump-and-treat technology, particularly in low conductivity formations, such as silts and clays impacted by VOCs. DPE typically uses a high vacuum (greater than 15 inches of mercury) applied to an extraction well head to increase groundwater removal rates (and consequently the dissolved-phase mass) and to volatilize and extract contaminant from the sorbed or NAPL phases. Vacuum lift of water (maximum of approximately 25 feet at sea level) is not a limiting factor in the application of the technology as a mixed vapor/liquid column (often water droplets or a mist) is extracted from the well.

A dewatered zone is created in the drawdown produced by a pumping well. In formations with low hydraulic conductivity, DPE will produce an enlarged drawdown zone. Dual-phase extraction increases the hydraulic gradient toward an extraction well, increasing well yield and, therefore, increasing the removal of the soluble fraction of contaminants. Concurrently, air is also pulled through the subsurface toward the well through the unsaturated and dewatered areas. Volatilized contaminants are entrained in the extracted air stream and are removed simultaneously with the water, thus enhancing the total yield of contaminants from a well. Figure 3 conceptually illustrates DPE in the subsurface.

Dual-phase extraction is optimized when it is applied to formations which can sustain a dewatered condition. This takes advantage of the vapor-phase removal mechanism. Although dewatering of high conductivity soil can occur with a sufficient number of wells, initial experience has indicated that soils with a hydraulic conductivity of less than approximately 10^{-5} cm/sec are good candidates for DPE. Soils with higher hydraulic conductivity values may also prove to be suited to remediation by DPE, depending on well spacing and/or sustainable yield of the aquifer.

The DPE system can be simpler technology to implement than conventional pump-and-treat systems. DPE technology employs a single piece of equipment (a high vacuum source) to remove contaminants in both the liquid and vapor phases, minimizing the number of extraction points required. In addition, pumps and wiring associated with conventional pumping systems are eliminated.

The inherent advantages of DPE are listed below.

- DPE systems can recover VOCs from soils above and below the static water table.
- DPE systems can recover VOCs from soil and groundwater at increased rates over conventional soil vapor and groundwater extraction systems.
- An applied vacuum can increase the radius of influence and capture zone of soil vapor and groundwater extraction wells.
- DPE systems can reduce the number of extraction wells required at a site.

By reducing the number of wells and increasing the radius of influence, a greater mass of VOCs can be removed in a shorter period of time. Therefore, a DPE system can result in substantial cost and time savings as compared to conventional extraction systems.

A DPE system is especially advantageous at sites with the following conditions:

- soil and groundwater contaminated with volatile organic compounds,
- sites with fluctuating groundwater levels which cause a smearing of the sorbed- and separate-phase contaminant throughout the vertical extent of the fluctuation,
- sites with shallow groundwater, although this is not a necessary condition for application as stated by Blake et al. (1990), and
- sites where low permeability soils (hydraulic conductivity of about 10^{-5} cm/sec and less) result in low groundwater extraction rates with conventional pumping systems.

DPE, and its related technologies, has been mentioned in literature recently as a means to expedite subsurface cleanup (The Hazardous Waste Consultant, 1991 and Hazmat World, 1991). A dual-phase extraction system was applied to a site in New York, resulting in rates of groundwater extraction of up to approximately 20 times greater than in low permeability settings (The Hazardous Waste Consultant, 1991).

Blake and Gates (1986) discussed three case studies which demonstrated the advantages of vacuum-enhanced extraction for low permeability soils and shallow groundwater. Two basic options for vacuum-enhanced groundwater extraction are noted by Blake and Gates (1986): (1) use of a single vacuum pump or blower to apply the vacuum and extract vapor and groundwater from the same well casing; and (2) use of a submersible pump to remove the extracted groundwater and a separate vacuum pump to apply a vacuum to the well. However, Blake and Gates (1986) and Blake et al. (1990) state that vacuum-enhanced extraction is limited to pumping depths of less than 25 feet below ground surface at an elevation of mean sea level. WCC pilot test experience has indicated that increased groundwater extraction rates can be achieved at depths exceeding 25 feet in low permeability soils by extracting groundwater as entrained droplets or a mist in the vapor flow. WCC has also applied vacuum-enhanced extraction to dual completion wells and paired extraction wells where a well casing screened in the vadose zone is installed alongside or in the same boring as a well casing screened in the aquifer.

3.1 Woodward-Clyde Consultants' DPE Applications and Experience

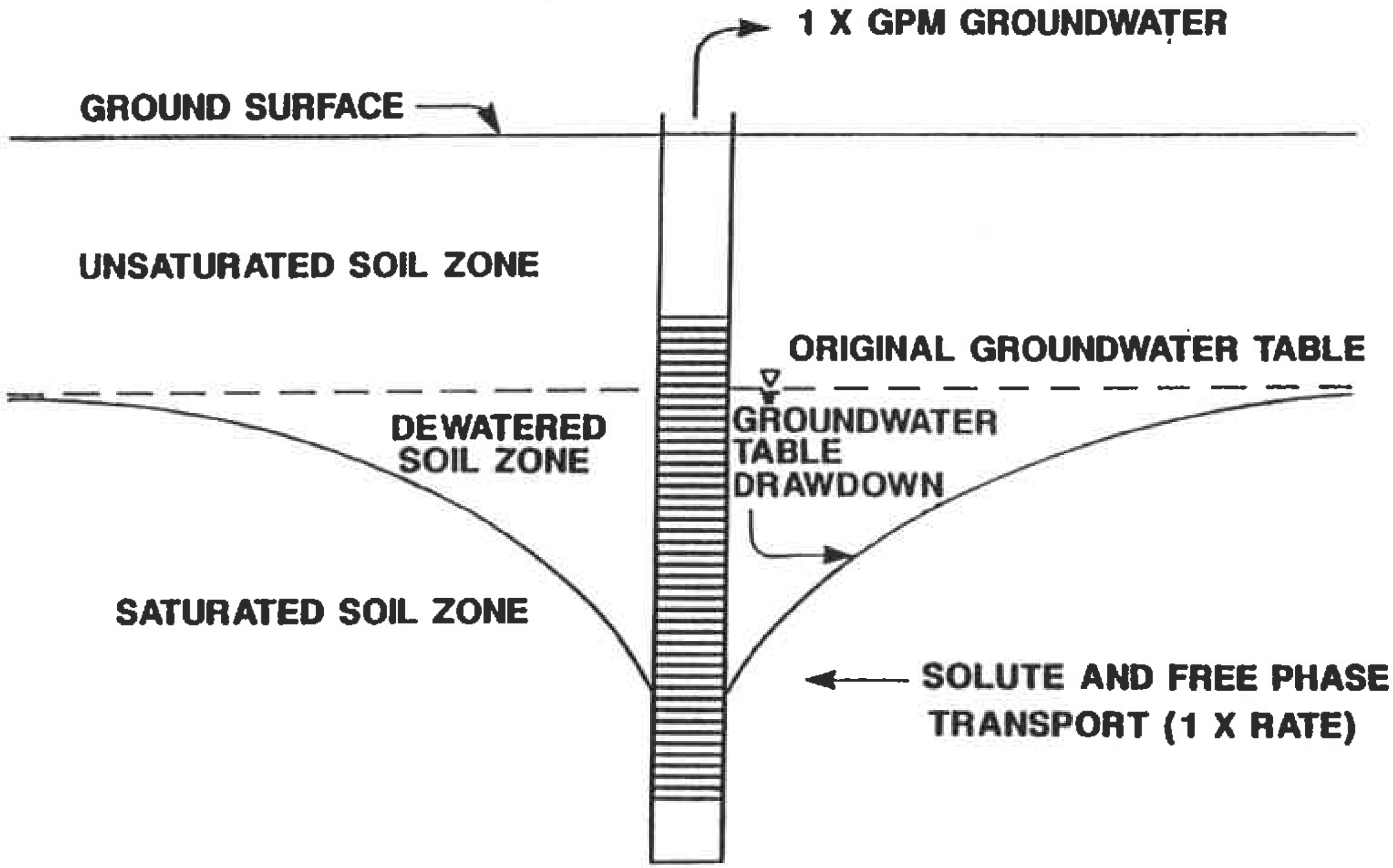
WCC has applied DPE to remediate soil and groundwater contamination at several commercial and industrial facilities across the country. The technique was developed for use at a Xerox Corporation facility in Irvine, California (Hajali, 1990). The DPE process has been patented by Xerox Corporation (U.S. Patent Nos. 5,050,676 and 5,172,764). Licensing agreements and royalty fees may be required for application of this technique at other facilities.

One Xerox site in California had been under full-scale remediation since 1989 with conventional pump-and-treat technology. DPE was introduced in the first quarter of 1991 by WCC. The groundwater removal rate increased from 2 to 8 times that experienced through conventional groundwater pumping in individual wells (Figure 4). The volatile organic compound removal rate increased approximately 100-fold due to the benefit of extracting vapors from the substantially expanded vadose zone (Figure 5). Further details of this case study are presented by Lewis et al., (1992) and Hajali (1990).

The DPE system has been demonstrated to extract groundwater at rates which exceed rates accomplished by conventional well pumping systems by 2 to 8 times in low permeability soils (see Lewis et al., 1992, Attachment 1). DPE systems can often be installed at a site using existing groundwater monitoring wells as dual-phase extraction wells, thus limiting the capital requirement of the system.

DPE extraction units in a variety of sizes have been installed at sites. A skid-mounted unit (rated at 150 scfm and 25 inches of mercury vacuum) is shown on the cover of this SOQ. Units as large as 500 scfm have been designed and implemented. WCC has designed and operated several types of extraction units with various arrangements for groundwater flow and control and types of vacuum pumps. The type of vacuum pump has a significant effect on the design of the extraction unit. Liquid ring positive displacement rotary blowers, dry positive displacement rotary blowers and dry vacuum jet blowers have been used for DPE units. WCC extraction units have been designed to operate at applied vacuums of up to 28 inches of mercury and at flow rates of up to 500 standard cubic feet per minute. Several 40-horsepower units have been designed and operated for use on 5 to 18 extraction wells each (Lewis et al., 1992).

A piping and instrumentation diagram (P&ID) of a typical dual-phase extraction system is given on Drawing No. I-1. The process flow is shown on the P&ID. Vapor and groundwater are extracted from the extraction wells and drawn into a water knockout tank. Groundwater is separated from soil vapor by gravity and centrifugal action at the surface in a water knockout tank. Vapors flow through the blower before discharge to an air emissions treatment system. Soil vapors may be treated by carbon adsorption, thermal oxidation, catalytic oxidation or exhausted directly to the atmosphere depending upon local regulations. Water accumulates in the knockout tank until an electronic float switches on the fluid transfer pump. Water is pumped out of the tank and into a groundwater treatment/discharge system. Treated groundwater may be discharged to the local sanitary sewer system or storm drain system, reinjected into the aquifer, or reclaimed for use depending on local conditions and regulations. The system has a number of safety switches and manual and automatic controls located on a control panel on the extraction unit. The system can operate unattended 24 hours a day, 7 days a week.



CONVENTIONAL PUMPING

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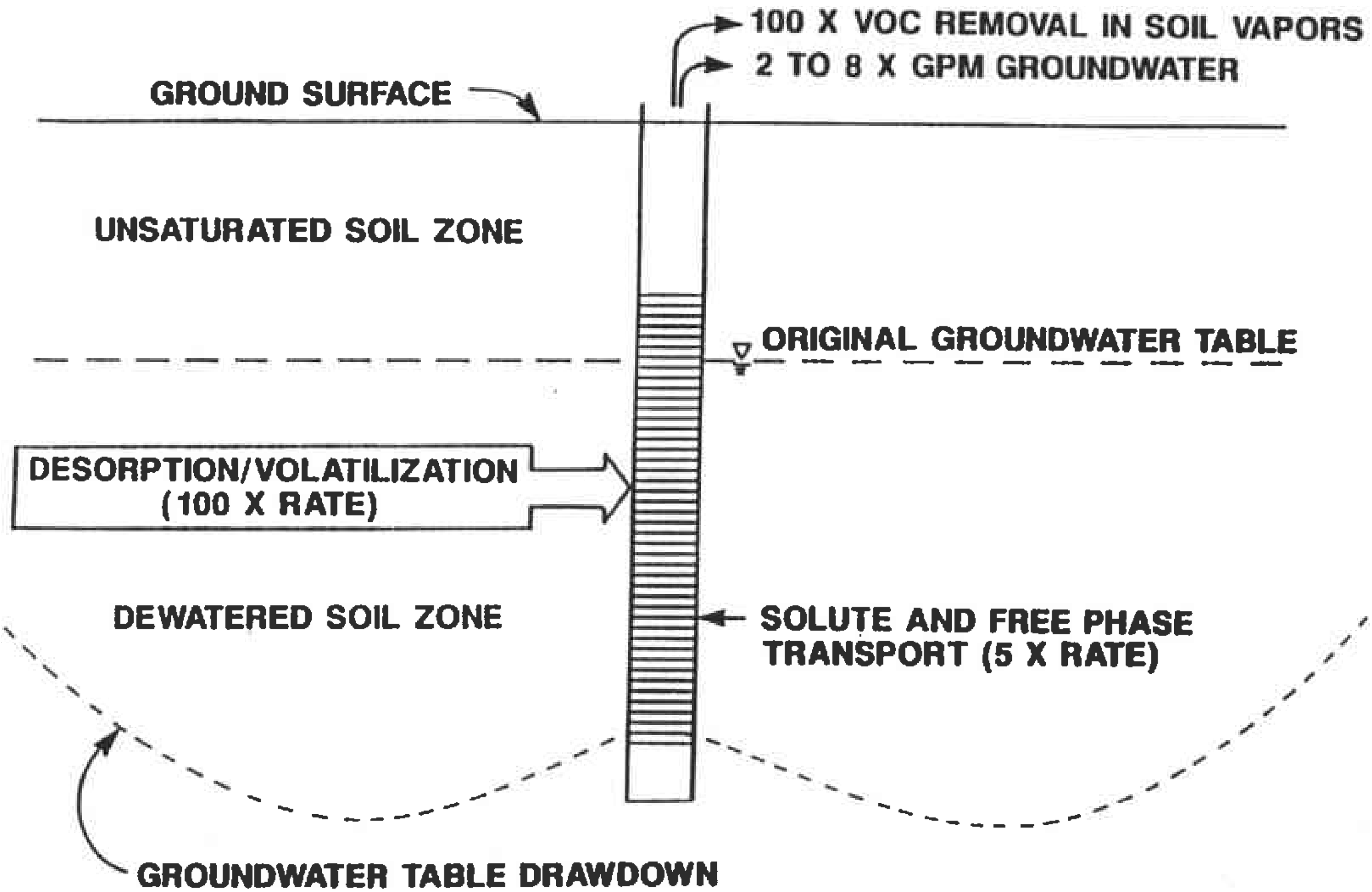

TWO PHASE EXTRACTION

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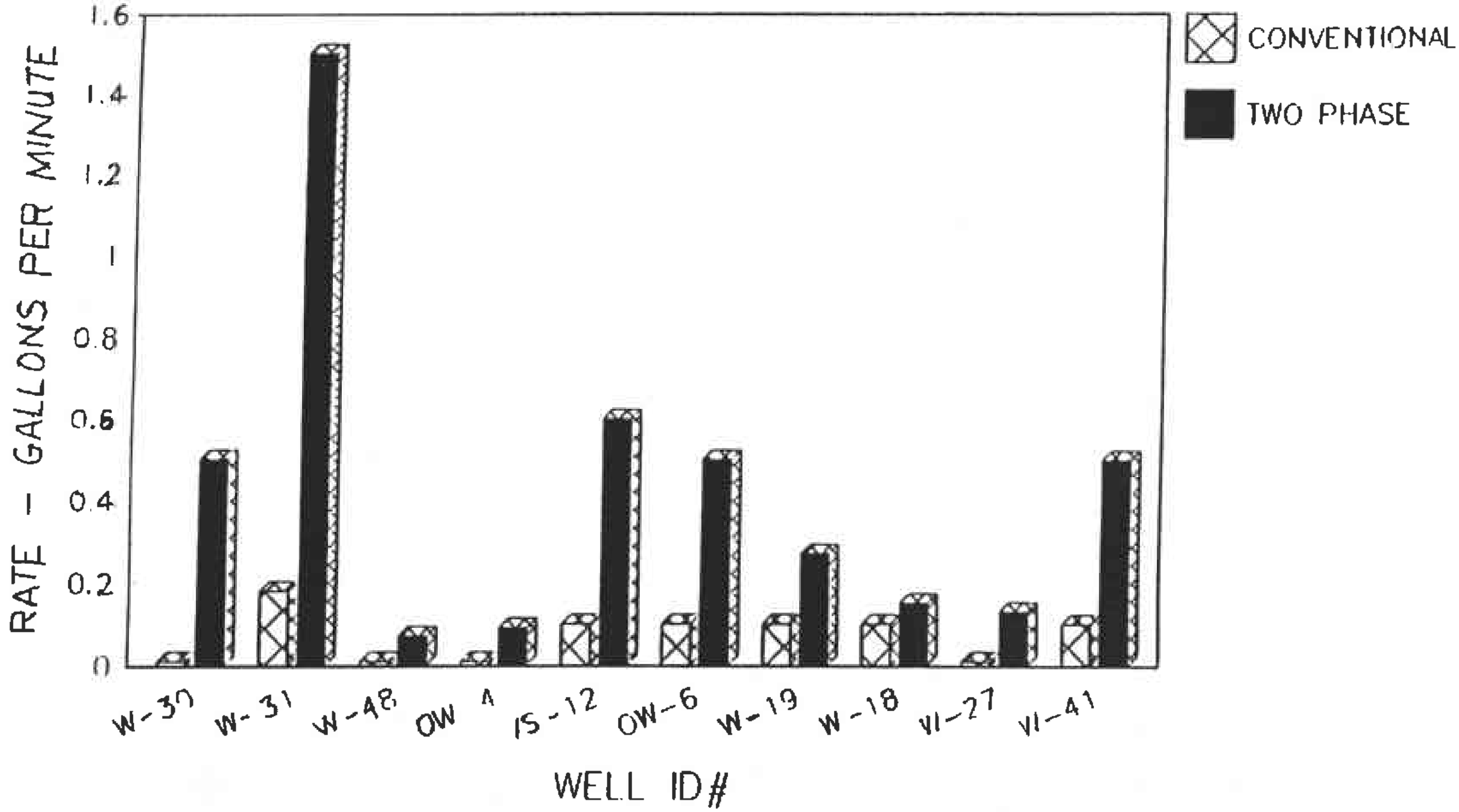

GROUNDWATER EXTRACTION RATE COMPARISON			
Project No.:	Date: JAN. 1993	Project:	Fig. 4

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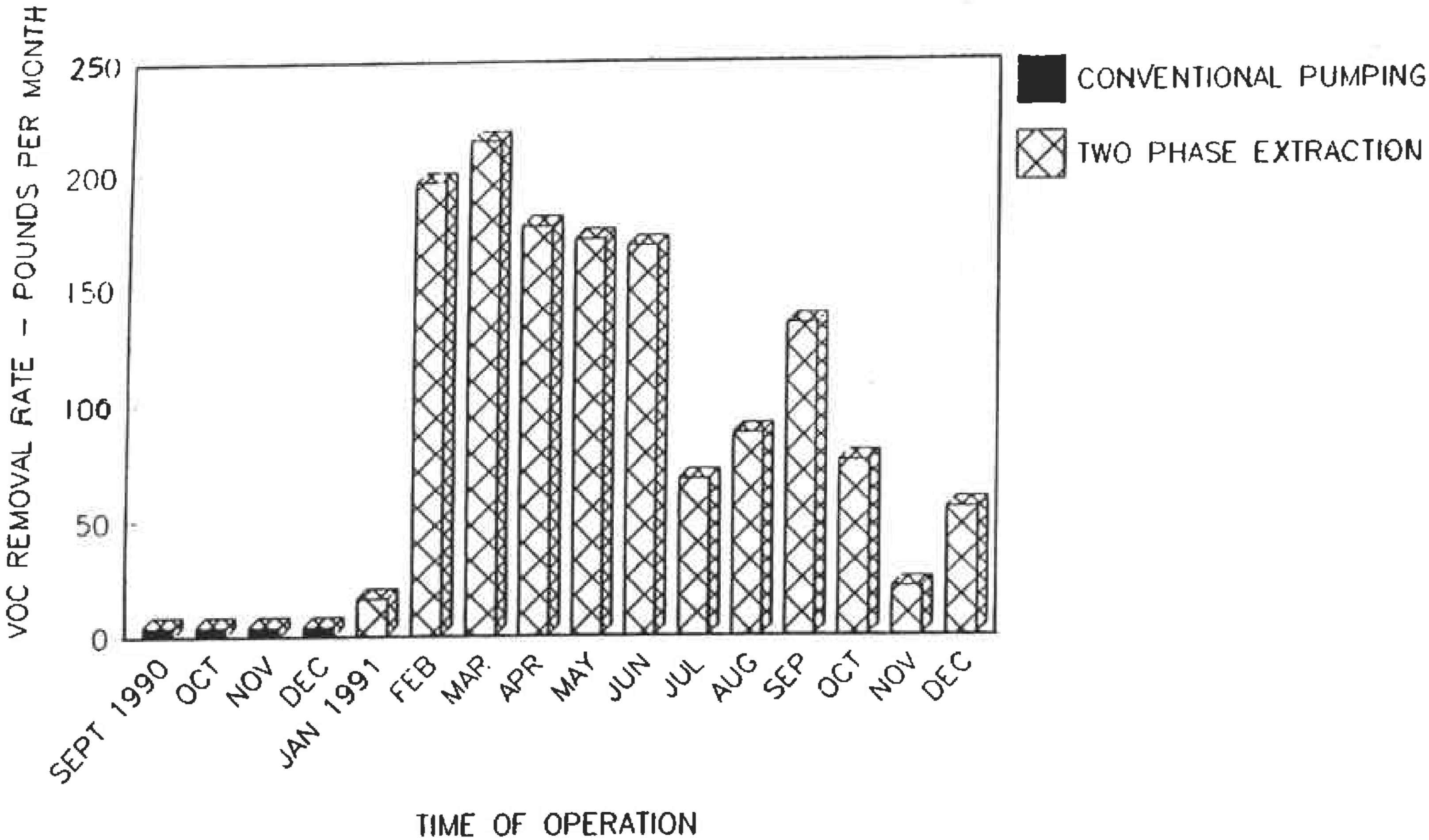

VOLATILE ORGANIC COMPOUND REMOVAL RATE COMPARISON			
Project No.:	Date: JAN. 1993	Project:	Fig. 5

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