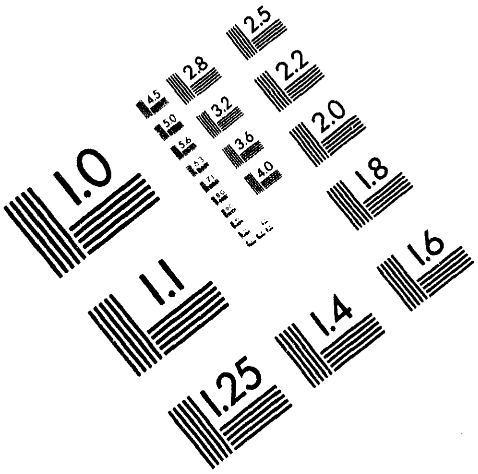

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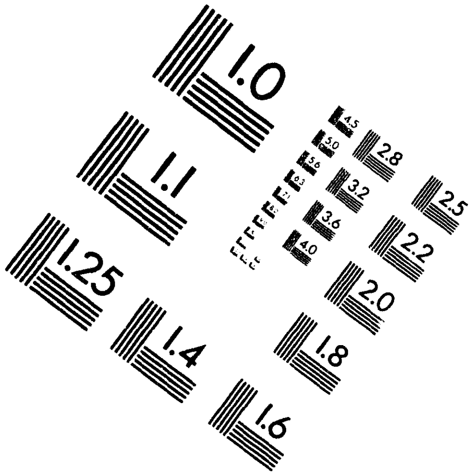

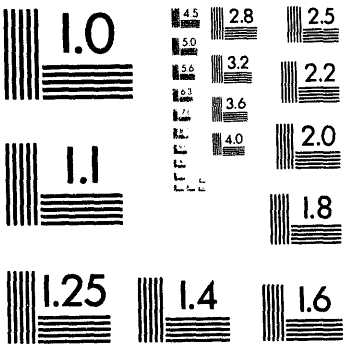

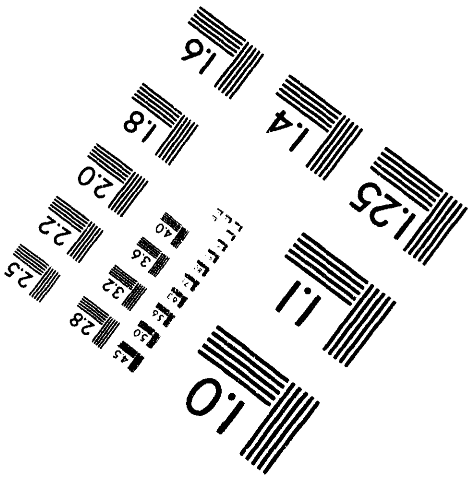

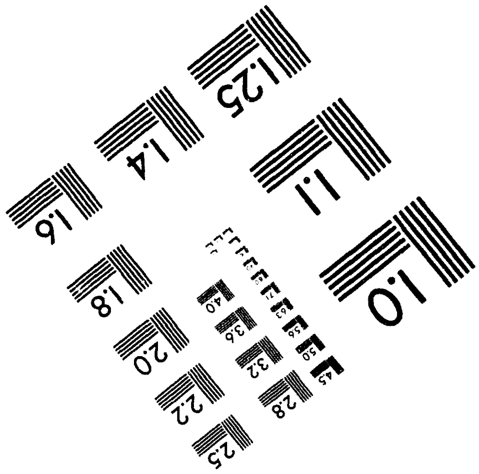

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SUMMARY

Between 1955 and 1973, a total of 363,000 to 580,000 L (577,000 to 922,000 kg) of liquid carbon tetrachloride, in mixtures with other organic and aqueous, actinide-bearing fluids, were discharged to the soil column at three disposal facilities--the 216-Z-9 Trench, the 216-Z-1A Tile Field, and the 216-Z-18 Crib--in the 200 West Area at the Hanford Site. In the mid-1980's, dissolved carbon tetrachloride was found in the uppermost aquifer beneath the disposal facilities, and in late 1990, the U.S. Environmental Protection Agency and the Washington State Department of Ecology requested that the U.S. Department of Energy proceed with planning and implementation of an expedited response action (ERA) to minimize additional carbon tetrachloride contamination of the groundwater. In February 1992, soil vapor extraction was initiated to remove carbon tetrachloride from the unsaturated zone beneath these disposal facilities. By May 1994, a total of 10,560 L (16,790 kg) of carbon tetrachloride had been removed, amounting to an estimated 2% of the discharged inventory.

In the spring of 1991, the Volatile Organic Compounds - Arid Integrated Demonstration (VOC-Arid ID) program selected the carbon tetrachloride-contaminated site for demonstration and deployment of new technologies for evaluation and cleanup of volatile organic compounds and associated contaminants in soils and groundwater at arid sites.

Site investigations conducted in support of both the ERA and the VOC-Arid ID have been integrated because of their shared objective to refine the conceptual model of the site and to promote efficiency. Site characterization data collected in fiscal year 1993 have supported and led to refinement of the conceptual model of the carbon tetrachloride site.

Carbon tetrachloride is found throughout the 65-m-thick unsaturated zone underlying the three primary disposal facilities. Laterally, the highest concentrations of carbon tetrachloride are consistently located in the vicinity of the 216-Z-9 Trench. Vertically, the highest concentrations are associated with the fine-grained, relatively impermeable Hanford lower fine and Plio-Pleistocene units, located at depths of 35 to 40 m below ground surface.

The highest near-surface vapor concentration of carbon tetrachloride measured during a soil-gas survey was 72 parts per million by volume (ppm_v) just north of the 216-Z-9 Trench. Maximum vapor concentrations observed at wellheads and deep soil-gas probes, which were measured twice a week for 25 months, exceeded 10,000 ppm_v total volatile organic compounds at monitoring locations above the Plio-Pleistocene unit and immediately north of the 216-Z-9 Trench. At similar locations above the Plio-Pleistocene unit in the 216-Z-1A/216-Z-18 area, maximum concentrations were an order of magnitude lower. However, maximum concentrations from monitoring ports below the Plio-Pleistocene unit were approximately 1,000 ppm_v in both areas. The highest carbon tetrachloride concentration in the sediment samples collected during drilling of 13 new wells was 37.8 ppm from the Hanford lower fine/Plio-Pleistocene interval at the 216-Z-9 Trench. In contrast, the highest carbon tetrachloride concentration in a sediment sample from the 216-Z-1A/216-Z-18 area was only 6.6 ppm, but was also associated with the Hanford lower fine/Plio-Pleistocene interval. The highest carbon tetrachloride concentrations in the in situ soil-gas samples collected during drilling exceeded

10,000 ppm_v in wells at the 216-Z-9 Trench. Carbon tetrachloride concentrations in soil vapor extracted using the vapor extraction systems exceeded 25,000 ppm_v carbon tetrachloride from intervals above the Plio-Pleistocene unit at the 216-Z-9 Trench. Extracted soil-gas concentrations from the 216-Z-1A/216-Z-18 wellfield are an order of magnitude lower.

Sorption of carbon tetrachloride onto soil particles within the unsaturated zone is thought to be fairly low (<0.2 mL/g). An estimated 6% of the original carbon tetrachloride inventory is currently sorbed on soil particles in the unsaturated zone. An additional 6% is estimated to be contained within soil gas and soil moisture in the unsaturated zone.

Nonaqueous-phase liquid carbon tetrachloride has not been observed in the unsaturated zone. However, the high vapor concentrations (~25% of the saturated vapor concentration) extracted from the 216-Z-9 wellfield suggest the presence of residual carbon tetrachloride, particularly associated with the Hanford lower fine and Plio-Pleistocene units.

Aqueous- and nonaqueous-phase liquids containing carbon tetrachloride infiltrated into the underlying soils and migrated through the unsaturated zone under their own hydraulic gradients. The presence of inadequately sealed wells, including some deep groundwater wells, during the time of active liquid waste disposal had the potential to provide vertical conduits for the downward migration of carbon tetrachloride and other contaminants directly to the aquifer. This is of particular concern near the 216-Z-9 Trench, where waste water has been found perched on low-permeability materials and has spread laterally for approximately 100 m. However, column pore volume estimates and numerical model simulations suggest that, at the 216-Z-9 Trench, the liquid wastes likely reached the water table by downward migration irrespective of whether poorly sealed wells provided a preferential pathway.

Volatilization of carbon tetrachloride from aqueous- and nonaqueous-phase liquids within the unsaturated zone results in vapor-phase carbon tetrachloride in soil pores. Due to the density of the carbon tetrachloride vapor, the density of the contaminated vapor phase is greater than uncontaminated vapor in the unsaturated zone. This contrast in densities can result in density-driven advective flow that would move the carbon tetrachloride vapor downward and laterally from the disposal facilities. As the contaminated vapor moves into uncontaminated areas, it may partition into the soil moisture and adsorbed phases and act to establish equilibrium. The carbon tetrachloride vapor may also provide a source of continuous contamination through diffusion into the groundwater. The higher vapor-phase carbon tetrachloride concentrations above the Plio-Pleistocene layer suggest that density-driven advective vapor flow may be significant.

Carbon tetrachloride vapors in the unsaturated zone that equilibrate with waste water from other liquid waste disposal facilities may then be transported to the unconfined aquifer in dissolved form. Carbon tetrachloride may also volatilize from the dissolved groundwater. The contaminant vapors would then move upward by diffusion and may become temporarily trapped below the Plio-Pleistocene confining layer until they find a vertical pathway upward.

Atmospheric pressure fluctuations appear to constitute a significant release mechanism for carbon tetrachloride vapor out of the unsaturated zone both through boreholes and through the soil surface. Based on continuous airflow measurements into and out of boreholes, average carbon tetrachloride concentrations in the vented air, and length of time each well was available as a pathway, an estimated 3% of the original carbon tetrachloride inventory has been lost to the atmosphere since 1955 through borehole venting. The calculated quantity of carbon tetrachloride lost to the atmosphere in 1990 from the soil/air interface, based on diffusion of the vapor phase from the water table to the ground surface, was estimated to be 0.15 $g/m^2/yr$ for the area overlying the groundwater plume. Measured soil flux rates in the vicinity of the 216-Z-9 Trench ranged from 0.0007 to 0.48 $g/m^2/yr$ in 1993. It is estimated that, between 1955 and 1990, 18% of the total carbon tetrachloride inventory was lost to the atmosphere through natural soil flux. Thus, a total of 21% of the carbon tetrachloride may have been released to the atmosphere.

The areal extent of the dissolved carbon tetrachloride groundwater plume has remained about 10 km^2 over the last 3 years. Concentrations of dissolved carbon tetrachloride detected in the groundwater have been estimated to account for approximately 2% of the original carbon tetrachloride inventory. Concentrations of carbon tetrachloride in wells at the perimeter of the plume appear to be increasing, suggesting that the groundwater plume is migrating laterally to the north, west, and south. However, the centroid of the dissolved carbon tetrachloride plume appears to be stationary. The fact that the zone of highest concentrations (4,000 to 7,000 µg/L) includes the 216-Z-9 Trench, which has been inactive since 1962, suggests that the carbon tetrachloride discharged there has been providing a continuous source of contamination to the groundwater. The highest observed groundwater concentration is approximately 1% of the aqueous solubility of carbon tetrachloride.

Groundwater samples from one well indicate that there is deeply distributed carbon tetrachloride near the 216-Z-9 Trench (up to 5,800 µg/L at the top of the aquifer and 3,800 µg/L at 52 m beneath the water table). However, the well itself, which lacked an annular seal until 1987 and has a long perforated interval, may have provided the preferential pathway for the downward migration of contaminants. Nonaqueous-phase liquid carbon tetrachloride has not been observed in the saturated zone.

Currently, an estimated 65% of the original carbon tetrachloride disposal inventory remains unaccounted for. High subsurface vapor concentrations, column-pore volume estimates, and numerical simulations suggest that much of this unaccounted for inventory may be held as residual saturation in soil pores of the unsaturated zone, and/or the saturated zone. A portion of the inventory may have been biodegraded.

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1.0 INTRODUCTION

Carbon tetrachloride was found in the unconfined aquifer beneath the 200 West Area at the Hanford Site in the mid-1980's. Additional groundwater monitoring indicated that the carbon tetrachloride plume was widespread and that concentrations were increasing. In December 1990, the U.S. Environmental Protection Agency and the Washington State Department of Ecology requested the U.S. Department of Energy (DOE) to proceed with detailed planning to implement an expedited response action (ERA) to minimize additional carbon tetrachloride contamination of the groundwater. In January 1991, site investigations in support of an ERA for the site were initiated, and in February 1992, a soil vapor extraction system began to recover carbon tetrachloride from the unsaturated zone. This ERA, a provision of the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*, is being implemented based on concerns that the carbon tetrachloride residing in the soils was continuing to spread to the aquifer and, if left unchecked, would significantly increase the area of groundwater contamination. The purpose of this ERA is to minimize or stabilize the carbon tetrachloride migration within the unsaturated zone beneath and away from the waste disposal facilities in the 200 West Area (DOE-RL 1991).

The Volatile Organic Compounds - Arid Integrated Demonstration (VOC-Arid ID) is a DOE Office of Technology Development program targeted at the acquisition, development, demonstration, and deployment of technologies for evaluation and cleanup of volatile organic compounds (VOCs) and associated contaminants in soils and groundwater at arid DOE sites. Candidate technologies are being demonstrated in the areas of site characterization; performance prediction, monitoring, and evaluation; contaminant extraction and ex situ treatment; in situ remediation; and site closure and monitoring. The initial focus of the VOC-Arid ID is on the carbon tetrachloride that was disposed to the unsaturated zone along with other volatile and nonvolatile organic and aqueous wastes and transuranic radionuclides at the Hanford Site's 200 West Area.

Site investigations have been conducted in support of both the ERA and VOC-Arid ID by Westinghouse Hanford Company (WHC) and Pacific Northwest Laboratory (PNL). These investigations have been fully integrated to promote the efficient use of time and resources and to ensure that each activity provides the maximum usefulness to both programs.

The purpose of this report is to refine the conceptual model of the ERA/VOC-Arid ID carbon tetrachloride site presented by Last and Rohay (1993) using information and data collected during the fiscal year (FY) 1993 site investigations (Rohay et al. 1993a). This report includes background information on the source of the carbon tetrachloride contamination, a description of the environmental setting, and a summary of the results of previous site investigations concerning the nature and extent of the contamination. This information is then used to develop a conceptual model of the carbon tetrachloride site.

Also provided in this report are several appendixes of pertinent background data. Appendix A includes information on the various carbon tetrachloride waste streams and the three primary carbon tetrachloride waste disposal facilities. Appendix B is an update of the geology underlying the carbon tetrachloride disposal sites. Appendix C contains data on water table elevations beneath the site. Appendix D presents a summary of 25 months of baseline soil-gas monitoring. Appendix E contains a final report on a passive soil-gas survey at the site. Appendix F provides schematic well-construction diagrams for the FY 1993 wells. Appendix G contains a complete listing of the volatile organic, chemical, and radiological analyses of both sediment and groundwater samples from the FY 1993 wells. Appendix H contains vertical concentration and physical property profiles for all the FY 1992 and FY 1993 wells. Appendix I lists the average carbon tetrachloride concentrations in 200 West Area groundwater.

2.0 BACKGROUND

The Hanford Site has been a defense materials production complex since 1943. Liquid wastes containing carbon tetrachloride, generated during plutonium recovery processes operated at Z Plant (currently called the Plutonium Finishing Plant), were discharged to nearby subsurface liquid waste disposal facilities from 1955 to 1973. These past discharges have contaminated the underlying soils and groundwater with carbon tetrachloride and other associated hazardous and radioactive wastes. This section of the report describes the location and layout of the ERA/VOC-Arid ID carbon tetrachloride site, the operational history of Z Plant, and the carbon tetrachloride waste disposal facilities. Much of this information was taken from Rohay and Johnson (1991). Detailed disposal inventories are provided in Appendix A.

2.1 LOCATION AND LAYOUT

The Hanford Site is located in south-central Washington State and is portioned into several operational areas (Figure 2-1). The chemical processing areas (200 East and 200 West Areas) are located near the center of the Hanford Site. Z Plant is located in the west-central portion of the 200 West Area (Figure 2-2). The carbon tetrachloride-bearing liquid wastes from Z Plant were discharged to the 216-Z-9 Trench, located east of Z Plant, and to the 216-Z-1A Tile Field and the 216-Z-18 Crib, both located south of Z Plant (Figure 2-3).

2.2 PLUTONIUM FINISHING PLANT OPERATIONS

Z Plant began operations in late 1949 to process plutonium nitrate solutions (extracted from irradiated uranium fuel rods) into final product forms (plutonium oxide and plutonium metal). Each of the three process lines generated side streams that contained recoverable quantities of plutonium. Recuplex and the Plutonium Reclamation Facility (PRF) were established to reclaim plutonium from recoverable solutions and solids and were the primary contributors of carbon tetrachloride to Z Plant soils.

2.2.1 Processes Using Carbon Tetrachloride

Historically, carbon tetrachloride was used, in mixtures with other organics, to recover plutonium from aqueous streams containing plutonium nitrate. Solvent extraction processes using pulse columns were used in PRF and its pilot facility, Recuplex, to recover the plutonium.

The extraction process involved an aqueous feed containing impurities and plutonium entering the bottom of the column, while the dense organic stream entered the top. As the aqueous stream moved upward and the organic stream moved downward in the column, the organic extracted the plutonium from the aqueous stream. The plutonium then left the bottom of the column with the organic, and most of the impurities left the top of the column with the aqueous waste. The plutonium-rich organic then entered another extraction column, where the organic stream was stripped of its plutonium by another aqueous stream. Although the solvent was routinely recycled, it was periodically purged and discharged as waste to the soil column.

Figure 2-1. Location of the ERA/VOC-Arid ID Carbon Tetrachloride Site.

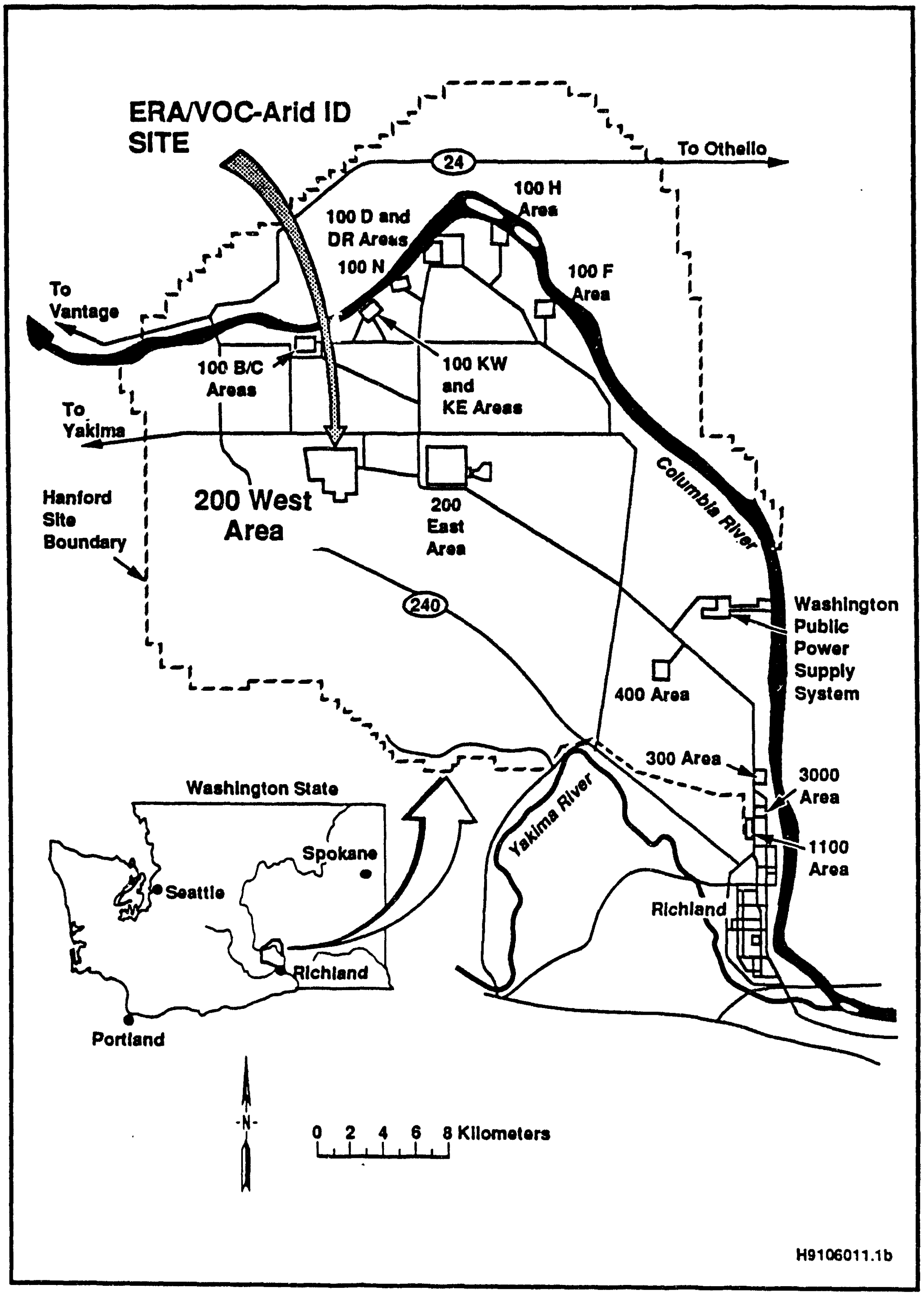


Figure 2-2. Site Map of the 200 West Area.

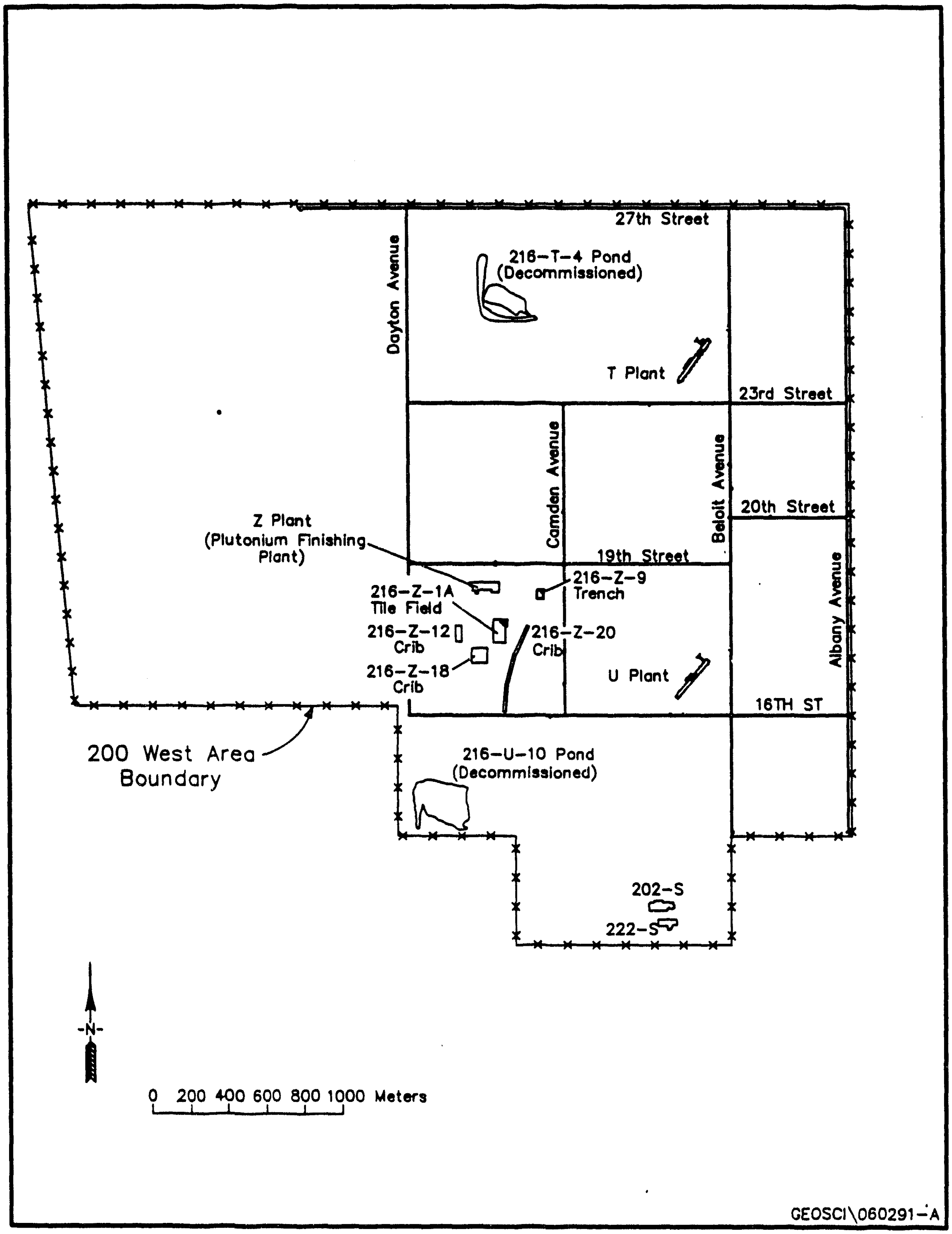
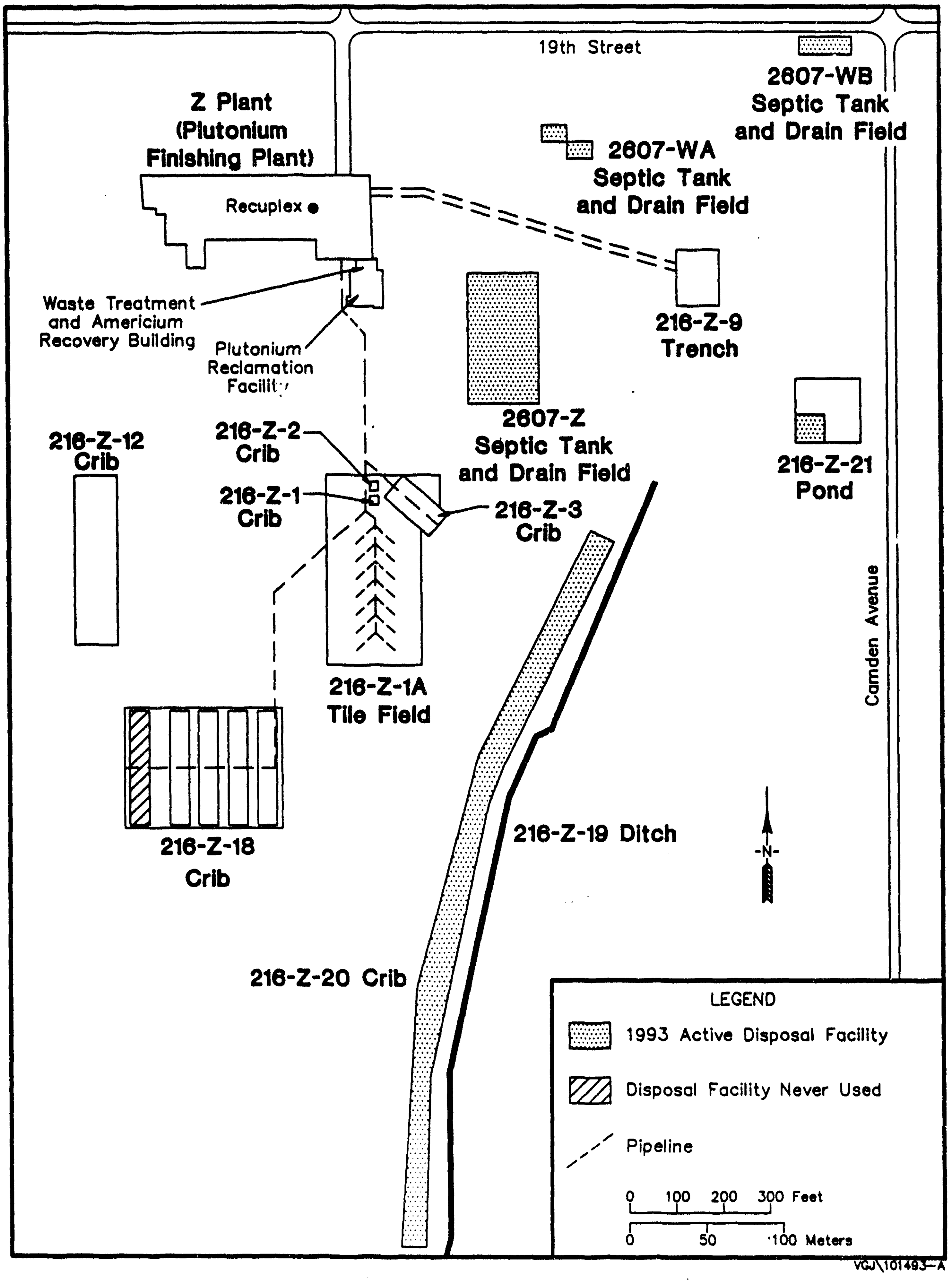


Figure 2-3. Map of the ERA/VOC-Arid ID Carbon Tetrachloride Site.



The organic stream in the process consisted of a mixture of carbon tetrachloride and tributyl phosphate (TBP). The TBP forms several complexes with the plutonium in the organic phase, thus extracting the plutonium from the aqueous phase. The carbon tetrachloride was added as a diluent (meaning that the TBP was diluted with carbon tetrachloride) for several reasons:

1. To increase the density of the organic stream. (TBP alone has a density nearly equal to that of the aqueous stream; the extraction processes require that the aqueous and organic streams have significantly different densities.)

2. To dissolve the TBP while remaining immiscible with the aqueous stream.

3. To serve as a fire suppressant in combination with the TBP, reducing the potential for fire in the process.

4. To reduce the viscosity of the TBP, thus improving mass transfer.

Carbon tetrachloride was also used, in lesser amounts, in the americium recovery process as a diluent for dibutyl butyl phosphonate (DBBP) and in lubrication oil for machining of metal parts.

The aqueous waste stream, characterized as a high-salt aqueous waste, was primarily a concentrated nitrate solution that had a pH of 1 (Kasper 1982). The aqueous phase was saturated with organic liquids consisting of carbon tetrachloride, TBP, and DBBP; the organic content of the aqueous phase was less than 1%. Large quantities of aqueous wastes (neutralized to a pH of 2.5) were also discharged to the soil column through the same cribs that received the organic liquids described above.

The chemical processes used to recover plutonium resulted in the production of actinide-bearing aqueous and organic waste liquids. The primary radionuclide components of these liquids were $^{239/240}$Pu and ^{241}Am.

2.2.2 Recuplex Operations

Recuplex operated from 1955 through 1962 at Z Plant (Figure 2-2). This process used nitric and hydrofluoric acids to produce soluble plutonium as plutonium nitrate and a carbon tetrachloride-TBP solvent to recover the plutonium from the plutonium nitrate solutions (DOE-RL 1992b). A criticality accident forced the closure of Recuplex in April 1962 (DOE-RL 1992b).

Two solvents were used for the entire period of Recuplex operation. An 85:15 ratio (by volume) of carbon tetrachloride to TBP was used in the extraction and stripping columns for the bulk of the separations. A 50:50 ratio of carbon tetrachloride to DBBP was used for batch rework of process liquids that did not meet waste discharge specifications because of plutonium concentrations.

With exposure to ionizing radiation and nitric acid, the TBP within the solvent would gradually degrade to dibutyl phosphate (DBP). DBP has a much greater affinity for plutonium than TBP and would not work in the process because of its poor stripping properties. The degraded solvent was periodically discharged batch-wise and replaced with fresh solvent. The DBBP solution was discharged after each use.

Tetrachloroethylene (PCE) and tetrabromoethane were used at different times in combination with carbon tetrachloride as a diluent for TBP or for cleaning agents (Smith 1973).

Degradation products of carbon tetrachloride include chloroform and methylene chloride. Breakdown products of TBP include DBP, monobutyl phosphate (MBP), and butyl alcohol.

2.2.3 Plutonium Reclamation Facility Operations

The PRF replaced Recuplex in 1964 and operated until 1979 (Figure 2-3). The PRF operated again from 1984 to May 1991, and it is planned to restart in the near future (DOE-RL 1992b). The PRF had essentially the same mission as Recuplex and used similar but superior solvent extraction column technology. An 80:20 ratio (by volume) of carbon tetrachloride to TBP was used as the extractant.

An americium recovery facility, the Waste Treatment and Americium Recovery Facility, was added on to PRF (Figure 2-3) and also began operation in 1964. The process used a 70:30 volumetric mixture of carbon tetrachloride and DBBP. Between 1964 and 1970, americium was recovered by a batch operation. Between 1970 and 1976, this process operated as a continuous countercurrent solvent extraction process. This ancillary waste treatment facility was operated concurrently with PRF and was not considered a separate operation (Rohay and Johnson 1991). This facility was shut down in 1976 after a chemical explosion in an ion-exchange column (DOE-RL 1992b).

2.2.4 Lubrication Oil

Another source of carbon tetrachloride discharged to the soil was in a cutting oil used in Z Plant. "Fabrication oil" (a 75:25 volumetric mixture of carbon tetrachloride and lard oil) was used as a lubricant on Z Plant plutonium cutting and milling tools. In 1967, the composition of stored fabrication oil was estimated to be 50:50 volumetric mixture of carbon tetrachloride and lard oil due to evaporation of carbon tetrachloride (Sloat 1967, Appendix B). The carbon tetrachloride was also used to clean the cutting oil from the millings and work surfaces. The carbon tetrachloride/oil mixture was disposed to the same cribs used for solvent disposal.

2.3 WASTE DISPOSAL FACILITIES

Aqueous and organic wastes from the Recuplex and PRF processes were disposed to the soil column via subsurface infiltration facilities. Wastes from the Recuplex process were discharged from 1955 to 1962 to the 216-Z-9 Trench. Wastes from the PRF were discharged from 1964 to 1969 to the 216-Z-1A Tile Field (and the associated 216-Z-1 and 216-Z-2 Cribs). From 1969 to 1973, these wastes were discharged to the 216-Z-18 Crib. No organic liquid waste was sent to cribs after 1973. The physical design of these liquid waste disposal facilities are described by Rohay and Johnson (1991) and by

Last et al. (1991); schematic drawings of each facility are shown in Figure 2-4. Descriptions of each waste stream, each waste disposal facility, and estimated disposal inventory are given in Appendix A. A summary of the estimated waste inventories is given in Table 2-1. A total of 363,000 to 580,000 L (577,000 to 922,000 kg) of carbon tetrachloride is estimated to have been discharged to the soil column between 1955 and 1973 (Rohay and Johnson 1991). Current inventory calculations presented throughout this report are based on a total estimated discharge quantity of 470,000 L (750,000 kg).

Based on a nuclear and soil analysis of the 216-Z-9 Trench in 1973, the plutonium content of the soil was estimated to be 26 to 69 kg with 38 kg in the top 30 cm of soil. A potential for a criticality incident was recognized, and cadmium nitrate (a neutron absorber) was sprayed onto the trench floor. Subsequent studies determined that the risk of criticality had been less than originally believed. Even so, removal of the top 30 cm of contaminated soil from the trench bottom was viewed as a means of reducing the risk of environmental contamination. This was completed in July 1978 through a mining operation that successfully removed 58 kg of plutonium from the crib floor. The 58 kg of plutonium actually removed in the top 30 cm of soil was 54% higher than the estimated 38 kg. If this 54% correction factor is applied to the total plutonium content of the trench, at most 106 kg was originally present and 48 kg still remains (Ludowise 1978). The site still contains equipment from these mining operations (Owens 1981).

The 11,000 L of aqueous cadmium nitrate solution sprayed on the soil at the 216-Z-9 Ditch contributed 11 kg of cadmium to the soil. Tests in 1973 indicated that the bulk of the cadmium solution was retained in the top 30 cm of soil (Smith 1973). Therefore, a significant proportion of the cadmium was probably removed during the 1976-1978 mining operations.

Three other sites in the vicinity of Z Plant probably received some carbon tetrachloride wastes: the 216-Z-12 Crib, the 216-Z-19 Ditch, and the 216-T-19 Crib (Figure 2-3; 216-T-19 is north of the area shown). The 216-Z-12 Crib received analytical and development laboratory waste from Z Plant from 1959 to 1973 and is estimated to have received a small volume of organics including carbon tetrachloride (Kasper 1981). The 216-Z-19 Ditch was used to convey process cooling water and steam condensate from Z Plant from 1971 to 1981; apparently, carbon tetrachloride was also occasionally or accidentally released to this ditch (Rohay and Johnson 1991). The 216-T-19 Crib received approximately 880 L of carbon tetrachloride between 1973 and 1976 in the overhead condensate discharged from the 242-T evaporator (Rohay et al. 1993b).

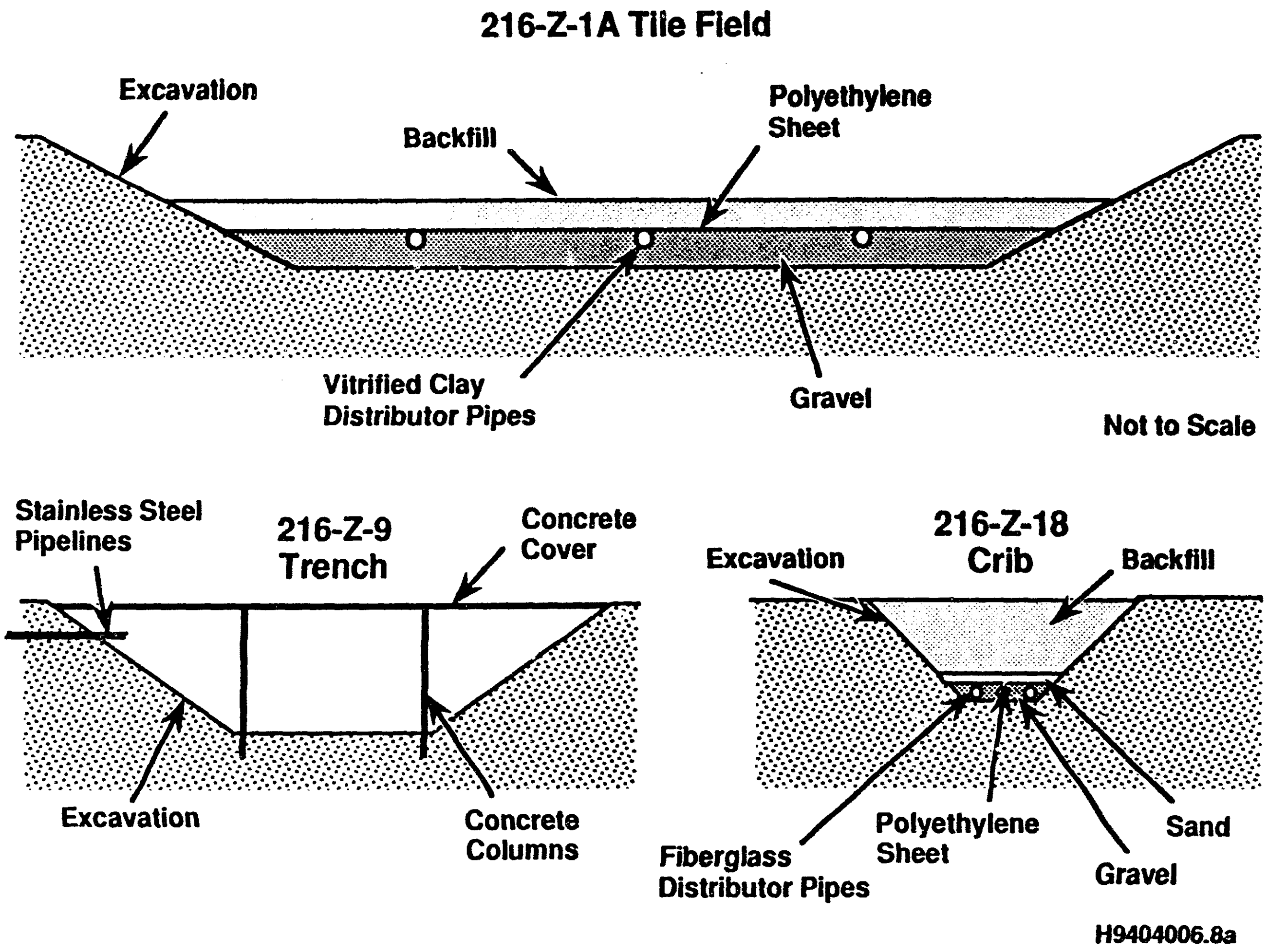


Figure 2-4. Schematic Design of the 216-Z-1A Tile Field, 216-Z-9 Trench, and 216-Z-18 Crib.

Table 2-1. Waste Constituent Inventory Summary for the Three Carbon Tetrachloride Disposal Facilities.

Facility	Operating dates	Waste source	Total volume (L)	Plutonium (kg)	Americium (kg)	CCl_4 (L)	TBP (L)	DBBP (L)	Lard oil (L)
216-Z-9	1955 to 1962	Recuplex	4.09E+06	106[a]	2.5	8.3E+04 to 3.00E+05	2.79E+04	4.65E+04	9.30E+03
216-Z-1A	1949 to 1959	Z Plant crib overflow	1.00E+06	0.05	ND	ND	ND	ND	ND
	1964 to 1969	Plutonium Reclamation Facility	5.20E+06	57	1	1.7E+05[b]	2.39E+04	2.75E+04	1.10E+04
216-Z-18	1969 to 1973	Plutonium Reclamation Facility	3.86E+06	23	0.4	1.10E+05	1.64E+04	1.91E+04	ND
Total			1.42E+07	186	3.0	3.63E+05 to 5.80E+05	6.82E+04	9.31E+04	2.03E+04

[a] 58 kg were later removed.

[b] Includes lard oil.

CCl_4 = carbon tetrachloride; DBBP = dibutyl butyl phosphonate; TBP = tributyl phosphate.

ND = no data available.

Based on information from Owens (1981), Rohay and Johnson (1991), DOE-RL (1992b), and Piepho et al. (1993).

3.0 ENVIRONMENTAL SETTING

This chapter describes the meteorology, geology, and hydrogeology of the ERA/VOC-Arid ID carbon tetrachloride site.

3.1 METEOROLOGY

The Hanford Site lies in a rainshadow on the east side of the Cascade Range, which results in its semiarid climate. The weather is monitored and recorded at the Hanford Meteorological Station, located 2.5 km northeast of the ERA/VOC-Arid ID site. The Hanford Site receives an annual average of 16 cm of precipitation, approximately half falling between November and February. The average yearly humidity at the Hanford Site between 1946 to 1980 was 54.4%, with a low of 32.2% in July and a high of 80% in December (Stone et al. 1983). The prevailing northwest winds result from cold air drainage out of the Cascade Range. Mean monthly wind speed from 1946 to 1980 averaged 3.4 m/s, with peak gust speeds from 28 to 36 m/s. Minimum winter temperatures vary from -33 °C to -6 °C, and maximum summer temperatures vary from 38 °C to 46 °C.

The average atmospheric pressure for the site is 29.2 in. of mercury. In general, the atmospheric pressure is higher in winter than in summer, although both the highest and lowest recorded pressures at the Hanford Site occurred during winter (DOE 1988). In 1990, average daily barometric pressure measured at the Hanford Meteorological Station ranged from approximately 28.6 to 29.9 in. of mercury (DOE-RL 1991).

3.2 GEOLOGY

The Hanford Site is situated within the Pasco Basin, a structural depression in the Columbia Plateau, which accumulated thick deposits of Miocene continental flood basalts and younger sediments. The Pasco Basin is locally bisected by the Gable Mountain anticline (Figure 3-1). The Hanford Site's 200 West Area, containing the ERA/VOC-Arid ID carbon tetrachloride site, is situated south of this anticline on the generally southward-dipping limb of the Cold Creek syncline. The ERA/VOC-Arid ID site lies at an elevation of approximately 200 m above mean sea level. The surface topography of the ERA/VOC-Arid ID carbon tetrachloride site (Figure 3-2) reflects numerous excavation and construction activities associated with nuclear materials production and waste management practices.

The subsurface geology of the ERA/VOC-Arid ID carbon tetrachloride site consists of a thick accumulation (>150 m) of clastic sedimentary deposits overlying the Miocene Columbia River Basalt Group. These suprabasalt sediments include lithologic units assigned to the late Miocene to Pliocene Ringold Formation, the Plio-Pleistocene unit, and the Pleistocene Hanford formation (informal name). A thin veneer of Holocene eolian sand locally overlies the Hanford formation.

Figure 3-1. Structural Geology of the Hanford Site.

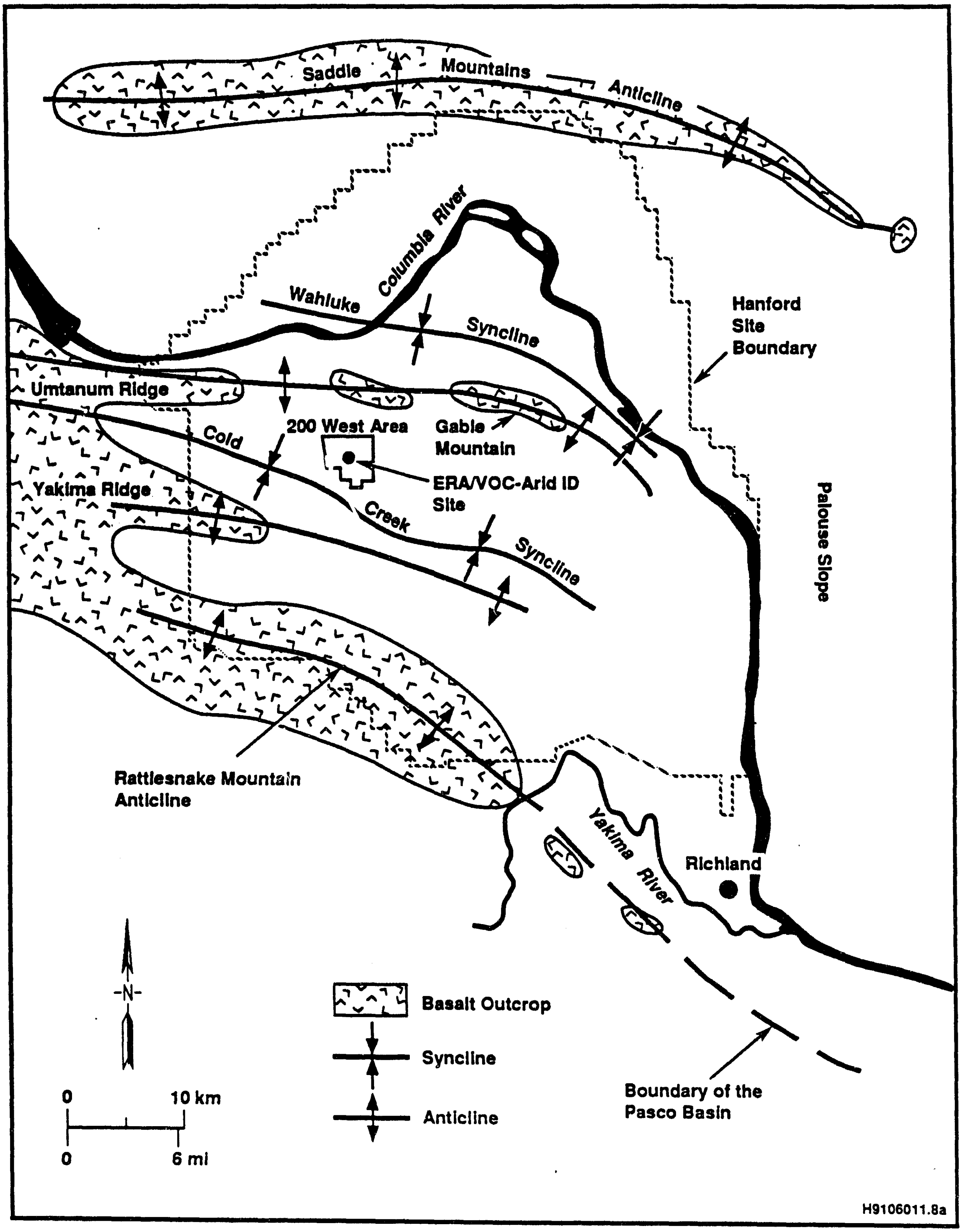
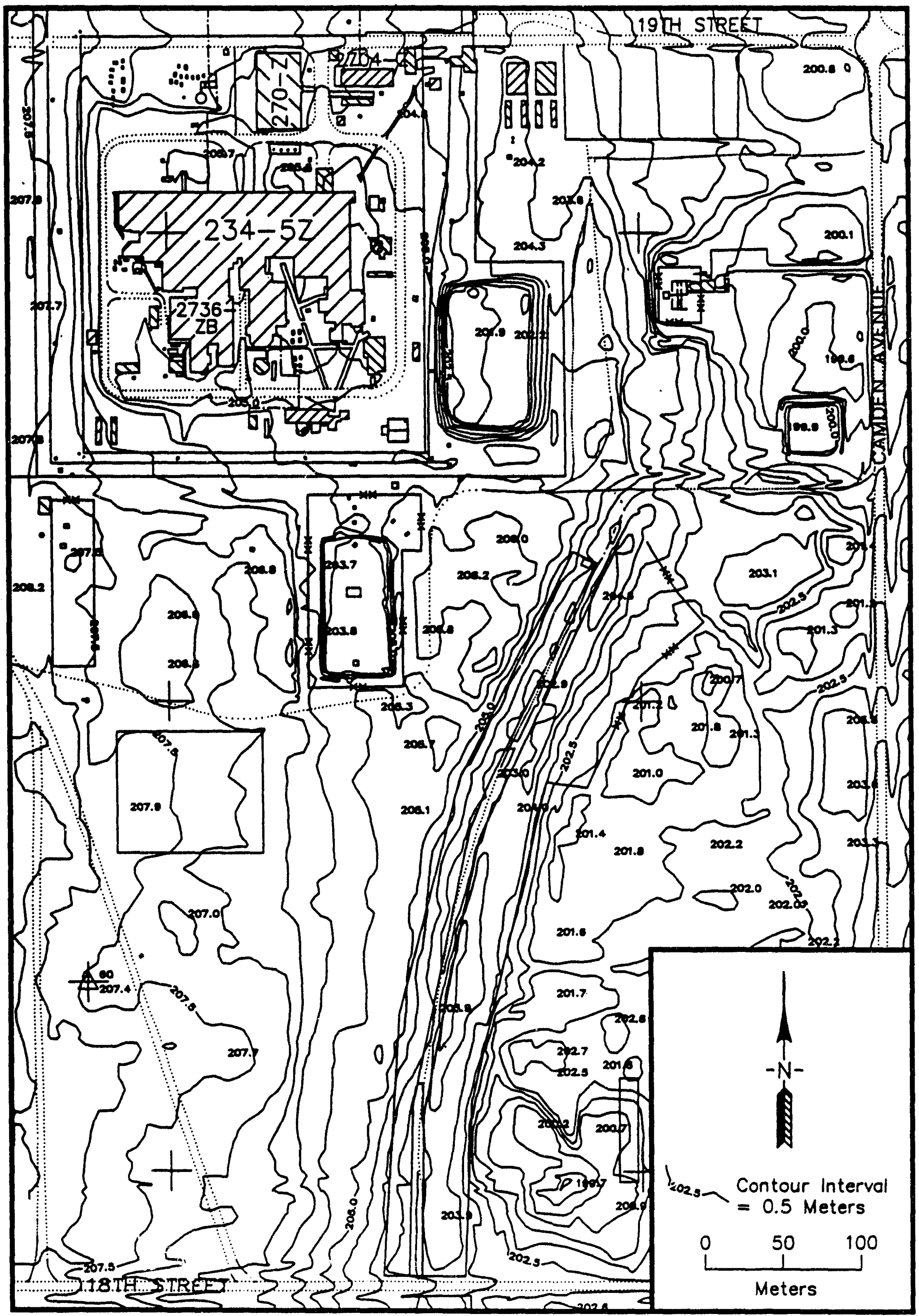


Figure 3-2. Topography of the ERA/VOC-Arid ID Carbon Tetrachloride Site.



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The lithologic and stratigraphic relationships beneath the site have been refined from previous interpretations (DOE-RL 1991, 1992; Last et al. 1991; WHC 1992; Last and Rohay 1993; Rohay et al. 1993a; Singleton and Lindsey 1994), data from recently completed boreholes, and further interpretation of data from existing boreholes in the immediate vicinity of the site (Figure 3-3). Figure 3-4 illustrates the general stratigraphy and nomenclature of the principal geologic units. The lithology (i.e., composition, grain size, sorting, porosity, cementation) and stratigraphic relationships between the geologic units beneath the site and the updated surface (structure-contour) and isopach (thickness) maps of the principal stratigraphic units are given in Appendix B. The quality and quantity of borehole data vary greatly from borehole to borehole and are subject to multiple interpretations. In addition, many of the boreholes have not been accurately surveyed, resulting in uncertain elevations of the various geologic contacts by as much as a few meters. NOTE: Existing wells are currently being surveyed, and additional evaluation of borehole data in combination with detailed examination of archived sediment samples should reduce these uncertainties.

3.3 HYDROGEOLOGY

The hydrogeology of the site is dominated by a thick, unsaturated zone (vadose zone) within the Hanford formation, Plio-Pleistocene unit, and upper Ringold Formation; an unconfined aquifer system within the Ringold Formation; and a system of confined aquifers within the Columbia River Basalt Group. Of primary interest to this study is the movement of water and contaminants within the unsaturated zone and the uppermost unconfined aquifer.

Groundwater flow in the unconfined aquifer is from areas of natural recharge from precipitation on and adjacent to basaltic ridges primarily west of the 200 West Area toward points of discharge to the east along the Columbia River. The annual natural recharge in and near the 200 Areas has been estimated (Gee 1987, Routson and Johnson 1990, Murphy et al. 1991) as near zero (0.1 cm/yr) in areas with established vegetation and fine-grained soils. However, in areas devoid of vegetation and having coarse-grained or gravel-covered soils, much of the annual precipitation (as much as 10 cm/yr) may drain to the water table. Artificial recharge to the unconfined aquifer occurs in both the 200 West and 200 East Areas from discharge of waste streams and cooling water to the soil column. In the past, artificial recharge was estimated to be approximately 10 times the natural recharge at the Hanford Site (Graham et al. 1981). The major source of artificial recharge in the 200 West Area has been the 216-U-10 Pond (U Pond), which was decommissioned in 1984 (Figure 2-2). Recently, waste water discharges to the soil column have been significantly reduced.

Figure 3-3. Location of Wells at the ERA/VOC-Arid ID Carbon Tetrachloride Site.

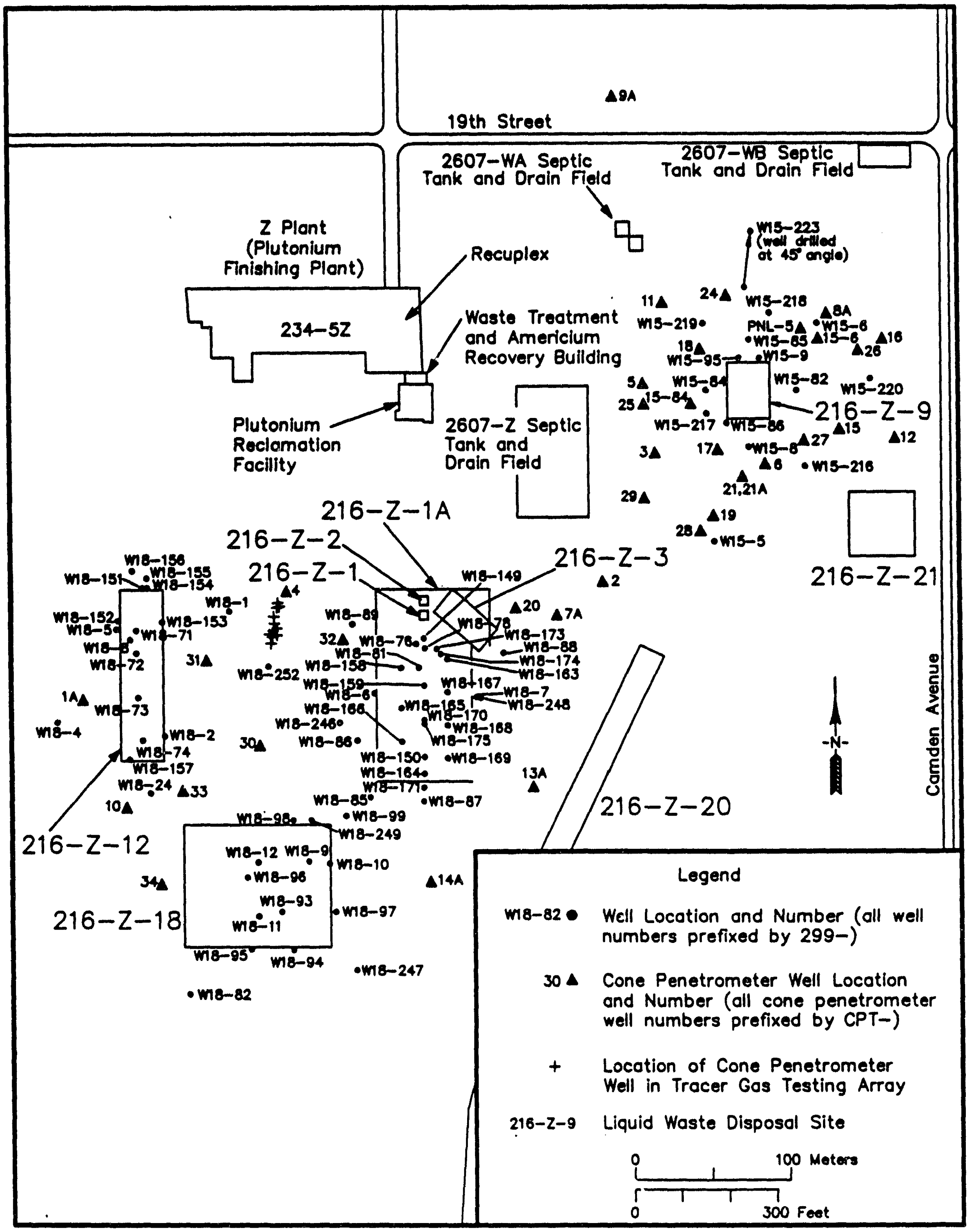

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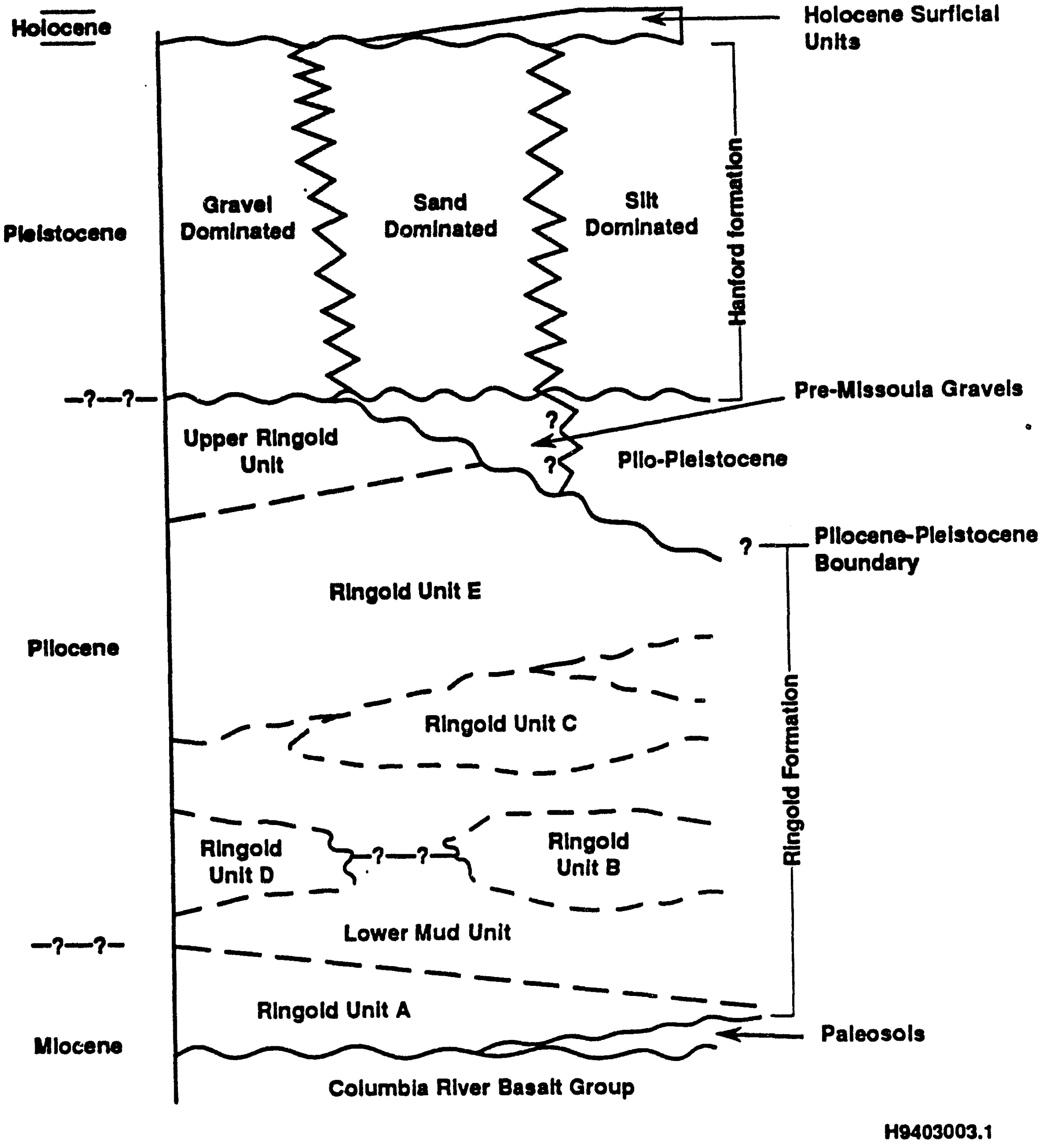
Figure 3-4. Stratigraphic Nomenclature for Geologic Units Beneath the ERA/VOC-Arid ID Carbon Tetrachloride Site.



3.3.1 Local Recharge

Several local sources of artificial recharge are present within the vicinity of the carbon tetrachloride disposal sites. These sources of recharge include two active liquid waste disposal sites (216-Z-20 Crib and 216-Z-21 Pond) and three sanitary tile fields (Figure 2-3). Current annual discharge rates to these facilities are estimated as follows:

Facility	Annual Discharge (L/yr)
216-Z-20 Crib	9.5 E+07[a]
216-Z-21 Pond	9.8 E+07[b]
2607-Z Drain Field	8.4 E+06 to 1.5 E+07[b]
2607-WA Drain Field	2.2 E+06[c]
2607-WB Drain Field	Unknown

---

[a] Johnson (1993b).
[b] Rohay and Johnson (1991).
[c] DOE-RL (1992b).

3.3.2 Unsaturated Zone

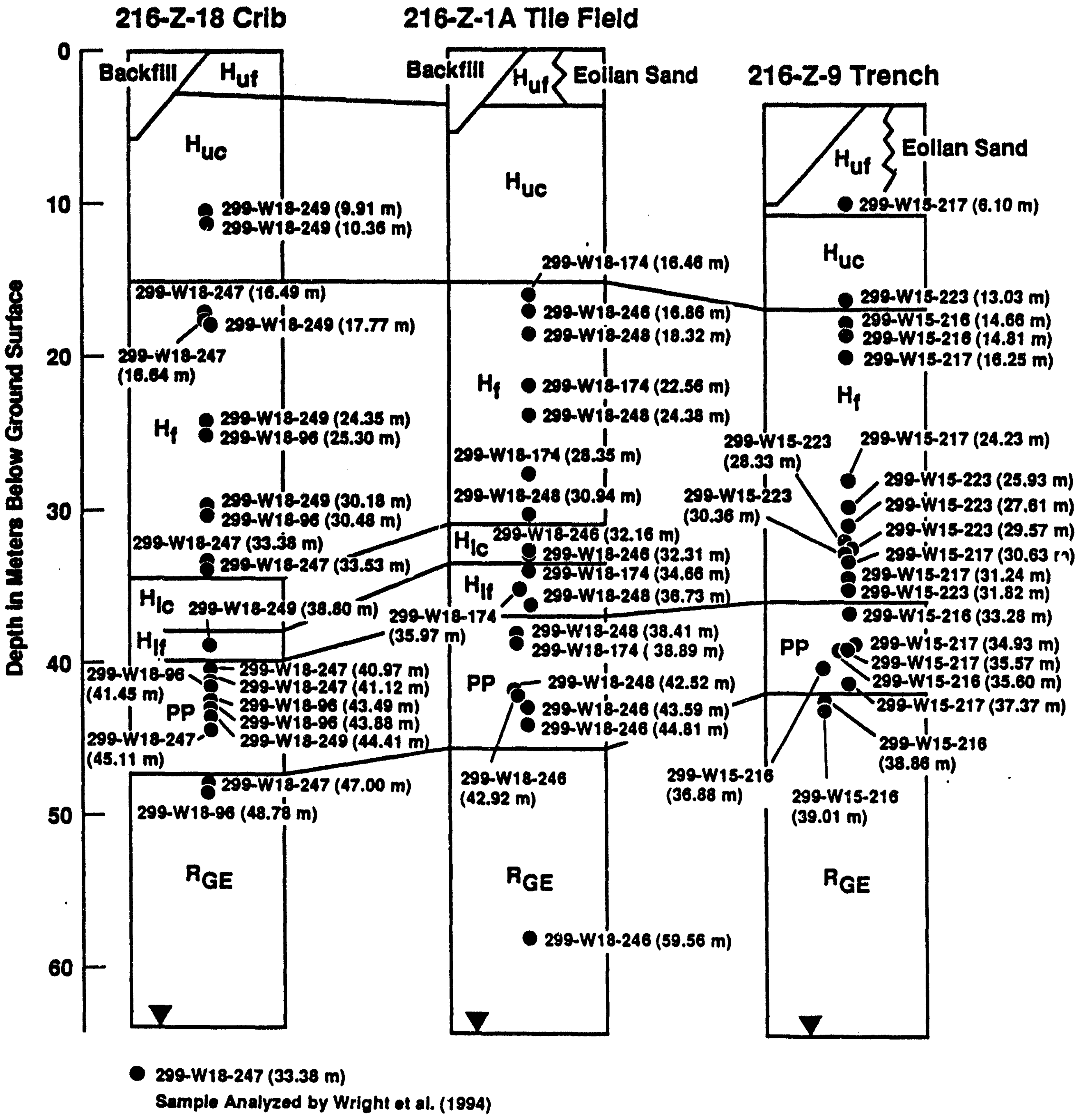
The unsaturated zone beneath the site ranges in thickness from 60 to 71 m. The geologic units found beneath this site have a wide range of textures (Appendix B) and, thus, a wide range of hydraulic properties are expected. For discussion purposes, the unsaturated zone has been divided into seven hydrogeologic units (hydrofacies) based on the stratigraphic facies. These hydrogeologic units are, in descending order (Figure 3-5):

H_{uf} - Hanford gravelly sand and sand (upper fine unit)
H_{uc} - Hanford gravels (upper coarse unit)
H_f - Hanford sand (fine unit)
H_{lc} - Hanford sandy gravel (lower coarse unit)
H_{lf} - Hanford interbedded silt and fine sand (lower fine unit)
PP - Plio-Pleistocene unit (caliche)
R_{ge} - Ringold gravel unit E (unsaturated).

The thickness and configuration of these units vary beneath each of the three contaminant sources of interest (216-Z-1A, 216-Z-9, and 216-Z-18) and are discussed in detail in Appendix B. Figure 3-6 illustrates the general configuration of geologic materials beneath the carbon tetrachloride disposal sites.

Calcium carbonate and moisture contents were determined for nearly 500 samples from 13 boreholes drilled during FY 1992 and FY 1993. The data are tabulated in Rohay et al. (1992a, 1993a, respectively) and used to create vertical profiles for each well in Appendix H. Additional measurements of air permeability, porosity, bulk density, and saturated hydraulic conductivity were made on selected samples from two wells, 299-W18-174 within the 216-Z-1A Tile Field and 299-W18-96 within the 216-Z-18 Crib (Rohay et al. 1993a).

Figure 3-5. Hydrogeologic Units of the Unsaturated Zone Beneath the Carbon Tetrachloride Disposal Sites.



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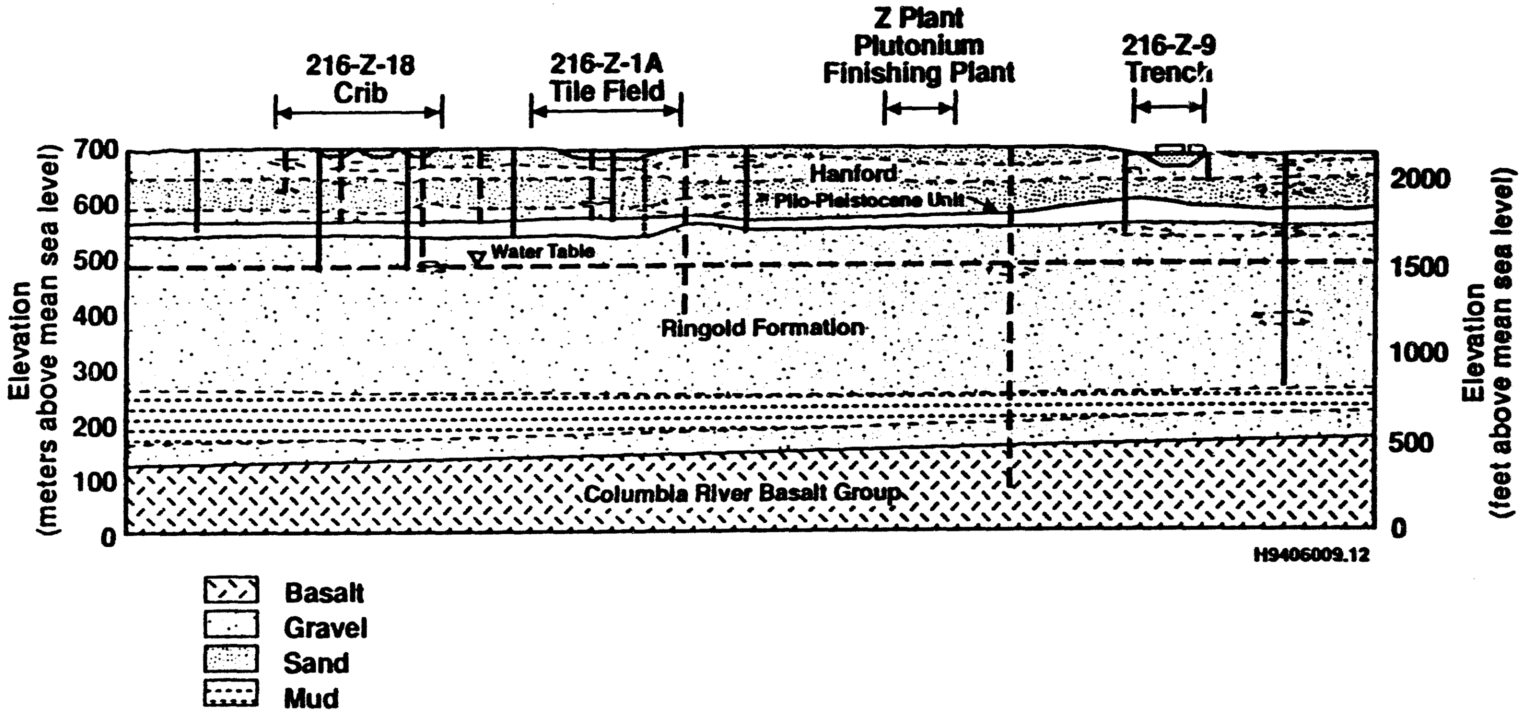


Figure 3-6. Generalized Southwest-Northeast Geologic Cross Section Through the Carbon Tetrachloride Disposal Sites.

The attenuation and delay of a barometric pressure wave as it propagates through the unsaturated zone soils appears to be influenced by the depths and permeabilities of the soil layers through which it moves. This results in pressure differentials in the subsurface between the barometric pressure and the soil pressure. Differential pressure data collected from above and below the relatively impermeable Plio-Pleistocene caliche layer within well 299-W18-247 show the effect of this layer on wave propagation (Figure 3-7). The well is sealed between the open intervals. The data show similar results between the upper interval (36- to 39-m depth) and the barometric pressure, indicating that the attenuation or delay of the pressure wave is minimal through the upper zone of relatively permeable sands and gravels (Figure 3-7). However, the differential between the lower interval (49 to 52 m) pressure and barometric pressure shows a delay and strong attenuation. The attenuation is most likely the result of the intervening caliche layer, which can be considered partially opaque to the pressure wave (Rohay et al. 1993b). Additional differential pressure data collected in the same way from above and below the Plio-Pleistocene layer in well 299-W18-252 and from several subsurface monitoring probes in the same area also show the dramatic effect of the caliche layer (Table 3-1).

The physical properties, including bulk density, field moisture content, particle-size distribution, and unsaturated hydraulic conductivity, of 62 samples collected from 9 boreholes installed during FY 1992 and FY 1993 were reported by Wright et al. (1994). These samples represent all seven hydrogeologic units (Figure 3-5). A summary of the major particle sizes and field moisture contents for these units is presented in Table 3-2. Figures 3-8 through 3-12 illustrate the hydraulic conductivity curves (unsaturated hydraulic conductivities at various moisture contents) of five of these units (Wright et al. 1994). Wright et al. (1994) also provide mineralogical compositions, determined using x-ray diffraction and optical microscopy, for two size fractions for each sample: for silt- and sand-sized particles (>2 μm) and for clay-sized particles (<2 μm).

Based on this hydraulic conductivity data, Wright et al. (1994) prepared a generalized hydrostratigraphic cross section through the carbon tetrachloride disposal sites (Figure 3-13). They used the data to define four regions of hydraulic behavior (Figure 3-13 inset) and assigned each sample to its appropriate region. In general, the hydrostratigraphic units correspond to the lithostratigraphic units (Wright et al. 1994).

Field percolation tests were conducted in the early 1980's in the immediate vicinity of the 216-Z-20 Crib (Last and Rohay 1993). Based on the ponded infiltration rates during these tests and assuming a unit hydraulic gradient, hydraulic conductivities for the upper Hanford formation materials were calculated and were found to range from 2.0×10^{-2} to 3.5×10^{-3} cm/s, over a volumetric water content range of 35% to 23.4%.

The field moisture content and unsaturated hydraulic conductivity curve for each sample were used to determine the subsurface flux (recharge) into that sample prior to sampling. The subsurface flux was then compared to the expected natural recharge rate for arid soils in this region to indicate whether the sample had been affected by artificial recharge (Wright et al. 1994). Based on these comparisons, Wright et al. (1994) inferred a moisture plume from the waste disposal facilities (Figure 3-14).

Figure 3-7. Effect of Relatively Impermeable Plio-Pleistocene Layer on Attenuation of Barometric Pressure Wave in Well 299-W18-247.

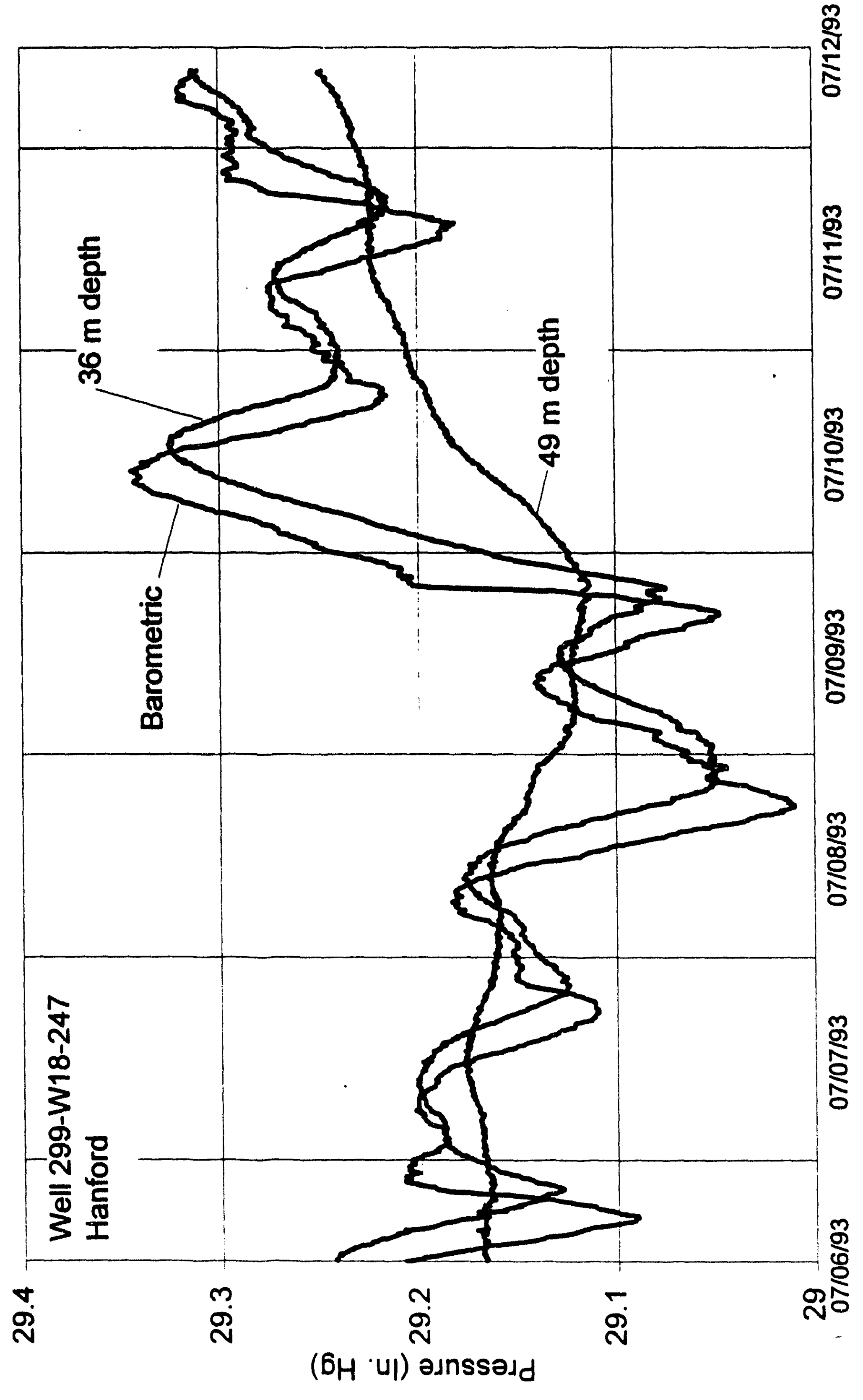


Table 3-1. Summary of Soil Pressure Data.

Location	Sealed well/soil probe	Depth of interval (m)	Included dates	Average differential pressure[a]	Maximum differential pressure[a]
W18-247U	Sealed well	36 - 39	11/1/93 - 12/15/93	0.06	0.59
W18-247L	Sealed well	49 - 52	11/1/93 - 12/31/94	1.97	5.82
W18-252U	Sealed well	34.5 - 40.5	11/1/93 - 12/31/93	0.31	1.58
W18-252L	Sealed well	50 - 56	11/1/93 - 11/30/93	1.70	6.59
CPT4A/50	Soil probe	15	11/1/93 - 12/31/93	0.24	.83
CPT4A/75	Soil probe	23	11/1/93 - 12/31/93	0.36	1.46
CPT4A/109	Soil probe	33	11/1/93 - 12/31/93	0.44	1.99

[a] Pressures included in calculating the average and maximum pressures include only the positive differential pressures (soil pressure greater than the barometric pressure).

Table 3-2. Physical Properties of Unsaturated Zone Sediments.

Well No.	Depth	Hydrogeo	Bulk	Field	Gravel	Sand	Silt	Clay
		Unit	Density	Moisture				
	m		g/cc	Vol. %	%	%	%	%
W15-216	14.66	Hf	1.55	5.92	3	90	5	2
	14.81	Hf	1.64	4.95	2	94	4	0.5
	33.28	PP silt	1.71	38.51	0	37	56	7
	35.60	PP carb	1.49	20.67	49	32	13	6
	36.88	Rge	1.94	5.78	31	30	33	6
	38.86	Rge	1.90	10.7	28	56	14	2
	39.01	Rge	1.82	16.74	30	53	15	2
W15-217	6.10	Huf	2.01	5.47	55	39	5	1
	16.25	Hf	1.61	9.47	2	90	5	3
	24.23	Hf	1.52	4.56	2	87	9	2
	30.63	Hf	1.54	7.27	0	89	10	1
	31.24	Hf	1.57	7.6	NA	NA	NA	NA
	34.93	PP silt	1.79	9.66	0.3	81	16	3
	35.57	PP silt	1.73	31.88	0	1	85	14
	37.37	PP carb	1.48	24.43	NA	NA	NA	NA
W15-223	13.03	Huc	1.63	4.62	NA	NA	NA	NA
	25.93	Hf	1.68	5.89	NA	NA	NA	NA
	27.61	Hf	1.62	5.26	NA	NA	NA	NA
	28.33	Hf	1.43	11.99	NA	NA	NA	NA
	29.57	Hf	1.76	8.57	NA	NA	NA	NA
	30.36	Hf	1.42	6.78	NA	NA	NA	NA
	31.82	Hf	1.77	1.77	NA	NA	NA	NA
W18-96	25.30	Hf	1.50	NA	NA	NA	NA	NA
	30.48	Hf	1.49	NA	NA	NA	NA	NA
	41.45	PP silt	1.73	NA	NA	NA	NA	NA
	43.49	PP silt	1.75	NA	NA	NA	NA	NA
	43.88	PP silt	1.63	NA	NA	NA	NA	NA
	48.78	PP silt	1.58	NA	NA	NA	NA	NA
W18-174	16.46	Hf	1.38	NA	NA	NA	NA	NA
	22.56	Hf	1.59	NA	NA	NA	NA	NA
	28.35	Hlc	1.92	NA	NA	NA	NA	NA
	34.66	Hlf	1.73	NA	NA	NA	NA	NA
	35.97	Hlf	1.73	NA	NA	NA	NA	NA
	38.89	PP silt	1.63	NA	NA	NA	NA	NA
W18-246	16.86	Hf	1.51	8.20	0	88	11	1
	32.16	Hlc	1.66	5.26	40	55	4	1
	32.31	Hlc	1.81	5.05	64	32	4	0.25
	42.92	PP silt	1.66	26.33	1	19	77	3
	43.59	PP silt	1.65	8.15	0	16	76	8
	44.81	PP carb	1.66	16.07	20	63	14	3
	59.56	Rge	2.00	3.35	74	21	5	0.3
W18-247	16.49	Hf	1.51	7.08	0.2	88	7	4
	16.64	Hf	1.21	16.34	0	66	32	2
	33.38	Hf	1.63	5.15	3	93	2	2
	33.53	Hf	1.68	1.47	7	89	3	1
	40.97	PP silt	1.27	8.17	0	44	53	3
	41.12	PP silt	1.65	37.00	0	15	75	10
	45.11	PP carb	1.76	34.7	35	36	20	9
	47.00	Rge	1.59	17.64	1	92	4	3
W18-248	18.32	Hf	1.58	11.60	0	63	34	3
	24.38	Hf	1.45	9.76	1	84	14	1
	30.94	Hlf	1.60	8.98	5	64	28	3
	36.73	Hlf	1.49	6.07	0	86	12	2
	38.41	PP silt	1.59	8.64	0	71	26	3
	42.52	PP carb	1.64	24.12	0	8	89	3
W18-249	9.91	Huc	1.79	5.66	25	71	3.5	0.5
	10.36	Huc	1.82	5.01	7	85	7	1
	17.77	Hf	1.94	19.65	49	36	13	2
	24.35	Hf	1.66	7.37	1	88	10	1
	30.18	Hf	1.83	4.45	0	84	14	2
	38.80	Hlf	1.72	11.82	2	60	35	3
	44.41	PP carb	1.64	31.17	15	53	25	7

Figure 3-8. Hydraulic Conductivity Curves for the Hanford Formation Upper Coarse (H_{uc}) and Lower Coarse (H_{lc}) Units (after Wright et al. 1994).

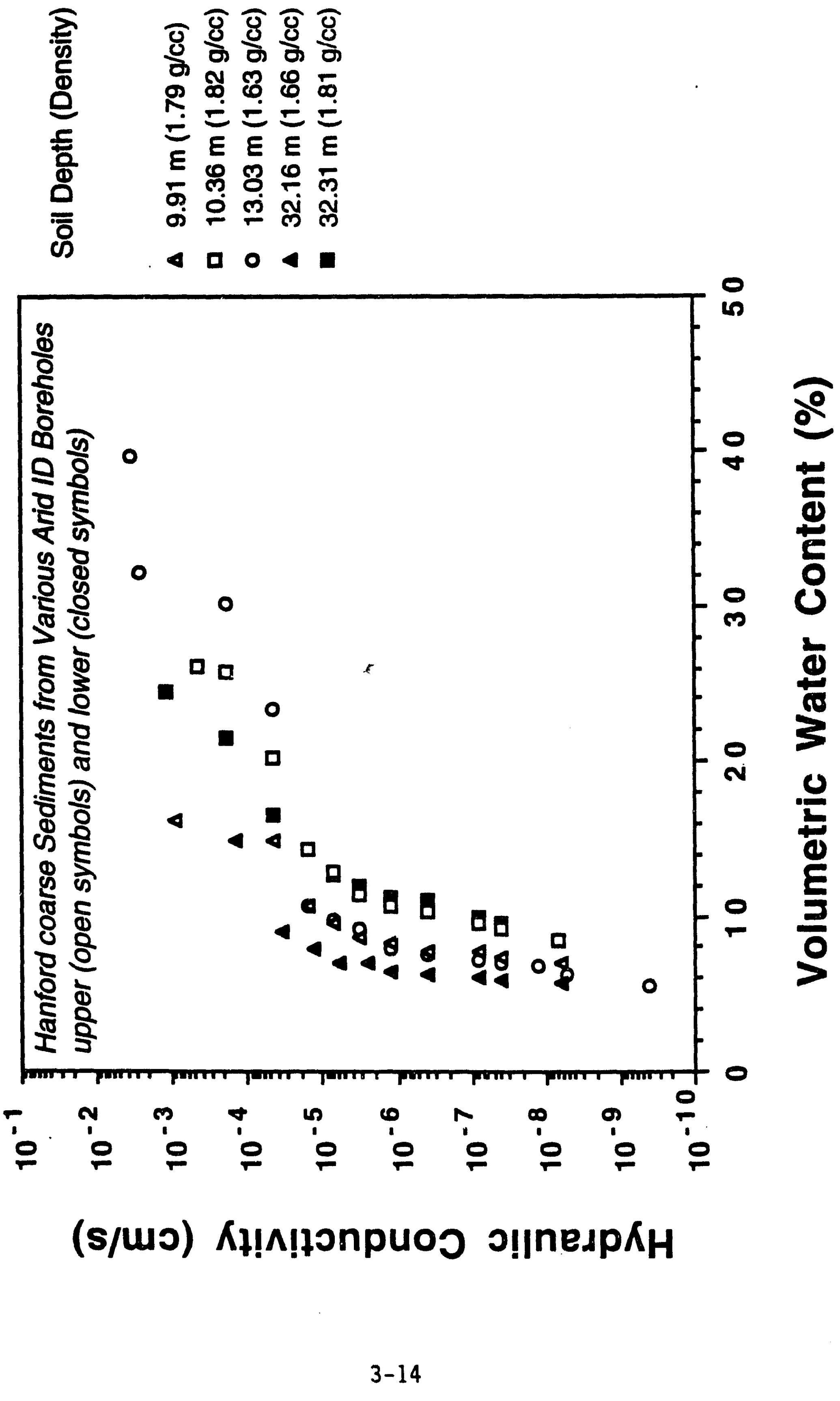
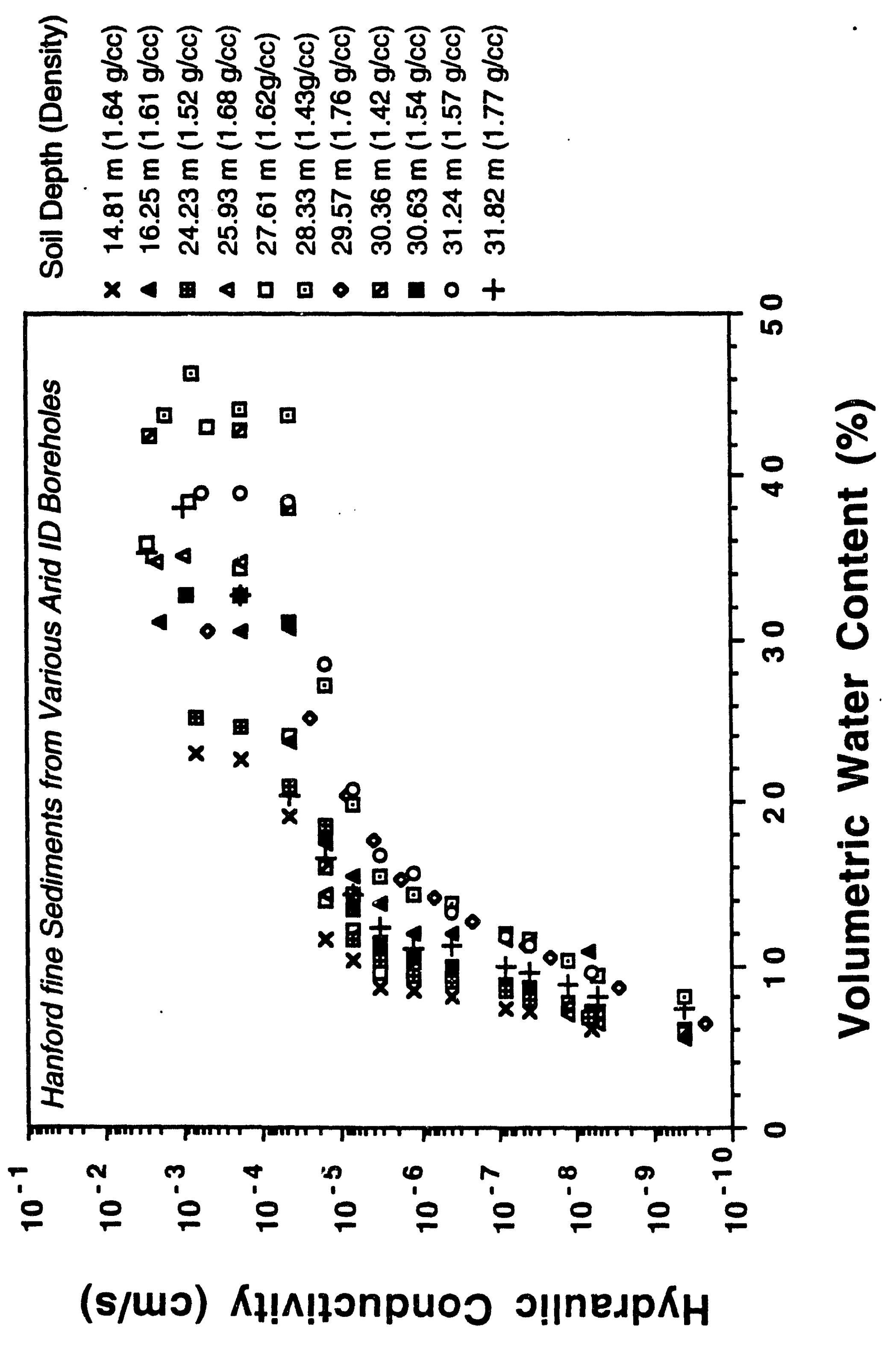


Figure 3-9. Hydraulic Conductivity Curves for the Hanford Formation Fine (H_f) Unit (after Wright et al. 1994).



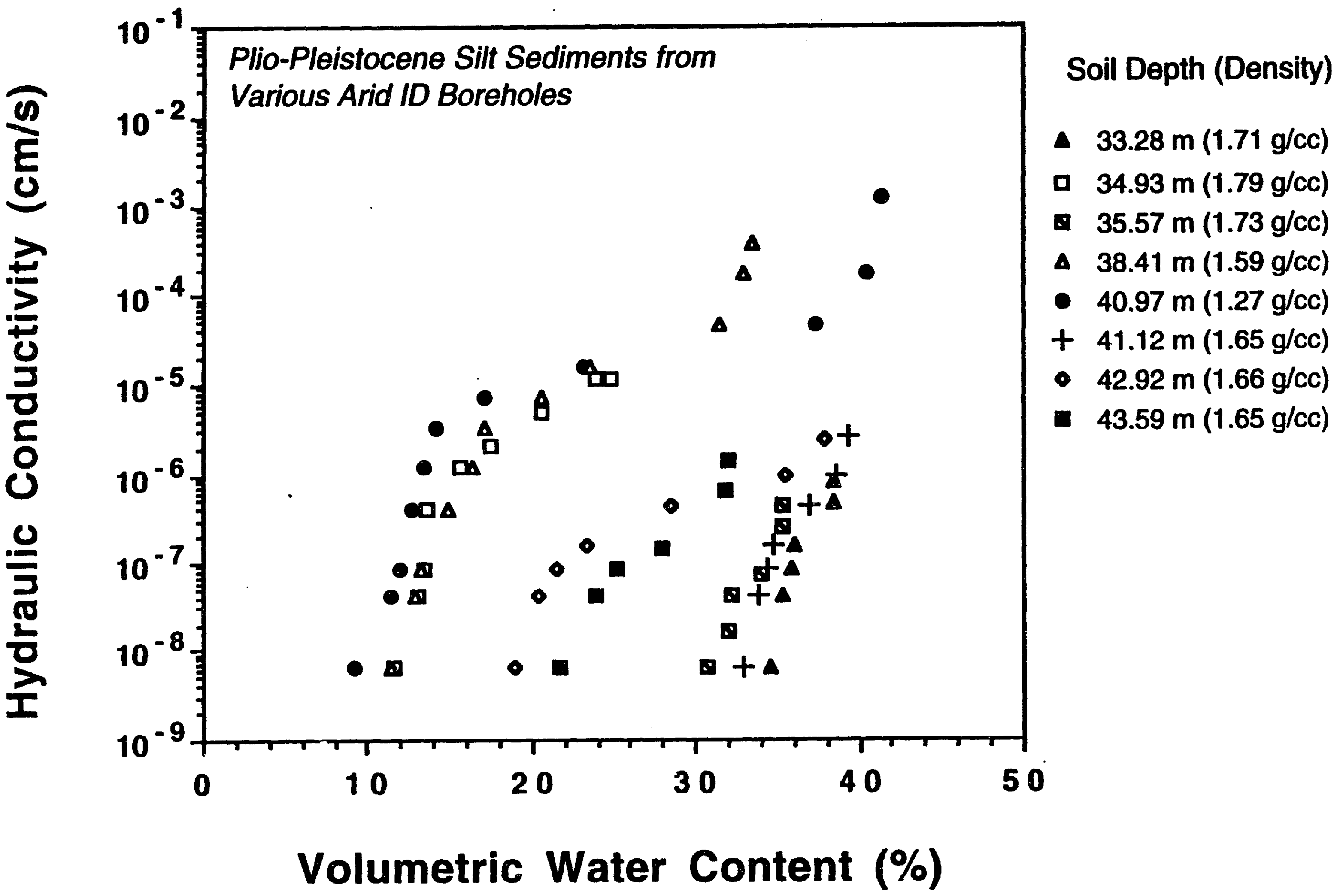


Figure 3-10. Hydraulic Conductivity Curves for the Plio-Pleistocene Unit Silt Deposits (PP_{silt}) (after Wright et al. 1994).

Figure 3-11. Hydraulic Conductivity Curves for the Plio-Pleistocene Unit Calcium Carbonate Deposits (PP_{carb}) (after Wright et al. 1994).

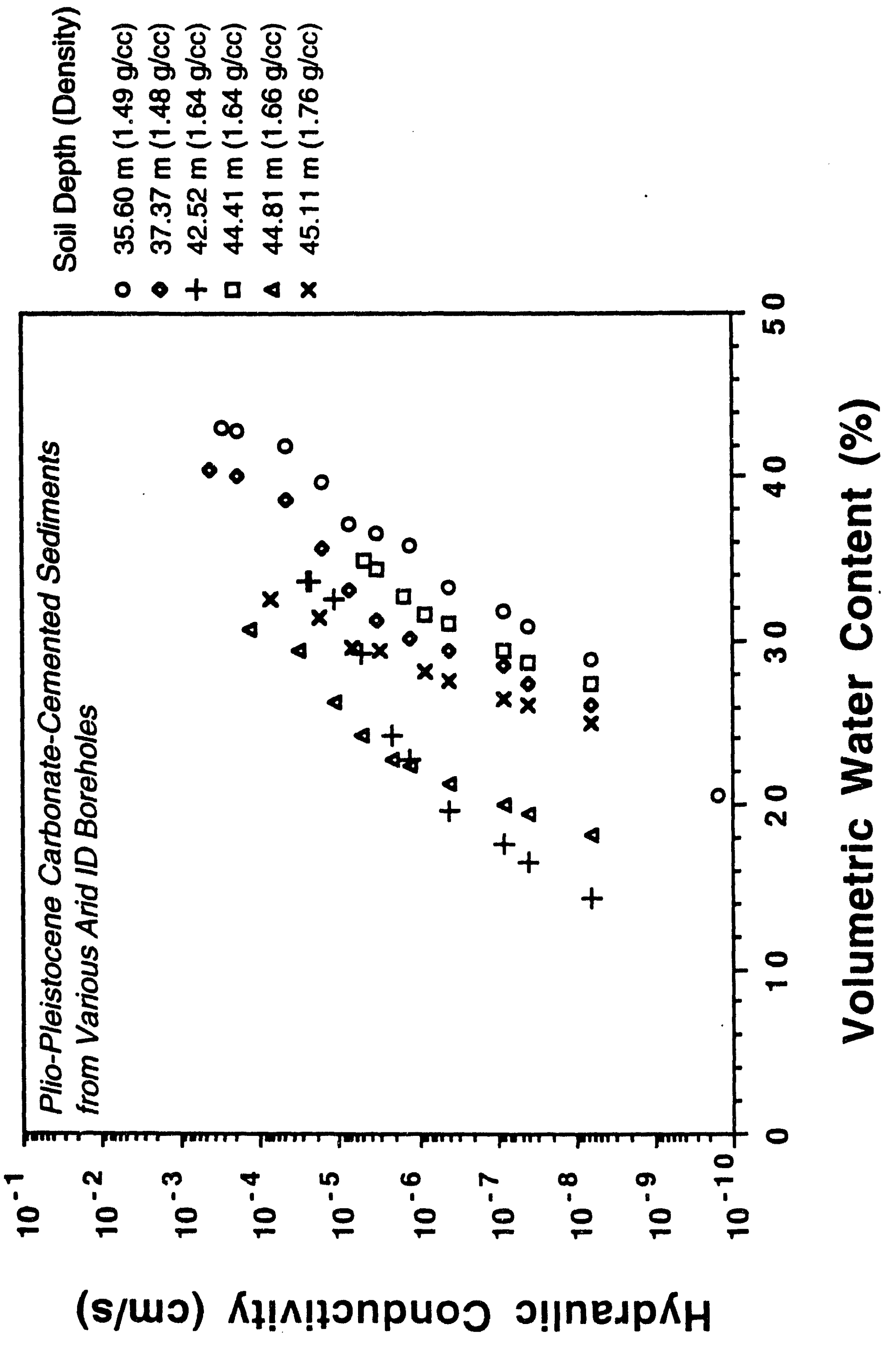


Figure 3-12. Hydraulic Conductivity Curves for the Ringold Formation Gravel Unit E (R_{ge}) (after Wright et al. 1994).

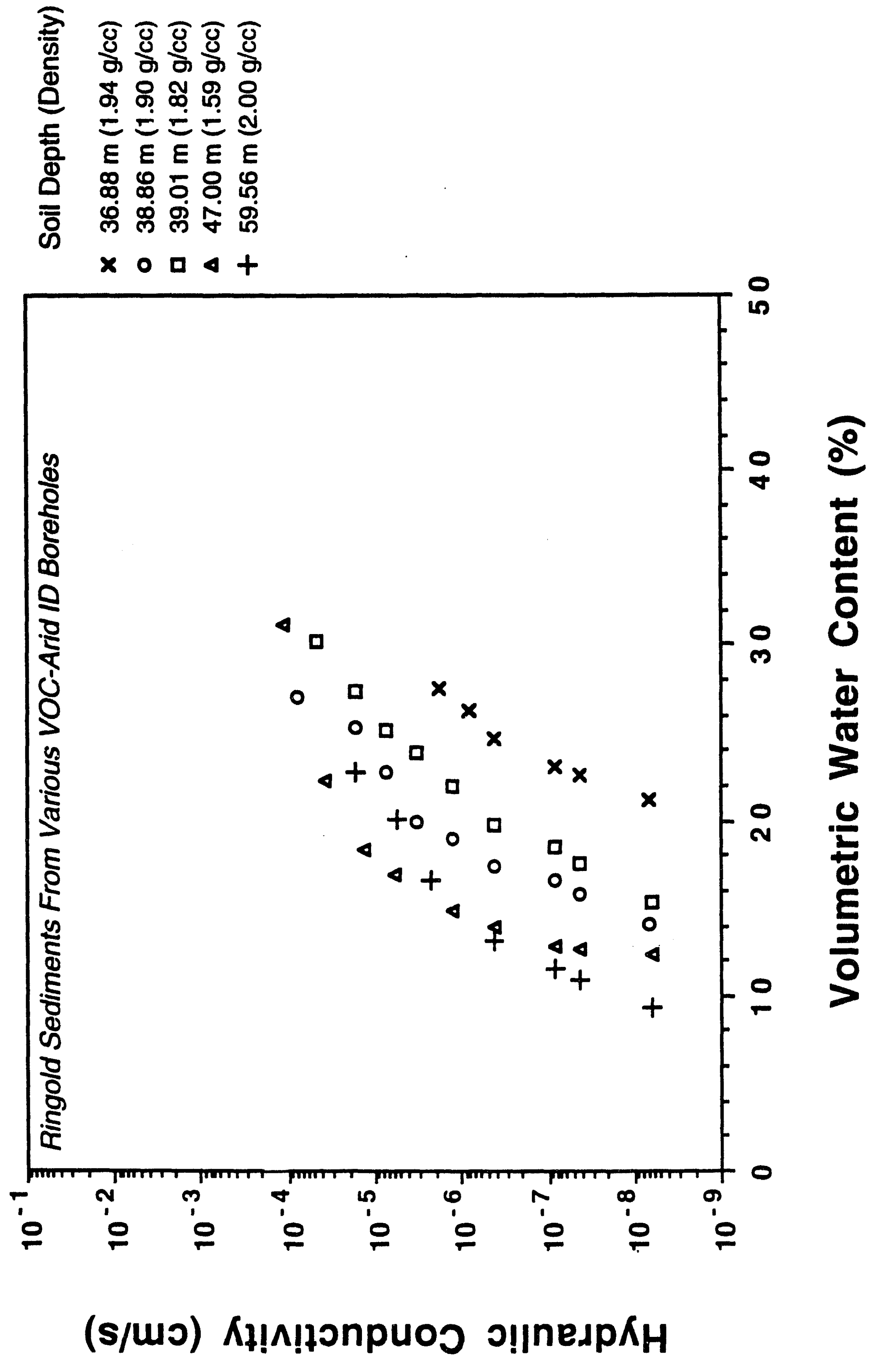


Figure 3-13. Generalized Hydrostratigraphic Cross Section Through the Carbon Tetrachloride Disposal Sites (from Wright et al. 1994).

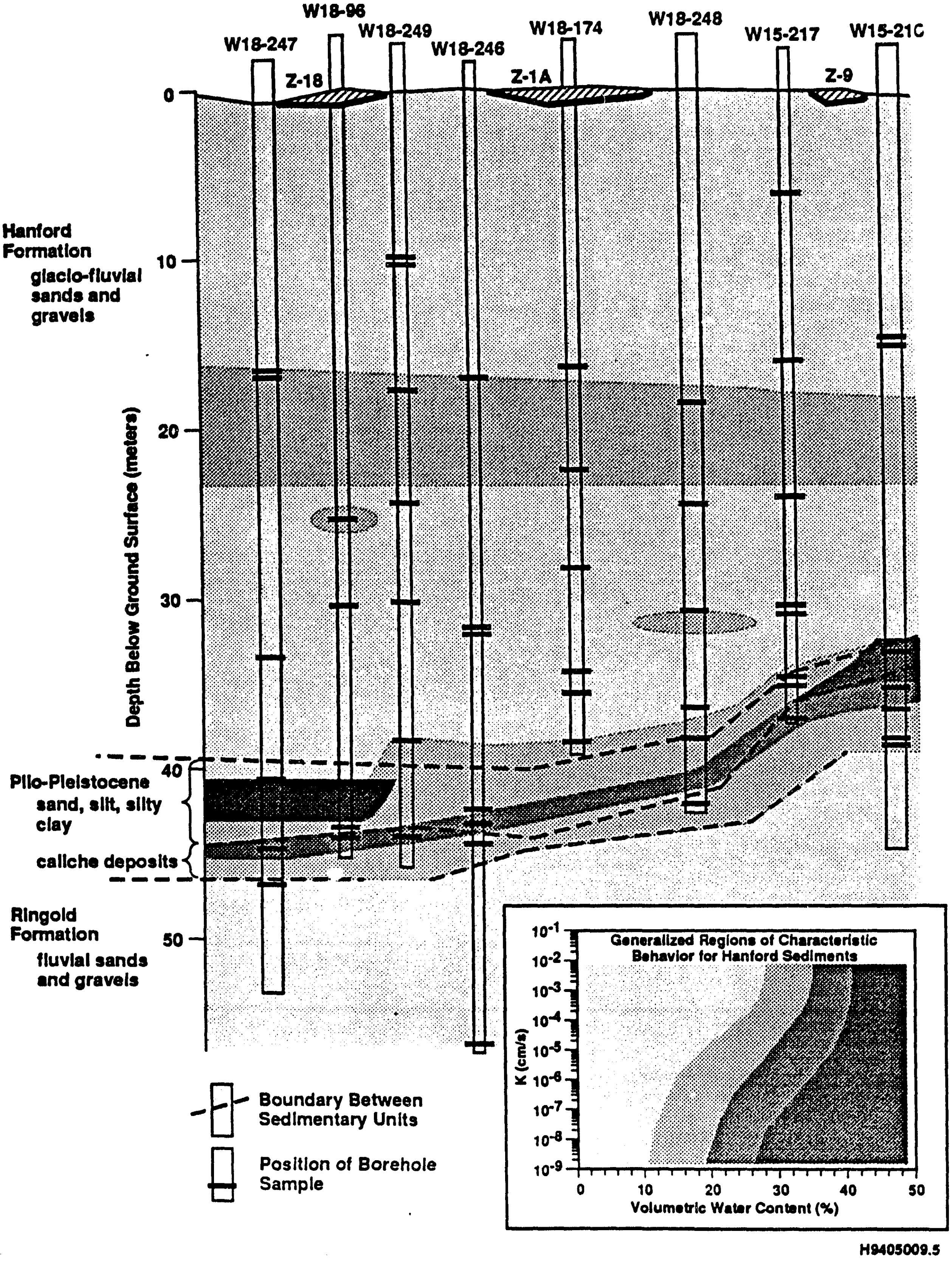
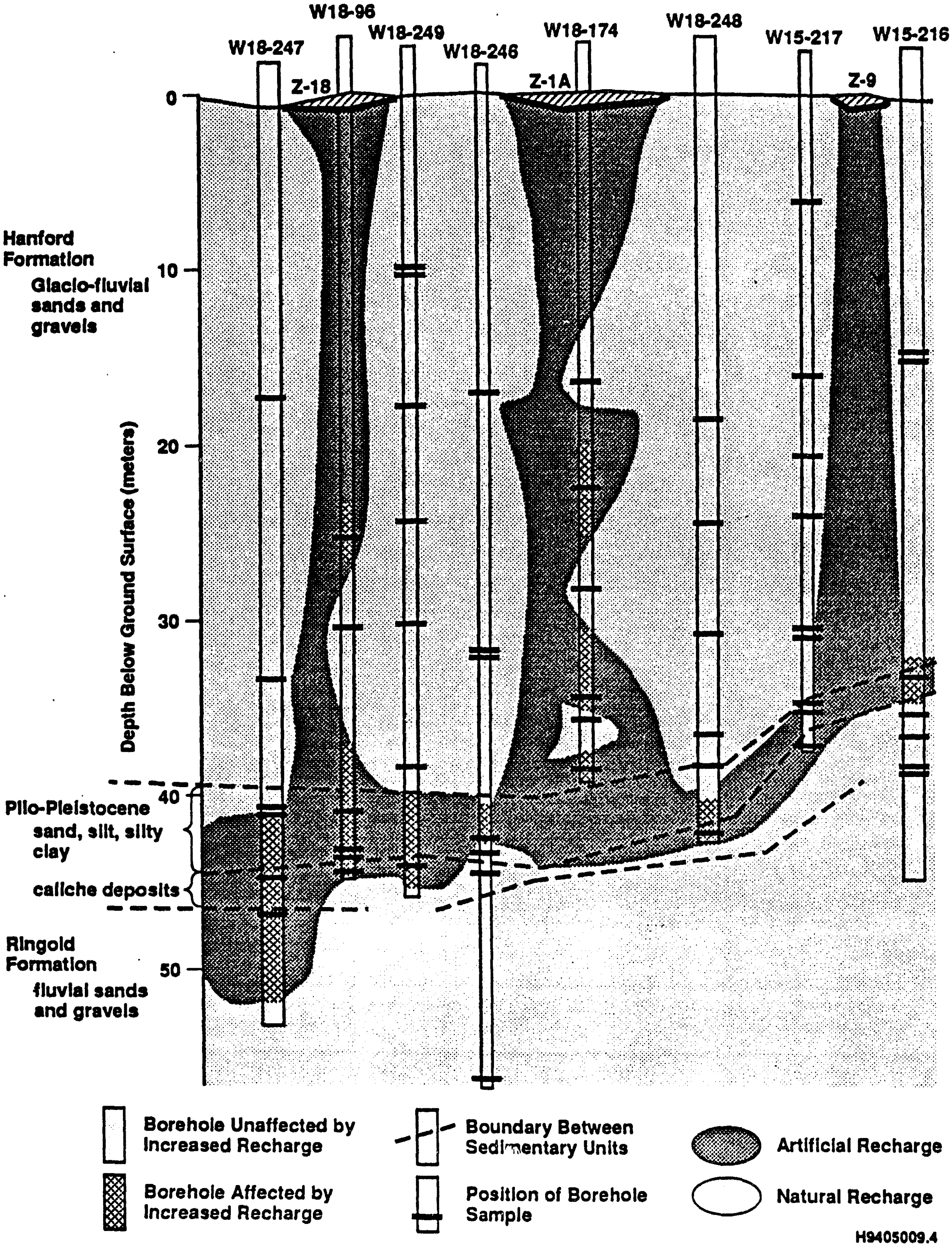


Figure 3-14. Inferred Recharge Distribution Below the Carbon Tetrachloride Disposal Sites (after Wright et al. 1994).



Samples of unsaturated zone pore water from 14 uncontaminated samples taken at different stratigraphic horizons from 6 boreholes were extracted by Wright et al. (1994). These small (1 to 15 mL) samples were sent to analytical chemistry laboratories to determine concentrations of major cations (using inductively coupled argon plasma atomic emission spectrometry) and anions (using ion chromatography). Based on the analytical results, Wright et al. (1994) determined a representative chemistry for pristine unsaturated zone pore water (Table 3-3).

Wright et al. (1994) compared the hydraulic conductivities of two samples at various fluid contents, using pure liquid carbon tetrachloride, a simulated natural pore water saturated with carbon tetrachloride (805 ppm), and a simulated natural pore water (Table 3-3). They concluded that the hydraulic conductivities of the pore water and the aqueous carbon tetrachloride solution were nearly identical. They also determined that the hydraulic conductivities measured using pure carbon tetrachloride were much higher than those measured using the simulated pore water and the aqueous carbon tetrachloride solution and that the differences were greater in the finer grained sample. In addition, they found that most of the bulk water from both samples was displaced by the pure carbon tetrachloride during these hydraulic conductivity tests, leaving an amount of water approximately equal to the residual saturation of the samples.

Table 3-3. Representative Chemistry of Uncontaminated Pore Water from Unsaturated Zone at Hanford (from Wright et al. 1994).

Cation	Concentration (mg/L)	Anion	Concentration (mg/L)
Na	18.49	F	0.72
K	4.08	Cl	23.88
Mg	7.56	SO_4	36.87
Ca	17.11	NO_3	10.77
		HCO_3	
pH		8.09	
Total dissolved solids		164.48 mg/L	
Ionic strength		0.0035 M	

3.3.3 Perched Water

Perched water was encountered near the 216-Z-9 Trench at a depth of 28 to 33 m in well 299-W15-216 in 1992 and at a depth of 32.5 to 33.5 m in 299-W15-220 in 1993 (Rohay et al. 1992, 1993a). This water was perched in the Plio-Pleistocene unit. It is hypothesized that the 216-Z-21 Pond, which lies approximately 40 m southeast of well 299-W15-216, is the source of the water. The 216-Z-21 Pond receives approximately 9.8 x 10^7 L of water per year (Rohay and Johnson 1991). This is consistent with an estimate that the maximum horizontal spreading from a 10-m-radius pond receiving 284 L/min (1.5 x 10^8 L/yr) for 20 years would be approximately 62 m (Last and Rohay 1993). (Note that the 216-Z-21 Pond has been in service since only the 1980's.)

Wright et al. (1994) analyzed samples collected at depths of 33.3 and 35.6 m, or 0.3 and 2.5 m below the perched water zone, in well 299-W15-216. The sample immediately below the perched water zone had a high subsurface flux, but the deeper sample was very dry. Given a hydraulic head of 5 m and using the saturated hydraulic conductivity measured for the shallower sample (from 33.3-m depth), they calculate that the perched water would take only 8 years to travel to the position of the deeper sample, suggesting that this perched water is relatively recent (Wright et al. 1994).

Perched water has also been encountered near the 216-Z-20 Crib in well 299-W18-29 (installed in 1991) at a depth of approximately 39 m (DOE-RL 1992b) and in other wells at various depths adjacent to the now decommissioned 216-U-10 Pond.

Four unsealed groundwater monitoring wells (299-W18-17, 299-W18-18, 299-W18-19, 299-W18-20) located within the perched water zone beneath and adjacent to the 216-Z-20 Crib were remediated between April and August 1993 as part of the groundwater impact assessment for that crib (Johnson 1993b). The wells were sealed from the water table to an elevation just above the Plio-Pleistocene layer, and 5 to 6 m of casing above the seal was perforated to allow perched water inflow and/or space for soil-gas monitoring. Following the remediation, perched water was observed in three of the wells (Figure 3-15). This suggests that perched water was previously draining down the outside of the unsealed casings, creating a dewatered zone around each well within the perched water layer (Johnson 1993b).

3.3.4 Unconfined Aquifer

The uppermost aquifer beneath the site is unconfined and lies within the Ringold Formation. The top of the aquifer, represented by the water table, lies within gravel unit E. The lower portion of this aquifer, contained within gravel unit A, is locally confined beneath the lower mud unit of the Ringold Formation. The hydrogeology of the uppermost aquifer beneath the ERA/VOC-Arid ID carbon tetrachloride site is represented by the following four principal hydrogeologic units (Figure 3-4):

R_{ge} - Ringold gravel unit E (saturated)
R_{lm} - Ringold lower mud unit
R_{ga} - Ringold gravel unit A
S_{em} - Saddle Mountains Basalt, Elephant Mountain Member.

Transmissivity and hydraulic conductivity values for saturated gravel unit E (R_{ge}) of the Ringold Formation have been calculated from aquifer test results. WHC (1992) lists the values from 47 wells within the 200 West Area. Transmissivity values from the top of the aquifer range from 2 to 4,700 m^2/d, with hydraulic conductivity values ranging from 0.3 to 1,500 m/d. Based on two wells, the bottom of the aquifer (within the lower portion of gravel unit E) ranged in transmissivity from 39 to 84 m^2/d, with a hydraulic conductivity of approximately 13 m/d. WHC (1992) also constructed maps of the

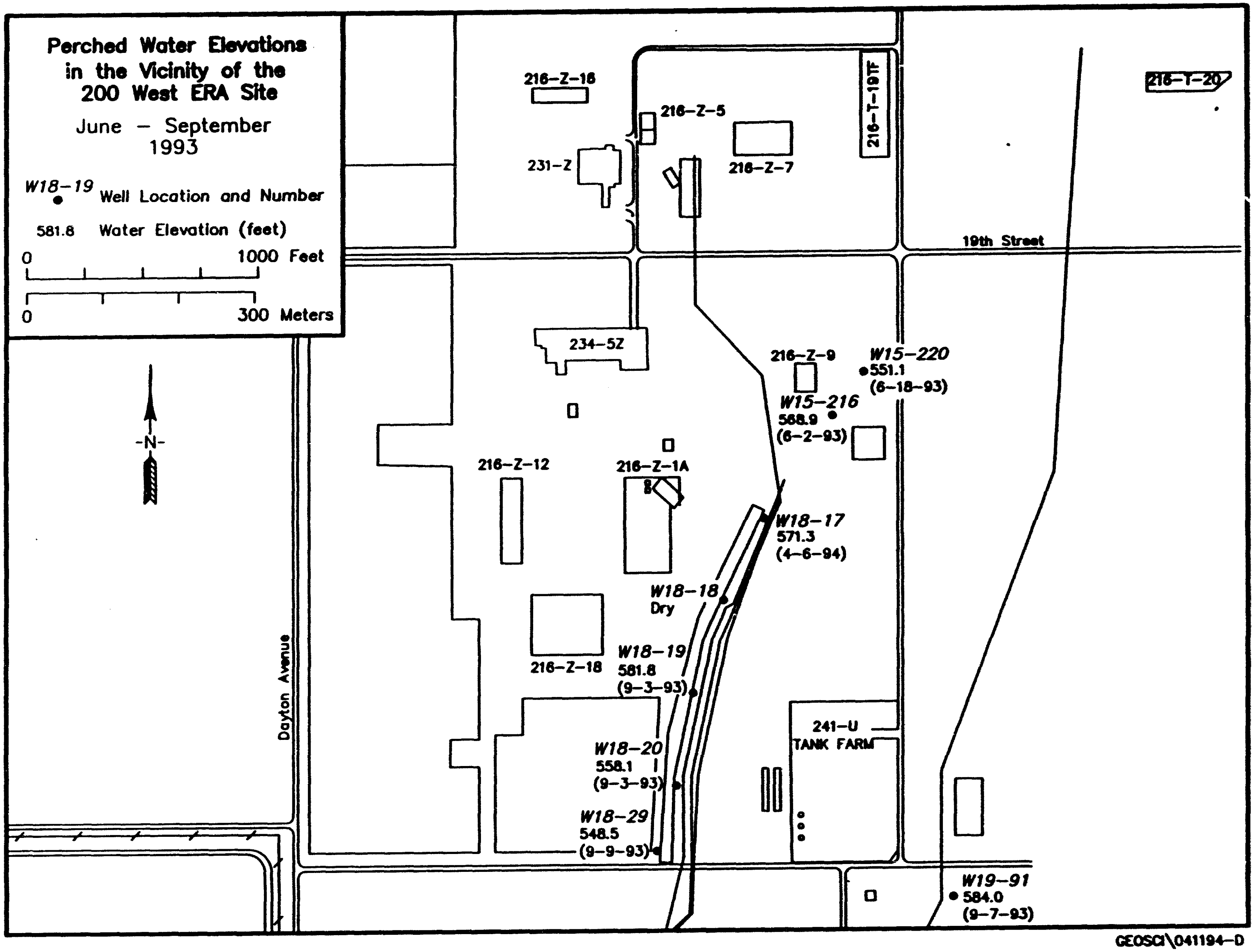


Figure 3-15. Elevation of Perched Water at the ERA/VOC-Arid ID Carbon Tetrachloride Site.

transmissivity and hydraulic conductivity values (Figures 3-16 and 3-17). Storativity values for this unit have been estimated to range from 0.001 to 0.038 (Last et al. 1989). Table 3-4 lists the principal hydrologic properties of the major hydrogeologic units.

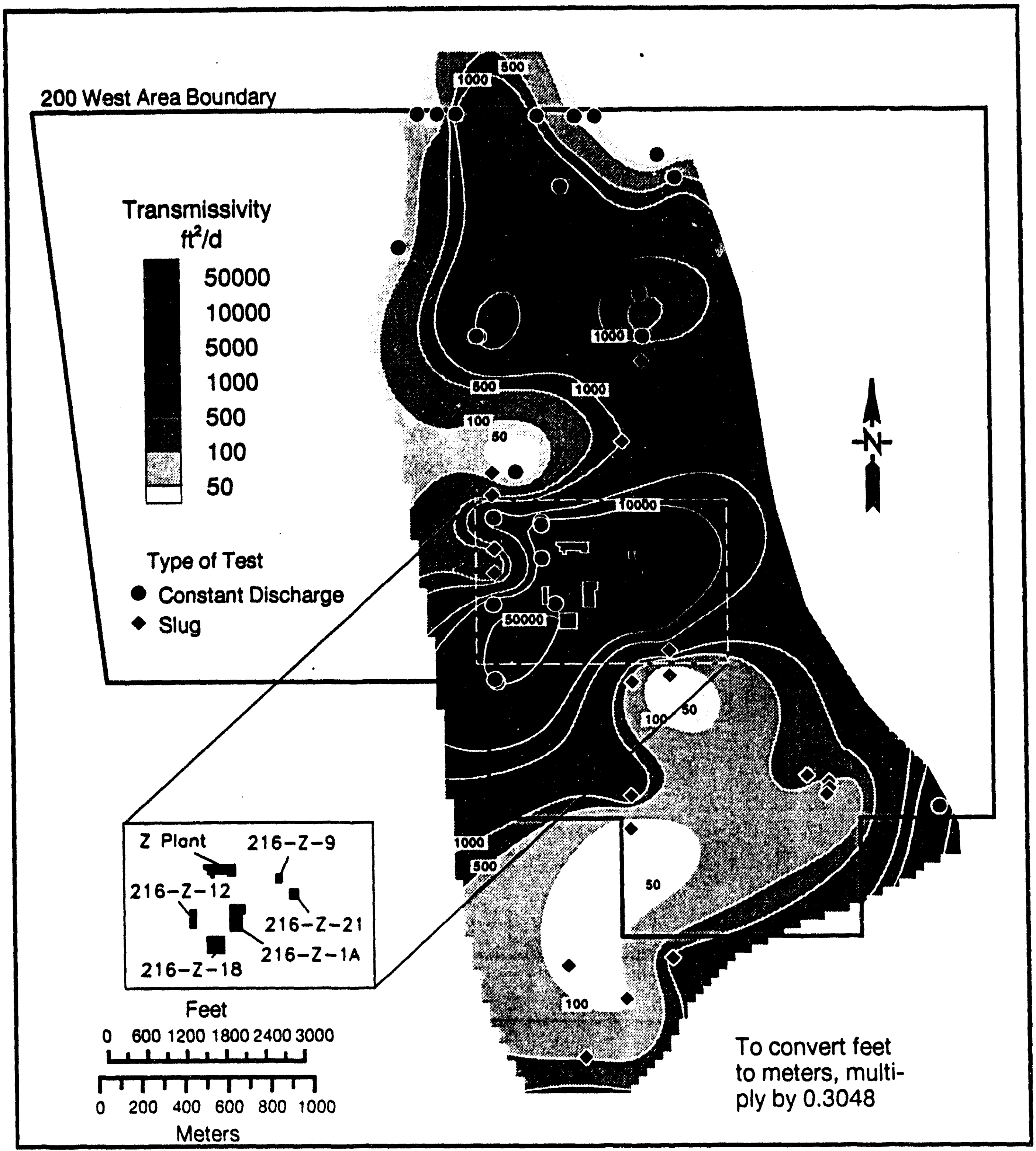
Regional groundwater flow is generally from west to east (Newcomer et al. 1991). The present direction of groundwater flow in the vicinity of the 200 West Area is largely influenced by a groundwater mound caused by past artificial recharge to the now inactive 216-U-10 Pond (Figure 2-2). Prior to deactivation of the pond, this groundwater mound had risen over 20 m above pre-Hanford conditions. Since the pond's decommissioning in 1984, the groundwater mound has been decreasing, causing the water table to drop as much as 5 m beneath the ERA/VOC-Arid ID carbon tetrachloride site in 8 years. This mound now appears to be centered northeast of the former 216-U-10 Pond (Figure 3-18). Continuing liquid discharges to other sites southeast of Z Plant (e.g., the 216-Z-20 Crib and portions of the 216-U-14 Ditch) may be responsible in part for this apparent shift (Rohay and Johnson 1991). This groundwater mound is expected to be the dominant force influencing local groundwater flow for a number of years.

The water table in the vicinity of the carbon tetrachloride disposal sites for June 1992, June 1993, and December 1993 are shown in Figures 3-19 through 3-21. In general, groundwater elevations decrease to the north, west, and east (underlying the waste disposal facilities), reflecting the mound shown in Figure 3-18. Water table elevations in this area dropped nearly 0.7 m between June 1992 and December 1993. Water levels in well 299-W18-15, near the former 216-U-10 Pond, dropped at the same rate, suggesting that the major drop in water level is related primarily to the pond's decommissioning.

Groundwater mounding occurred beneath the 216-Z-20 Trench in 1992 and 1993 (Figures 3-19 and 3-20). (NOTE: Data for the two wells along the 216-Z-20 Trench in Figure 3-20 were measured in March 1993.) Following remediation of unsealed wells 299-W18-17, 299-W18-18, 299-W18-19, and 299-W18-20 along this trench between April and August 1993, the mound diminished (Figure 3-21). This, too, suggests that prior to remediation, perched water was draining down the outside of the unsealed casings.

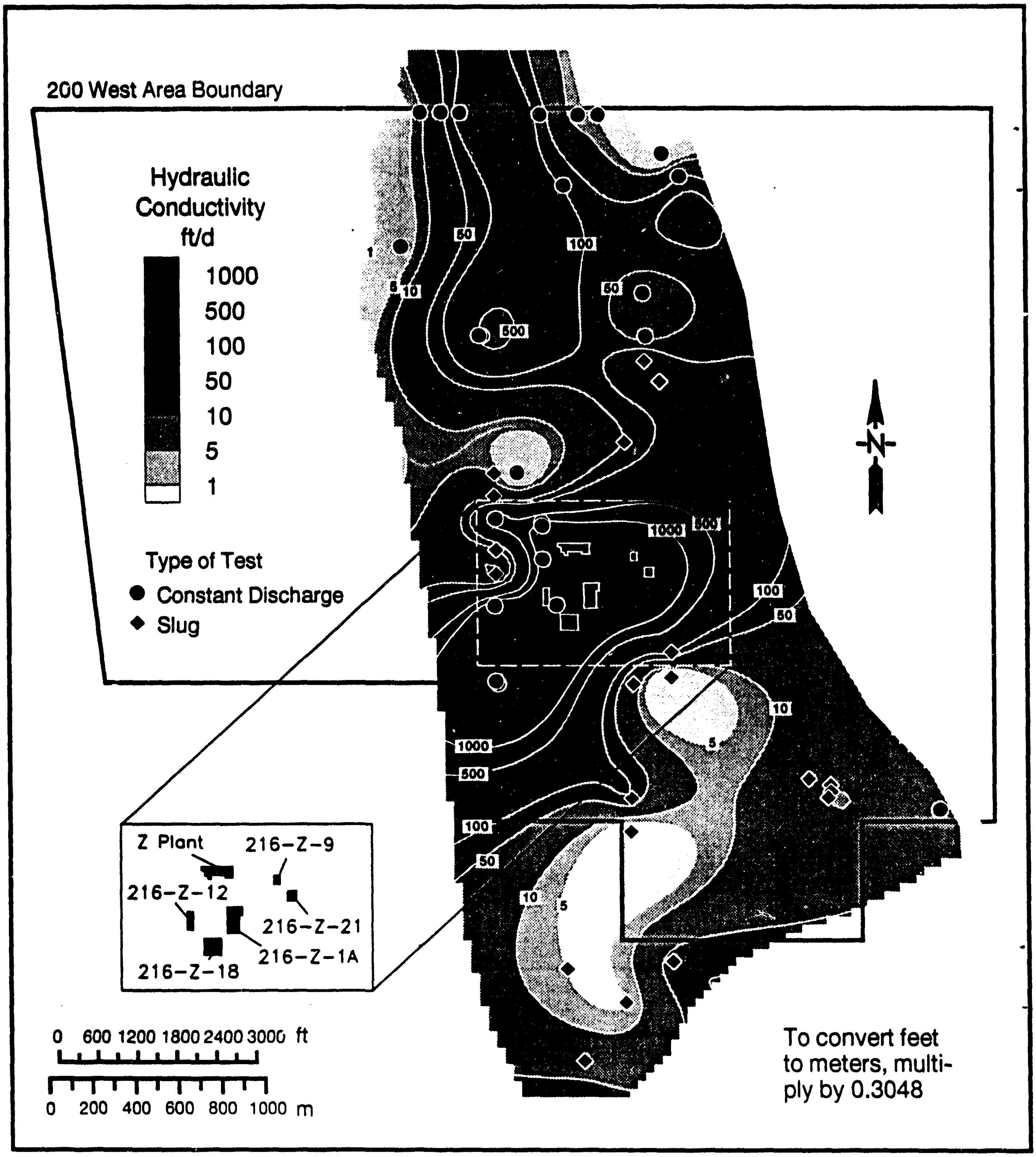
The elevations used to prepare the water table maps shown in Figures 3-19 through 3-21 are provided in Appendix C and were extracted from the Hanford Groundwater Data Base. Although most of the data are from June 1992, June 1993, and December 1993, data were used from January through October 1992 and February through July 1993 to obtain the coverage needed. Water levels dropped by nearly 0.3 m during each 6-month period. In addition, it should be noted that the number of significant figures does not indicate accuracy. While steel-tape readings can be made to ±0.3 cm, the greatest uncertainty is in the elevation of the well casing, for which an uncertainty of ±30 cm is likely (DOE-RL 1991). Finally, the continuing liquid discharges to nearby liquid waste disposal facilities and sanitary drain fields and the uncertainty in the extent and infiltration of the perched water in this area complicate the interpretation of the water-level data shown in Figures 3-19 through 3-21.

Figure 3-16. Transmissivity Map of the 200 West Area (from WHC 1992).



GSTEC061694-BHF

Figure 3-17. Hydraulic Conductivity Map of the 200 West Area (from WHC 1992).



To convert feet to meters, multiply by 0.3048

Table 3-4. Hydrologic Properties of the Unconfined Aquifer.

Well number	Hydrogeologic units	Sample	Transmissivity (m^2/d)	Conductivity (m/d)	Storatitivity
299-W15-16	R_{ge} (top)	Aquifer test	1,115	366	0.03
299-W15-17	R_{ge} (top)	Aquifer test	1,115	366	ND
299-W18-21	R_{ge} (top)	Aquifer test	4,738	1,554	ND
299-W18-24	R_{ge} (top)	Aquifer test	4,087	1,341	0.001
299-W18-22	R_{ge} (bottom)	Aquifer test	39	13	ND
ND	R_{lm}	ND	ND	0.03-3.0	0.002
ND	R_{ga}	ND	ND	0.001-0.61	ND

After Graham et al. (1981), Last et al. (1989), and WHC (1992).
ND = No data available.

Figure 3-18. Regional Potentiometric Surface Map of the Unconfined Aquifer in the Vicinity of the 200 West Area, June 1993 (after Kasza et al. 1994).

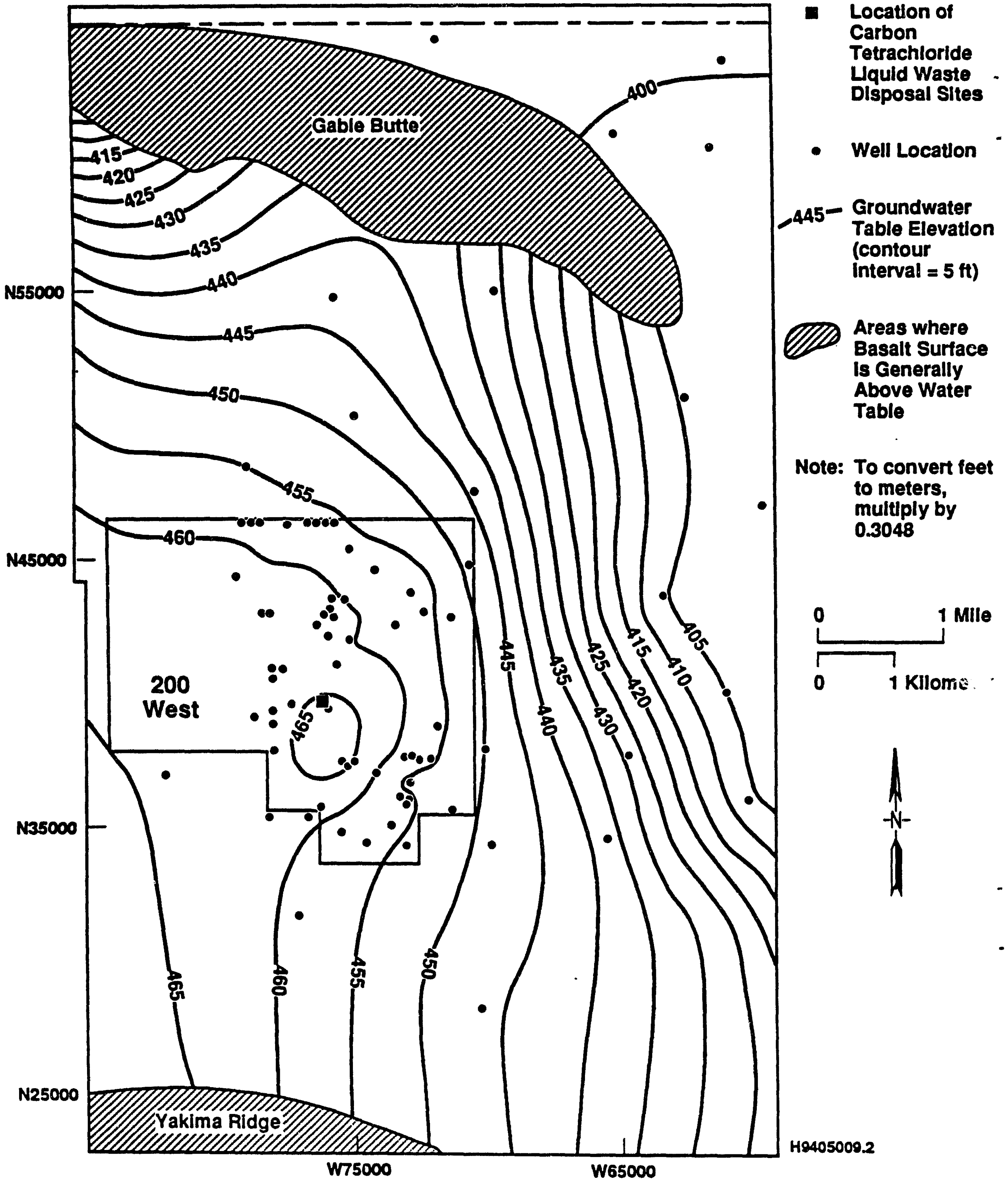


Figure 3-19. Water Table Map of the Unconfined Aquifer in the Vicinity of the Carbon Tetrachloride Disposal Sites, June 1992.

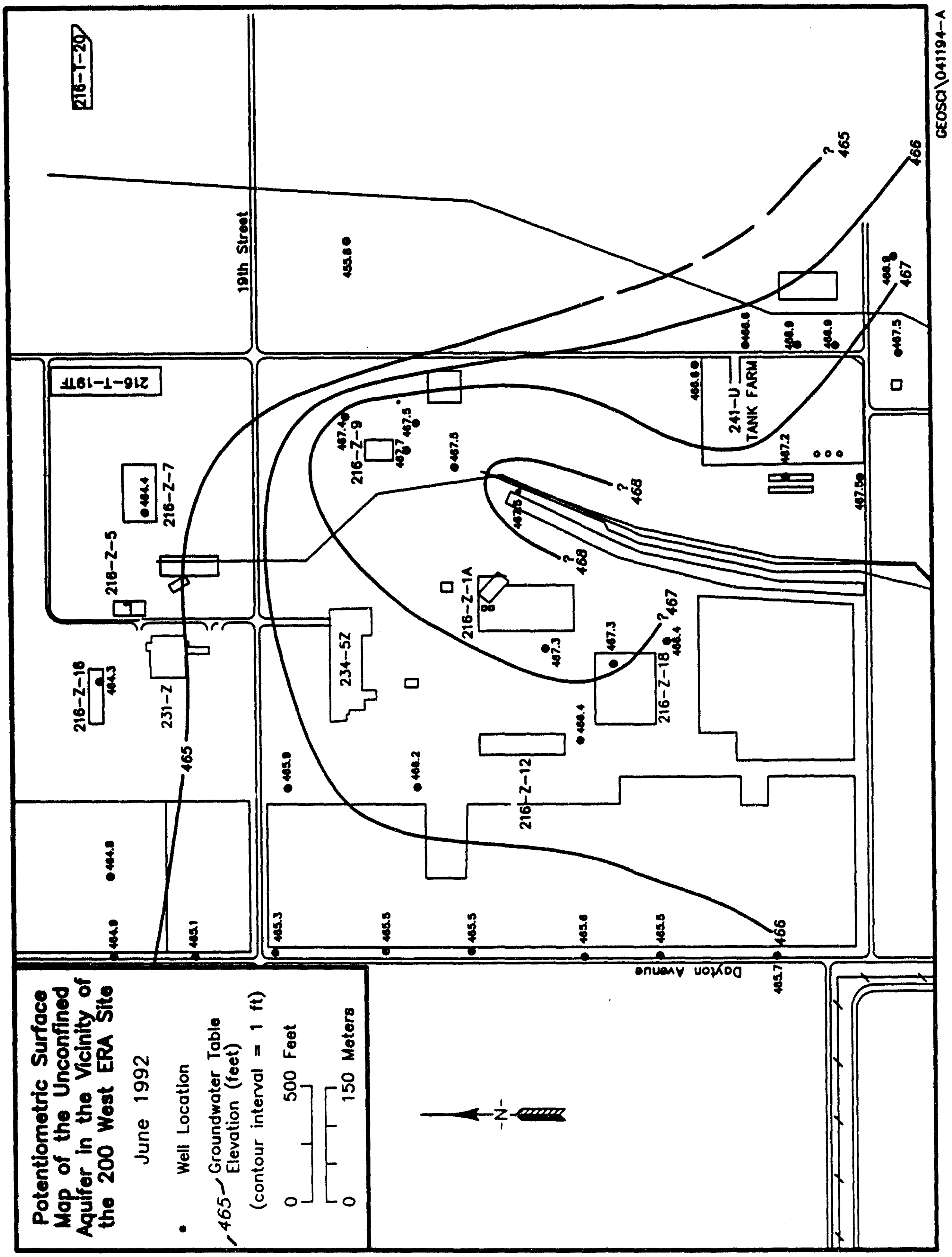


Figure 3-20. Water Table Map of the Unconfined Aquifer in the Vicinity of the Carbon Tetrachloride Disposal Sites, June 1993.

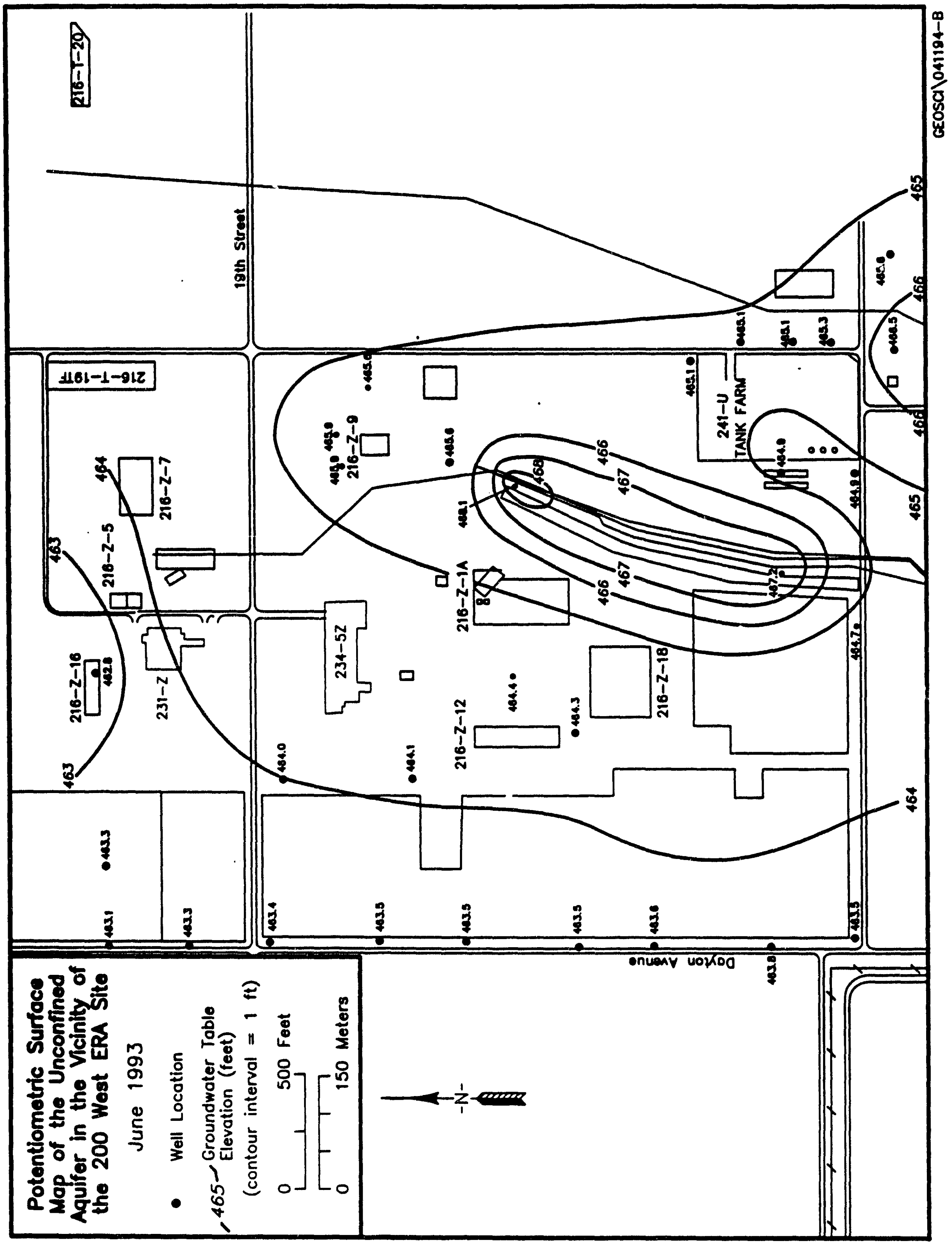
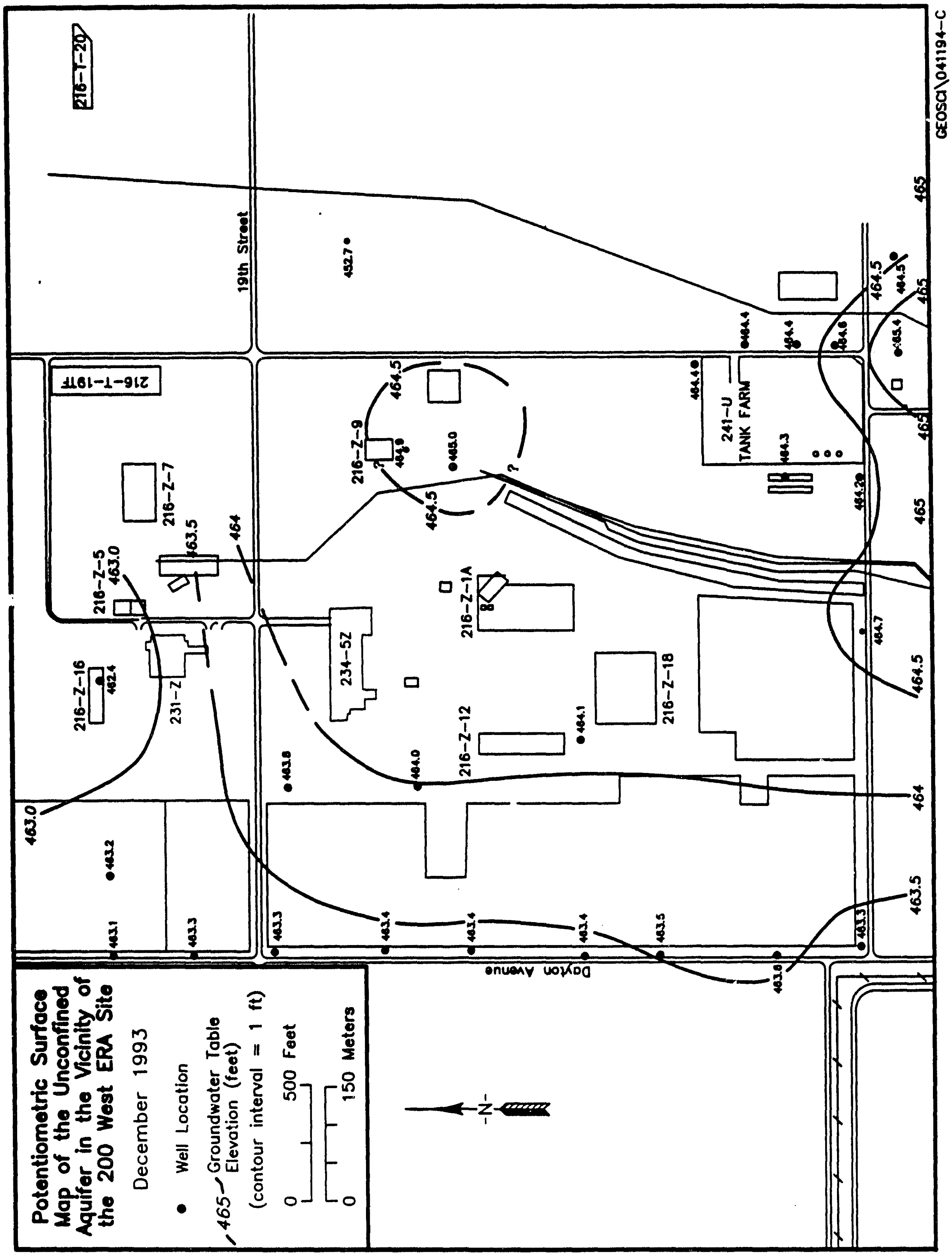


Figure 3-21. Water Table Map of the Unconfined Aquifer in the Vicinity of the Carbon Tetrachloride Disposal Sites, December 1993.



4.0 NATURE AND EXTENT OF CONTAMINATION

This chapter presents information regarding the nature and distribution of contaminants found beneath the 216-Z-1A Tile Field, 216-Z-9 Trench, and 216-Z-18 Crib carbon tetrachloride disposal sites. Also presented are current estimates of the quantity of carbon tetrachloride released to the atmosphere, retained in the unsaturated zone, and present within the groundwater. This information is based primarily on the results of the ongoing ERA and VOC-Arid ID investigations.

4.1 ATMOSPHERIC LOSSES

The carbon tetrachloride vapor may move from the subsurface to the atmosphere at the soil/air interface or along pathways such as existing wells. The following two sections on the natural flux of VOCs are based on an estimate of the atmospheric losses of carbon tetrachloride (WHC 1993a) and on field measurements made in support of the ERA (Rohay and Cameron 1992, Fancher 1993).

4.1.1 Soil/Air Interface

The quantity of carbon tetrachloride lost to the atmosphere in 1990 from the soil/air interface, based on diffusion of the vapor phase from the water table to the ground surface, is estimated (WHC 1993a) to be 0.15 g/m^2/yr, or 1,800 kg/yr, for the area overlying the groundwater plume. It is estimated that, between 1955 and 1990, 18% of the total carbon tetrachloride inventory was lost to the atmosphere through natural soil flux (WHC 1993a). For these rough order-of-magnitude estimates, it is assumed that 470,000 L (750,000 kg) of carbon tetrachloride was discharged to the soil column between 1955 and 1973.

The distribution and concentration of the carbon tetrachloride vapor in the unsaturated zone was calculated, based on (1) the distribution and concentration of the dissolved phase in the unconfined aquifer, (2) the corresponding equilibrium concentration of vapor just above the water table, and (3) a linear interpolation between the vapor concentration at the water table (64-m depth) and an assumed concentration of zero at the ground surface. To calculate the vapor loss to the atmosphere, it was assumed that the contaminated vapor diffused to 1 m below the ground surface. Air in the upper 1 m of the soil column was assumed to be swept out by fluctuations in barometric pressure, based on the measured range in the barometric pressure for 1992 (WHC 1993a).

To calculate the historical atmospheric losses, it was assumed that the upper 1 m of the soil column was swept clean 52 times per year by barometric pressure fluctuations (WHC 1993a). During the period of discharge, it was assumed that soil vapor in the upper 1 m was saturated with carbon tetrachloride and was confined to the lateral area of the crib and that the atmospheric loss rate remained constant. After discharge ceased, the carbon tetrachloride was assumed to diffuse outward and downward until it reached the estimated 1990 configuration. Atmospheric losses were assumed to decline steadily at a yearly rate designed to match the 1,800-kg/yr rate calculated for 1990. The total calculated quantity of carbon tetrachloride lost during the operational period (1955 to 1973) was calculated to be 54,000 kg. From 1955 to 1990, the total loss to the atmosphere through the soil surface is calculated to be 137,000 kg (WHC 1993a).

The EMFLUX (a trademark of Quadrel Services, Inc.) passive soil-gas-sampling technology, owned and operated by Quadrel Services, Inc., of Clarksburg, Maryland, was deployed in August 1992 and in July 1993 (Section 4.2.1.2). The soil-surface flux ranged from 111 to 686 $ng/m^2/min$ (0.06 to 0.36 $g/m^2/yr$) in 1992 and from 1.4 to 922.7 $ng/m^2/min$ (0.0007 to 0.48 $g/m^2/yr$) during the 1993 sampling period near the 216-Z-9 Trench (Table 4-1).

4.1.2 Borehole Releases

During the period 1949 to 1994, boreholes were drilled to characterize and/or monitor liquid waste disposal facilities in the 200 West Area. For example, in the vicinity of the three carbon tetrachloride disposal facilities, 59 boreholes are potentially available for monitoring (Figure 3-3). Many of these wells serve as pathways for soil vapor to reach the atmosphere (Rohay and Cameron 1992, Rohay et al. 1993b).

The boreholes with open (screened, perforated, or open bottom) intervals naturally breathe in response to meteorological phenomena, most notably fluctuations in barometric pressure. Thus, when barometric pressure is higher than the pressure in the soil near the open interval, fresh air moves through the borehole and into the soil pores exposed at the open interval. When barometric pressure is lower than the pressure in the soil near the open interval, the process operates in reverse; the borehole exhales, and soil vapor moves from the formation at the open interval through the borehole and out to the atmosphere. The soil-vapor-contaminant concentration venting from the boreholes depends in part on the permeability and contaminant concentration of the soils at the open interval, the amount of open interval, the static residence time of the air in the formation (to permit diffusion from the soil or liquid phase to the gas phase), and the rate of change of the barometric pressure.

The boreholes were installed by several contractors using different drilling and completion methods; some completions have since been modified. Most of the open intervals range in depth from 23 to 48 m below the surface. Construction details for carbon tetrachloride area boreholes are provided in the ERA proposal and the FY 1992 and FY 1993 year-end reports (DOE-RL 1991; Rohay et al. 1992, 1993a). Modifications to pre-1992 boreholes to provide subsurface access for vapor extraction are presented in Rohay and Cameron (1994).

Continuous airflow measurements have been recorded at 12 open intervals in 9 boreholes associated with the carbon tetrachloride disposal facilities since June 1992. However, corresponding continuous measurements of the contaminant concentrations in the venting air are generally not available. For example, the longest continuous data record is available for well 299-W18-6, which is open to the unsaturated zone just above the water table on the west side of the 216-Z-1A Tile Field. However, continuous data on the carbon tetrachloride concentration in that airflow were available for only two

Table 4-1. EMFLUX Emission Flux Rates. (sheet 1 of 3)

Sample location	Date	Contaminants (ng/m²/min)										
		Carbon tetrachloride	Chloroform	Chloro-methane	Chloro-ethane	Tetra-chloro-ethylene (PCE)	Trichlor-ethylene (TCE)	1,1-dichloro-ethene	Toluene	Acetone	Benzene	Xylene
1	Aug. 6-10, 1992	111.3	0.8									
	Jul. 28-31, 1993	34.4										
2	Aug. 6-10, 1992	349.5	2.3			10.4			1.6	2.8		
	Jul. 21-24, 1993	378.0				70.2						
	Jul. 28-31, 1993	188.0										
3	Aug. 6-10, 1992	199.5	1.1									
	Jul. 21-24, 1993	222.7				19.4			1.1			
	Jul. 28-31, 1993	186.1				1.2			1.1			
4	Aug. 6-10, 1992	127.4										
	Jul. 28-31, 1993	128.5				1.5			1.0			
5	Aug. 6-10, 1992	280.2										
	Jul. 21-24, 1993	922.7	1.0	1.9		120.5				1.9		
	Jul. 24-28, 1993	130.8	107.3	8.7	4.0	2.3		0.9		2.5	0.9	
	Jul. 28-31, 1993	181.7				2.6						
6	Aug. 6-10, 1992	686.3	18.3			2.4						
	Jul. 21-24, 1993	20.5		3.5		21.0				7.0		
	Jul. 24-28, 1993	2.5								5.0		
	Jul. 28-31, 1993	4.0								3.5		
7	Aug. 6-10, 1992	227.2	3.4			9.4				1.6		
	Jul. 21-24, 1993	548.8				93.0						
	Jul. 28-31, 1993	251.7				1.4						

Table 4-1. EMFLUX Emission Flux Rates. (sheet 2 of 3)

Sample location	Date	Contaminants (ng/m²/min)										
		Carbon tetrachloride	Chloroform	Chloro-methane	Chloro-ethane	Tetra-chloro-ethylene (PCE)	Trichlor-ethylene (TCE)	1,1-dichloro-ethene	Toluene	Acetone	Benzene	Xylene
8	Aug. 6-10, 1992	198.7	2.2			4.4						
	Jul. 21-24, 1993	876.0	1.4			312.9						
	Jul. 28-31, 1993	111.2				5.2						
9	Aug. 6-10, 1992	230.2	1.4			0.8						
	Jul. 21-24, 1993	340.3	1.0			107.3				2.5		
	Jul. 28-31, 1993	96.1				3.9						
10	Aug. 6-10, 1992											
	Jul. 21-24, 1993											
	Jul. 28-31, 1993								1.8	3.0		
11	Jul. 28-31, 1993	8.6										
12	Jul. 28-31, 1993	106.2				2.1			1.4			
13	Jul. 28-31, 1993	12.5										
14	Jul. 28-31, 1993	145.4				5.6						
15	Jul. 28-31, 1993	32.8										
16	Jul. 28-31, 1993	18.5										
17	Jul. 28-31, 1993											
18	Jul. 28-31, 1993	69.6										
19	Jul. 28-31, 1993	19.9										
20	Jul. 28-31, 1993	12.6							1.7	2.0		1.4
21	Jul. 28-31, 1993	5.0										

Table 4-1. EMFLUX Emission Flux Rates. (sheet 3 of 3)

Sample location	Date	Contaminants ($ng/m^2/min$)										
		Carbon tetrachloride	Chloroform	Chloro-methane	Chloro-ethane	Tetra-chloro-ethylene (PCE)	Trichlor-ethylene (TCE)	1,1-dichloro-ethene	Toluene	Acetone	Benzene	Xylene
22	Jul. 28-31, 1993	17.5								1.9		
23	Jul. 28-31, 1993											1.1
24	Jul. 28-31, 1993	2.0										
25	Jul. 28-31, 1993											
26	Jul. 28-31, 1993											
27	Jul. 28-31, 1993											
28	Jul. 28-31, 1993											
29	Jul. 28-31, 1993	1.4										
30	Jul. 28-31, 1993											
31	Jul. 28-31, 1993											
32	Jul. 28-31, 1993	2.2										
33	Jul. 28-31, 1993	2.8										
34	Jul. 28-31, 1993	3.5								2.6		

periods within 8 days in September 1992 at well 299-W18-6. The highest measured carbon tetrachloride concentration at this borehole was approximately 80 parts per million by volume (ppm_v). The airflow and contaminant data suggest that several grams per hour of carbon tetrachloride could be venting from this borehole during exhalation events (e.g., when barometric pressure is falling; Rohay and Cameron 1992).

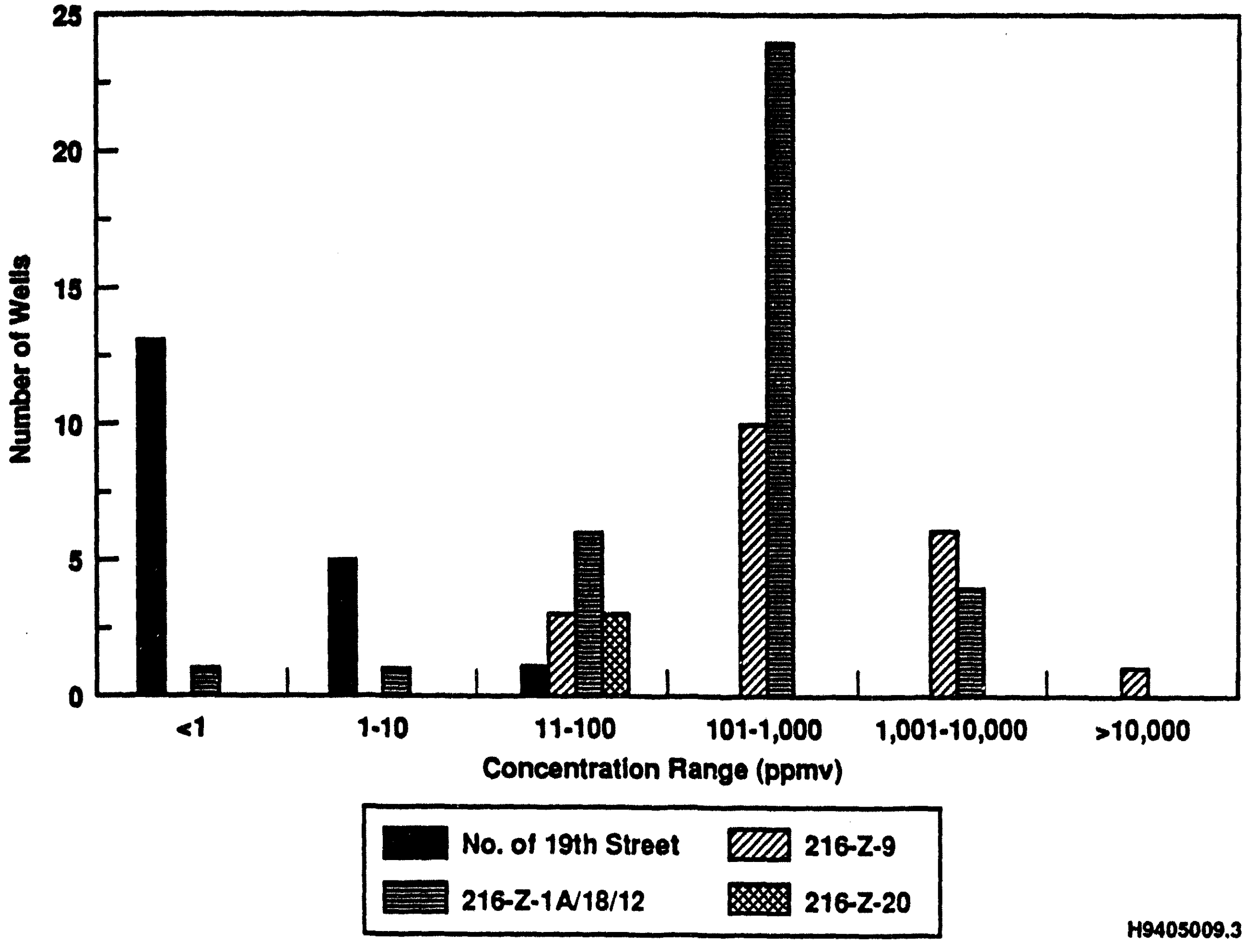
As part of the baseline monitoring program for the soil-vapor extraction system, 77 wells, typically at distances of 0 to 90 m from the carbon tetrachloride disposal facilities, were monitored twice per week from December 1991 through December 1993 (Fancher 1994, Rohay 1993). The wells are monitored with field-screening instruments at the wellhead, which provide an indication of the carbon tetrachloride concentration in the air within the well. These data are instantaneous samples that represent one point in the borehole-venting cycle. Work is continuing to determine the relationship between the venting cycles and barometric pressure fluctuations for various well configurations (Rohay 1993). Statistics for the entire 25-month period are provided in Appendix D. Interpretation of the data is provided by Fancher (1994).

The observed contaminant concentrations, monitored using a photoionization detector (PID), range from 0 to over 10,000 ppm_v total VOC, including carbon tetrachloride, chloroform, and methylene chloride. Previous analyses using a gas chromatograph indicate that the majority of VOC present in the wellheads is carbon tetrachloride (Rohay and Johnson 1991, Rohay et al. 1992a). Therefore, it is assumed that the VOC measured with the PID is carbon tetrachloride. The presence of carbon tetrachloride is confirmed at selected sample stations by using colorimetric tubes.

The carbon tetrachloride concentrations of soil gas exhaling from a well have been correlated with the flow rate of the gas and the rate of barometric pressure change. A zero reading may be indicative of an inhalation event, while the maximum baseline monitoring value for each well is judged to have the greatest likelihood of representing equilibrium conditions. Lower readings could be the effect of dilution from the previous inhalation event or the rapid transport of air that does not allow time to reach equilibrium conditions. Attainment of equilibrium conditions between exhalation events may not always have been achieved prior to taking the measurements; thus, the maximum values measured to date represent only an estimate of the subsurface concentrations. Of the 77 wells monitored, the maximum concentrations were less than 1 ppm_v in 14 wells, between 1 and 10 ppm_v in 6 wells, between 11 and 100 ppm_v in 13 wells, between 101 and 1,000 ppm_v in 33 wells, between 1,001 and 10,000 ppm_v in 10 wells, and greater than 10,000 ppm_v in 1 well (Figure 4-1). During an exhalation event, the carbon tetrachloride concentrations venting from boreholes increase from zero to a maximum value and then decrease back to zero. Therefore, the average of the vented carbon tetrachloride concentrations measured during baseline monitoring were used to estimate the natural flux from each borehole.

For this estimation of natural flux, the wells were assumed to be comparable despite their various ages, locations, depths, and completions. The average vented concentrations were contoured for the carbon tetrachloride area, based on available data for 43 wells in the baseline monitoring well network. However, all wells located within each contour interval were assumed to provide release pathways during the years they had intervals open to both

Figure 4-1. Distribution of Maximum Baseline Monitoring Wellhead Measurements.



the subsurface and the atmosphere. Based on airflow measurements in the boreholes and on the baseline monitoring data, it was estimated that the wells breathe out half of the year at an average flow of 0.14 m^3/min. Using the mid-range value for each concentration contour interval and the number of years each borehole within that contour interval was available to provide a potential pathway, it is estimated that 22,200 kg of carbon tetrachloride (or 3% of the estimated carbon tetrachloride inventory) may have been released to the atmosphere through existing boreholes between 1955 and 1990 (WHC 1993a).

4.2 UNSATURATED ZONE CONTAMINATION

This section discusses the nature and extent of carbon tetrachloride contamination within the unsaturated zone and is based on the results of near-surface soil-gas surveys, subsurface soil-gas measurements, and borehole sediment sampling.

4.2.1 Near-Surface Soil-Gas Surveys

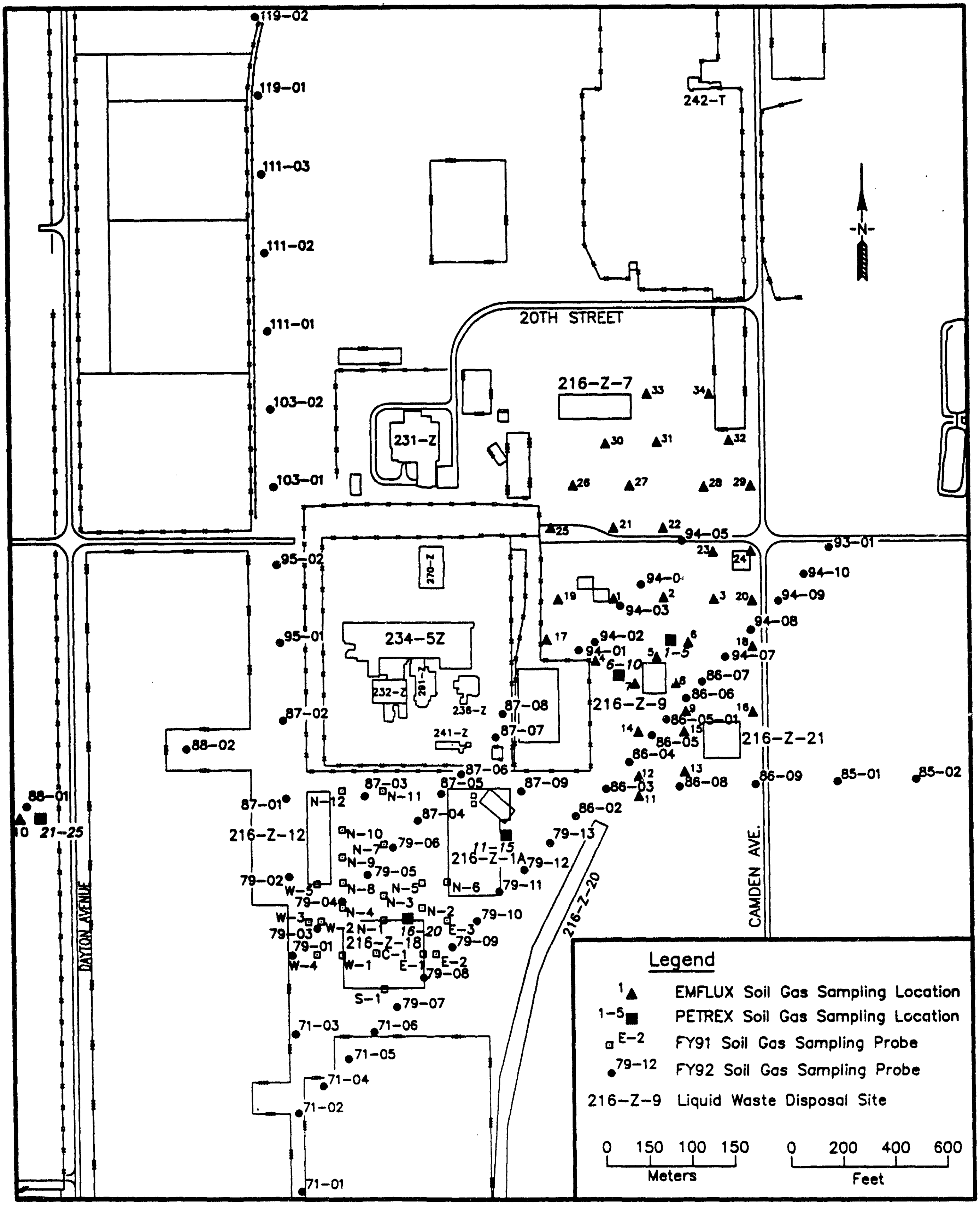
Near-surface soil-gas data are available from three main activities: active soil-gas sampling, passive soil-gas measurements using absorptive collectors, and baseline monitoring of near-surface soil-gas ports. Sampling locations are shown in Figure 4-2. Descriptions of these activities are presented in Rohay (1991), DOE-RL (1991), Rohay et al. (1992a, 1992b, 1993a), Rohay and Last (1992), Fancher (1994), and Last and Rohay (1993).

4.2.1.1 Active Soil-Gas Sampling Network. The soil-gas sampling network consists of 22 soil-gas probes installed during FY 1991 near the 216-Z-18 Crib (DOE-RL 1991) and 60 soil-gas probes installed along four transects in FY 1992 (Rohay et al. 1992a, Last and Rohay 1993). Soil-gas samples from the FY 1992 probes were analyzed in a mobile laboratory for VOCs using gas chromatography and measured in the field for carbon dioxide, oxygen, and total organic vapor concentrations (Last and Rohay 1993). The constituents detected included carbon tetrachloride, chloroform, tetrachloroethylene (PCE), and trichloroethylene (TCE). Figure 4-3 illustrates the near-surface carbon tetrachloride soil-gas concentrations measured in May 1992. By far, the largest concentration of carbon tetrachloride appears to be located just to the north of the 216-Z-9 Trench. Extension of the plume to the north, away from the sampling transects, is considered to be an artifact of the contouring interpolation scheme and is not bounded by any sampling data. Chloroform concentrations are also higher north of the 216-Z-9 Trench (Figure 4-4). The maximum concentrations of TCE and PCE detected during the May 1992 survey were 0.08 ppm_v and 0.06 ppm_v, respectively (Last and Rohay 1993).

4.2.1.2 Passive Soil-Gas Measurements. Two passive soil-gas technologies have been deployed at the site: EMFLUX technology and PETREX technology [owned and operated by the Northeast Research Institute (NERI), Inc., Farmington, Connecticut].

The EMFLUX soil-gas collection system is a passive, surface-based system that employs a variety of sorbent collectors, depending on the nature and number of target contaminants. Once retrieved, the collectors were shipped to

Figure 4-2. Locations of Near-Surface Active and Passive Soil-Gas Sampling Networks at the ERA/VOC-Arid ID Carbon Tetrachloride Site.



WHC:JJA:200WEST:VJR-2

Figure 4-3. Near-Surface Soil-Gas Concentrations of Carbon Tetrachloride Measured in May 1992.

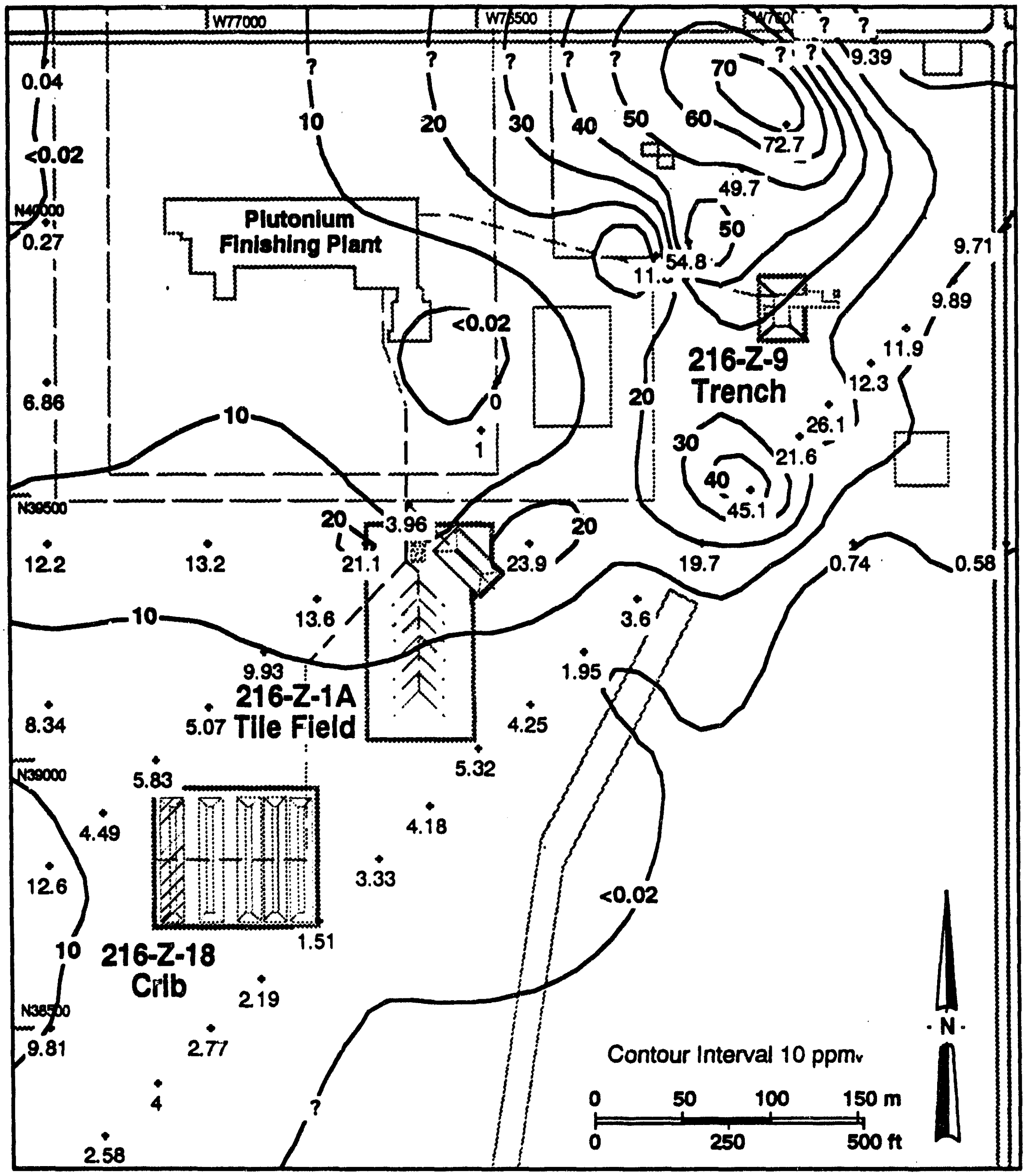
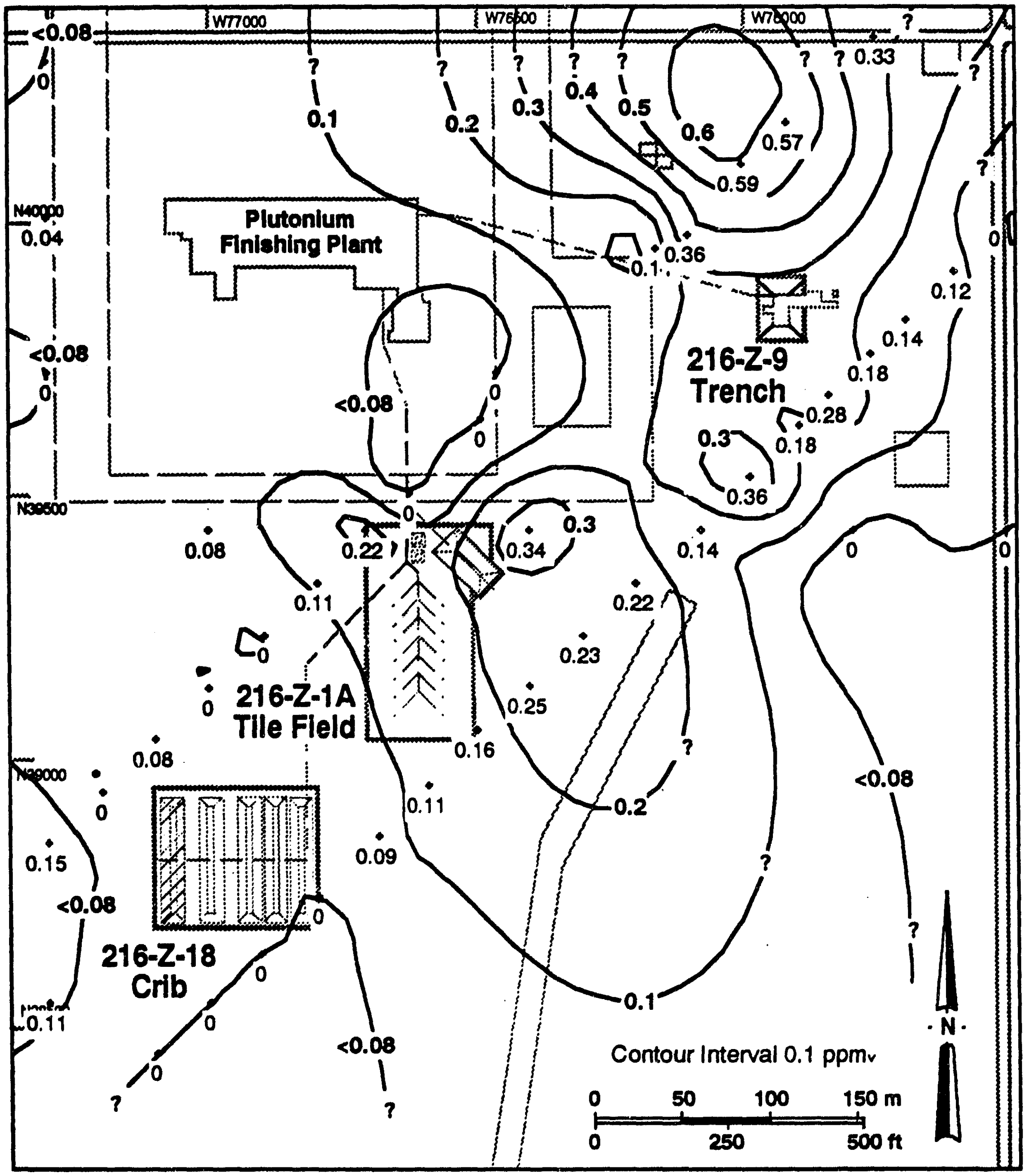


Figure 4-4. Near-Surface Soil-Gas Concentrations of Chloroform Measured in May 1992.



Quadrel Services, Inc., where the contaminants were thermally desorbed from the sorbent collectors and analyzed using a gas chromatograph/mass spectrometer. The results are used to calculate a flux rate out of the soil for each contaminant. The EMFLUX technology was first deployed between August 6 and August 10, 1992, in a small nine-station configuration around the 216-Z-9 Trench and at one background station (Figure 4-2). The emission flux rates of carbon tetrachloride from this sampling ranged from 111 to 686 $ng/m^2/min$ (Last and Rohay 1993). The highest flux rate of carbon tetrachloride was measured northeast of the trench. The highest flux of chloroform observed in this survey was 18.3 $ng/m^2/min$ at the same location as the highest carbon tetrachloride flux (Table 4-1).

The PETREX technology was deployed on August 11, 1992. A total of 25 samplers were installed at 5 five different locations near the 3 carbon tetrachloride disposal sites and at 1 background station (Figure 4-2). The purpose of this deployment was to demonstrate the technology, evaluate which compounds of interest were detectible, and determine the most appropriate field exposure time for these samplers (Rohay and Last 1992). The first of the batch of samplers (one from each location) was retrieved 9 days after deployment. The remaining samplers were retrieved in batches (again, one from each location) at 7-day intervals, with the last batch of samplers retrieved on September 17, 1992. Upon retrieval, the samplers were shipped by overnight express to the NERI laboratory for analysis. Each sampler contained two ferromagnetic wires coated with an activated carbon adsorbent. One wire from each sampler was analyzed by thermal desorption-mass spectrometry (TD-MS), and the other was analyzed by thermal desorption-gas chromatography/mass spectrometry (TD-GC/MS). The target compounds of interest consisted of carbon tetrachloride, chloroform, methylene chloride, PCE, TCE, tributyl phosphate (TBP), dibutyl phosphate (DBP), dibutyl butyl phosphonate (DBBP), monobutyl phosphate (MBP), and triglycerides (lard oil). The final report on results of these analyses was delivered in April 1993 (Appendix E). Of the target analytes, only carbon tetrachloride, chloroform, PCE, and TCE were detected; however, toluene and benzene were also detected. Analytical results were reported as ion counts and are provided in Table 4-2. These results show that for most compounds the ion count values stabilized after 2 weeks of field exposure. The results suggest that the concentrations of carbon tetrachloride, chloroform, PCE, and toluene were highest near the 216-Z-9 Trench, while the concentrations of TCE were highest both at the 216-Z-9 Trench and the 216-Z-1A Tile Field. Benzene concentrations were highest at 216-Z-9 and 216-Z-18, with one anomalous high value at the background station.

A second deployment of the EMFLUX technology was conducted between July 28 and July 31, 1993 (Rohay et al. 1993a). This deployment consisted of 34 sampling stations located primarily to the north of 216-Z-9 Trench, where available soil-gas data were lacking (Figure 4-2). The emission flux rates of carbon tetrachloride from this second deployment ranged from 1.4 to to 251.7 $ng/m^2/min$ (<40% of the maximum flux rate observed in the 1992 deployment) (Table 4-1). Other compounds detected included acetone, toluene, xylene, and TCE. The distribution of carbon tetrachloride flux rates (Figure 4-5) suggests that the highest fluxes occur surrounding the 216-Z-9 Trench. An area of lower carbon tetrachloride flux rates was found near the 216-T-19 Crib, recently identified as a waste disposal facility for minor amounts of carbon tetrahcloride (Rohay et al. 1993a). Highest fluxes of TCE were also found in the vicinity of and to the southwest of the 216-Z-9 Trench.

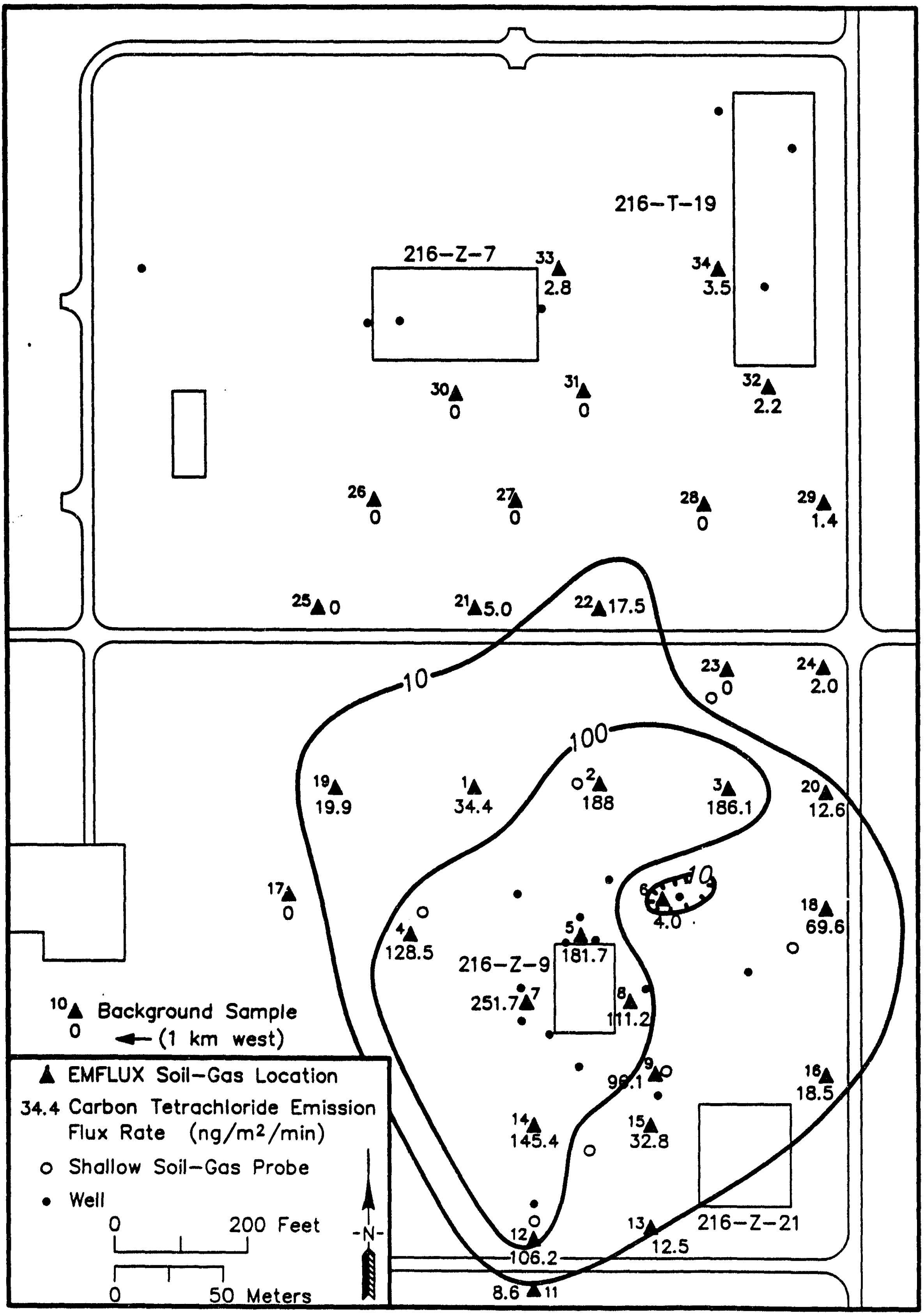
Table 4-2. Analytical Results (reported as ion counts) from the PETREX Soil-Gas Test, August 11 - September 17, 1992.

Site number	Sample number	Toluene	Carbon tetrachloride	Benzene	TCE	Chloroform	PCE
Week 1: August 11 - August 20, 1992							
1	1	688	129688	2008	1299	21660	23693
2	6	0	80088	507	1222	6821	16901
3	11	309	79307	1189	3555	4063	10023
4	16	630	7521	2514	0	636	2046
5	21	394	321	717	0	1069	239
Week 2: August 11 - August 27, 1992							
1	2	2141	119722	4662	3627	20876	99638
2	7	0	109823	731	3310	15887	38627
3	12	375	24462	864	1704	1833	12132
4	17	419	3849	1602	0	359	1682
5	22	0	0	312	0	0	0
Week 3: August 11 - September 3, 1992							
1	3	2115	148962	4321	0	0	152635
2	8	0	127762	877	10858	0	119372
3	13	201	113508	1952	8234	13447	46583
4	18	228	19425	5741	460	2253	4122
5	23	0	0	464	0	0	0
Week 4: August 11 - September 10, 1992							
1	4	1533	115139	4697	0	0	119676
2	9	0	62139	412	3068	7430	42925
3	14	0	63419	604	3766	5769	10919
4	19	0	2260	1286	0	252	1392
5	24	0	0	330	0	238	0
Week 5: August 11 - September 17, 1992							
1	5	5332	130917	13419	0	57102	153725
2	10	272	92321	2145	11439	42381	95495
3	15	448	100544	1999	7632	11947	26515
4	20	786	20448	7087	478	3044	2513
5	25	1575	0	11978	0	278	0

NOTE: Toluene = mass 92; carbon tetrachloride or tetrachloromethane = mass 121; benzene = mass 78; TCE (trichloroethene) = mass 130; chloroform = mass 83; PCE (tetrachloroethene) = mass 164.

All values are in units of ion counts derived from thermal desorption-mass spectrometry.

Figure 4-5. Carbon Tetrachloride Soil-Gas Flux Rates from the July 28-31, 1993 EMFLUX Passive Soil-Gas Survey.



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The detection of acetone, toluene, and xylene was rather randomly dispersed in the southern portion of the sampling grid. During additional EMFLUX sampling at the 216-Z-9 Trench in July 1993 (from July 21-24 at stations 2-3 and 5-10 and from July 24-28 at stations 5-6), the highest carbon tetrachloride flux rate observed was 922.7 ng/m^2/min on the north side of the trench (Table 4-1).

4.2.1.3 Baseline Monitoring of Near-Surface Soil-Gas Ports. Selected probes in the FY 1991 and FY 1992 networks have been monitored approximately twice per week from December 1991 through December 1993 using an organic vapor monitor (Fancher 1994, Rohay 1993). A description of the sampling and analysis methods are described in Fancher (1993, 1994). Statistics for the 25-month dataset are provided in Appendix D.

The maximum VOC concentration recorded at each shallow soil-gas probe in the baseline monitoring network is displayed in Figure 4-6. Each probe in the 1991 network at the 216-Z-18 Crib was measured approximately 120 times. Each probe in the 1992 network anchored at the 216-Z-9 Trench was measured approximately 85 times. The 1992 probes were added to the baseline monitoring network in February 1993. At about the same time, a change was implemented in the analytical method using the organic vapor monitor. For that reason, data from the two areas should not be compared. A more detailed analysis of these data is provided in Fancher (1994).

In general, the data in the 216-Z-1A/216-Z-18 area appear to be consistent with the results of the active soil-gas sampling (Figure 4-3). Observed concentrations are higher north and northwest of 216-Z-18, west of 216-Z-1A. At the 216-Z-9 Trench, higher soil-gas concentrations are found north of the trench.

4.2.2 Subsurface Soil-Gas Measurements

Subsurface soil-gas data are available from several investigative activities: wellhead detections/monitoring throughout the 200 West Area, baseline monitoring of wellheads and deep soil-gas ports at the ERA/VOC-Arid ID carbon tetrachloride site, active sampling/measurement of new wells under construction, and sampling/ monitoring of the vapor extraction gases. Descriptions of these activities are presented in Rohay and Johnson (1991); Rohay (1991, 1993); Rohay et al. (1992a, 1992b, 1993a); Fancher (1993, 1994); Rohay and Cameron (1993); and Last and Rohay (1993).

4.2.2.1 Far-Field Wellhead Detection of Carbon Tetrachloride. Carbon tetrachloride (mostly measured as total chlorinated hydrocarbons) has been detected using field screening instruments in wells under construction throughout much of the 200 West Area since January 1987 (Rohay and Johnson 1991, Last and Rohay 1993). These wellhead measurements are strongly affected by barometric pressure changes and are used to examine the distribution of carbon tetrachloride vapors either above or below the caliche layer (Plio-Pleistocene unit). Most of the reported detections have been from below the caliche layer, often in the capillary fringe zone just above the water table. However, wells drilled adjacent to the carbon tetrachloride disposal facilities, and some wells drilled west and south of the 216-Z-18 Crib, have detected carbon tetrachloride both above and below the caliche layer.

Figure 4-6. Maximum Carbon Tetrachloride Concentrations Recorded at Shallow Soil-Gas Probes, December 1991 Through December 1993 (from Fancher 1994).

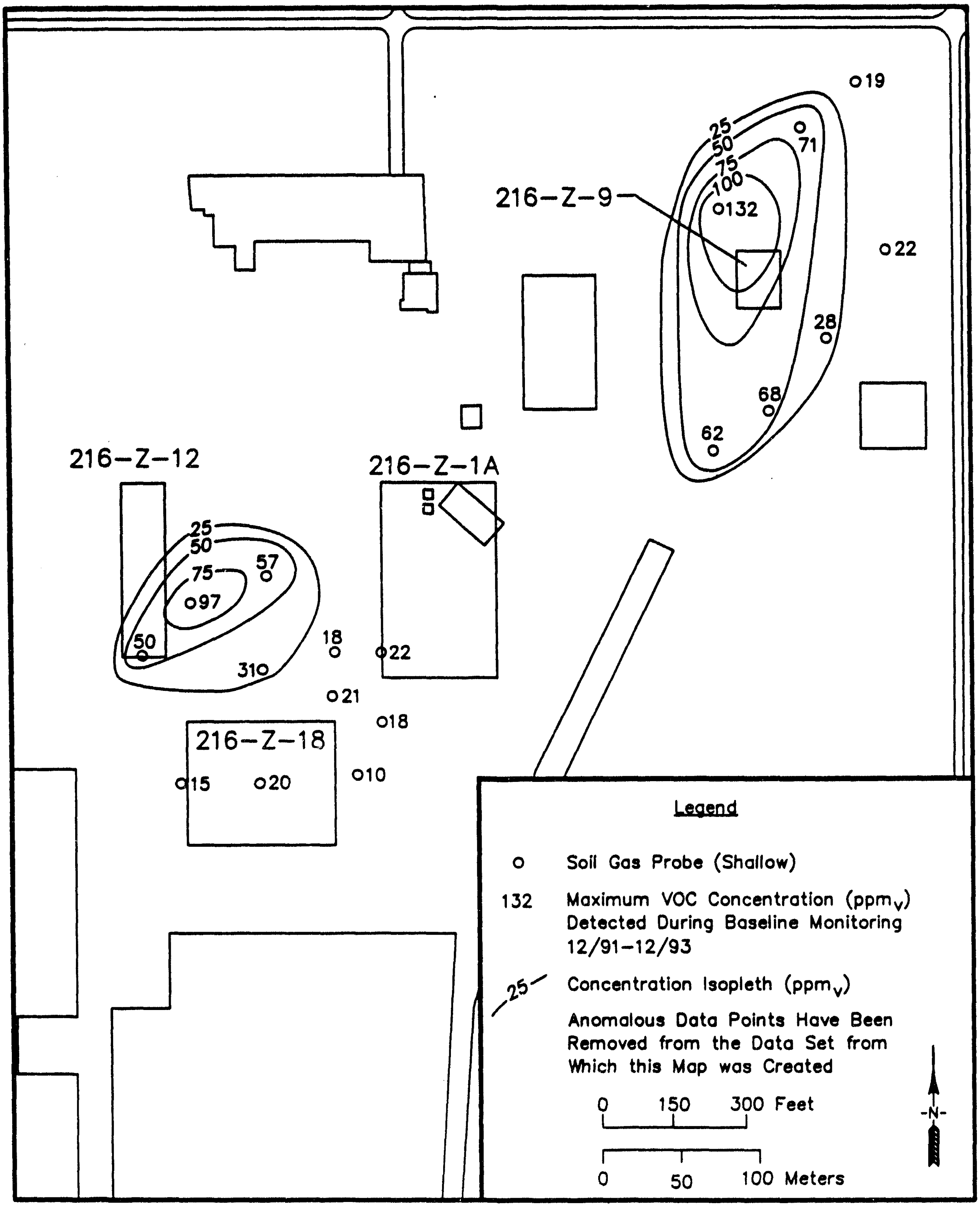

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Figure 4-7 illustrates the location of wellhead detections of carbon tetrachloride (or total chlorinated hydrocarbons) between January 1987 and September 1992. Note that carbon tetrachloride (as chlorinated hydrocarbons) has been detected in wellheads located outside the maximum extent of the groundwater plume (Section 4.3).

4.2.2.2 Deep Soil-Gas Monitoring in the Carbon Tetrachloride Disposal Site Area. The baseline monitoring program for the vapor extraction system consists of 116 selected wells and deep soil-gas probes that have been monitored twice per week from December 1991 to December 1993 (Fancher 1994). Statistics for the entire 25-month period are included in Appendix D. Interpretation of all the data is provided in Fancher (1994).

The wells and deep soil-gas probes are monitored using a total organic vapor monitor. The total VOC measurement is assumed to consist solely of carbon tetrachloride, based on its predominance in samples analyzed via gas chromatography (Section 4.1.2). The contaminant concentrations fluctuate in response to changes in the barometric pressure; observed carbon tetrachloride concentrations (measured as total organic vapor) range from 0 to over 10,000 ppm_v (Fancher 1994). Because a zero reading may be indicative of an inhalation event, the maximum baseline monitoring value for each well is judged to have the greatest likelihood of representing equilibrium conditions.

The maximum values for the baseline monitoring network measured between December 1991 and December 1993 at wells and deep soil-gas probes with open areas above the Plio-Pleistocene unit (caliche) are shown in Figure 4-8; the maximum values for wells with open areas below the caliche are shown in Figure 4-9. In constructing these figures, it was assumed that the monitoring points are comparable, despite their differing ages, locations, depths, and completions. Open intervals in the boreholes range from approximately 23 to 48 m. The deep soil-gas probes were emplaced using the cone penetrometer and range in depth from 3 to 33 m deep. In addition, the distributions of vapor shown in Figures 4-8 and 4-9 are limited by the extent of the monitoring network.

Carbon tetrachloride concentrations exceeding 10,000 ppm_v were observed above the caliche north/northeast of the 216-Z-9 Trench. By contrast, carbon tetrachloride concentrations observed above the caliche in the 216-Z-1A/216-Z-12 area are an order of magnitude lower (Figure 4-8). Carbon tetrachloride concentrations exceeding 1,000 ppm_v were observed below the caliche in both the 216-Z-9 and 216-Z-1A/216-Z-12 areas (Figure 4-9).

4.2.2.3 Vapor Extraction System Sampling. Downhole soil-vapor sampling was conducted during pilot tests of the vapor extraction system at the 216-Z-1A Tile Field in April 1991 (DOE-RL 1991). These tests found that the carbon tetrachloride had migrated to a depth of at least 40 m. Vapor concentrations generally increased with depth, with the highest concentrations [100 ppm_v found at 26 m below ground surface (or ~15 m above the caliche layer)]. Initial operating tests of the vapor extraction pilot system in the 35- to 42-m-depth interval in April 1991 found initial carbon tetrachloride concentrations on the order of 200 ppm_v, which gradually increased to 600 to 700 ppm_v after 30 h of venting, and peaked at 915 ppm_v 67 h into the test. Samples were analyzed in the laboratory using a gas chromatography mass spectrometer (DOE-RL 1991).

Figure 4-7. Location of Volatile Organic Compounds Detected Above and Below the Caliche Layer During Well Drilling Between January 1987 and September 1992 (from Last and Rohay 1993).

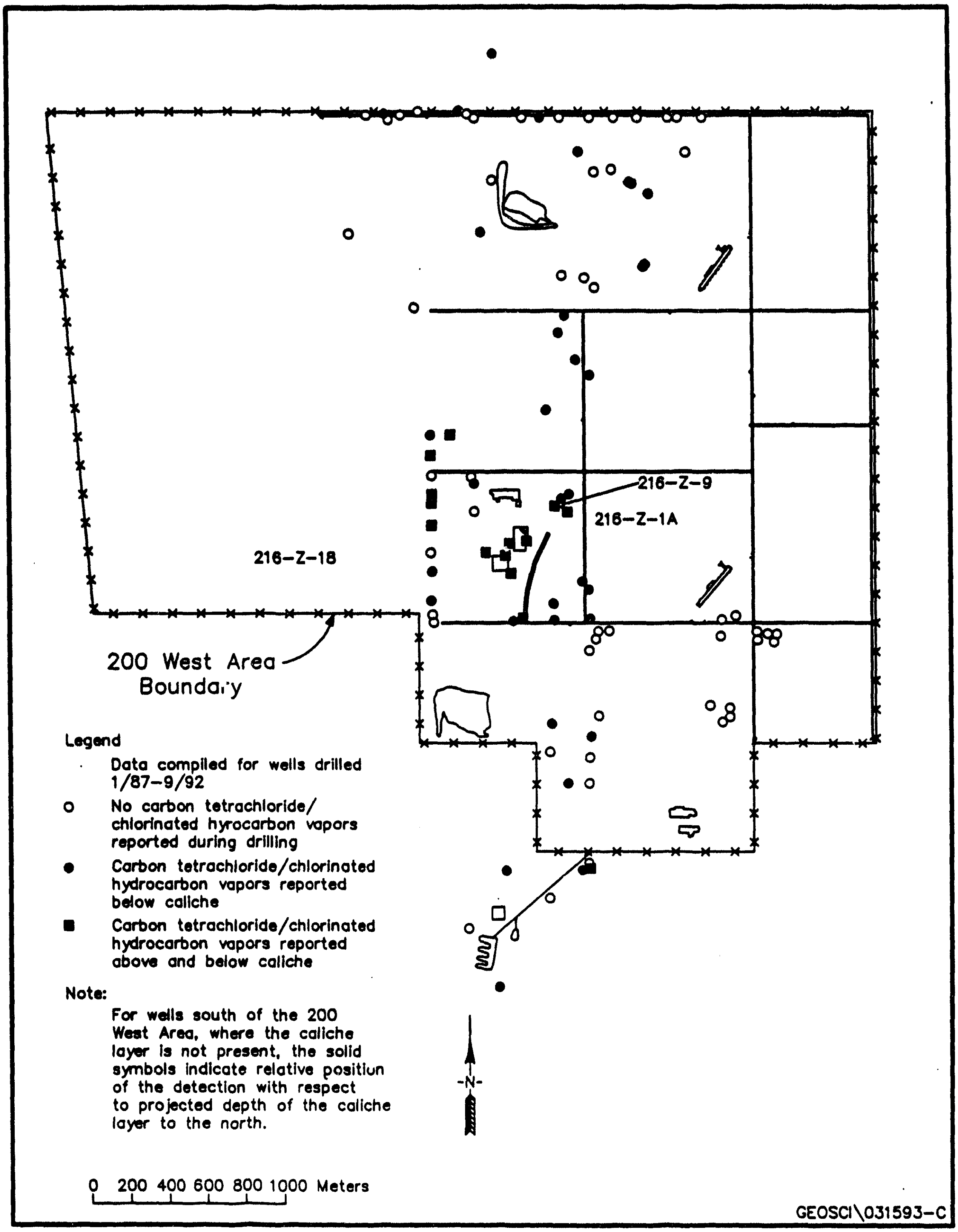

Figure 4-8. Maximum Carbon Tetrachloride Concentrations Recorded at Wells and Deep Soil-Gas Probes Open Above the Plio-Pleistocene Unit, December 1991 Through December 1993 (from Fancher 1994).

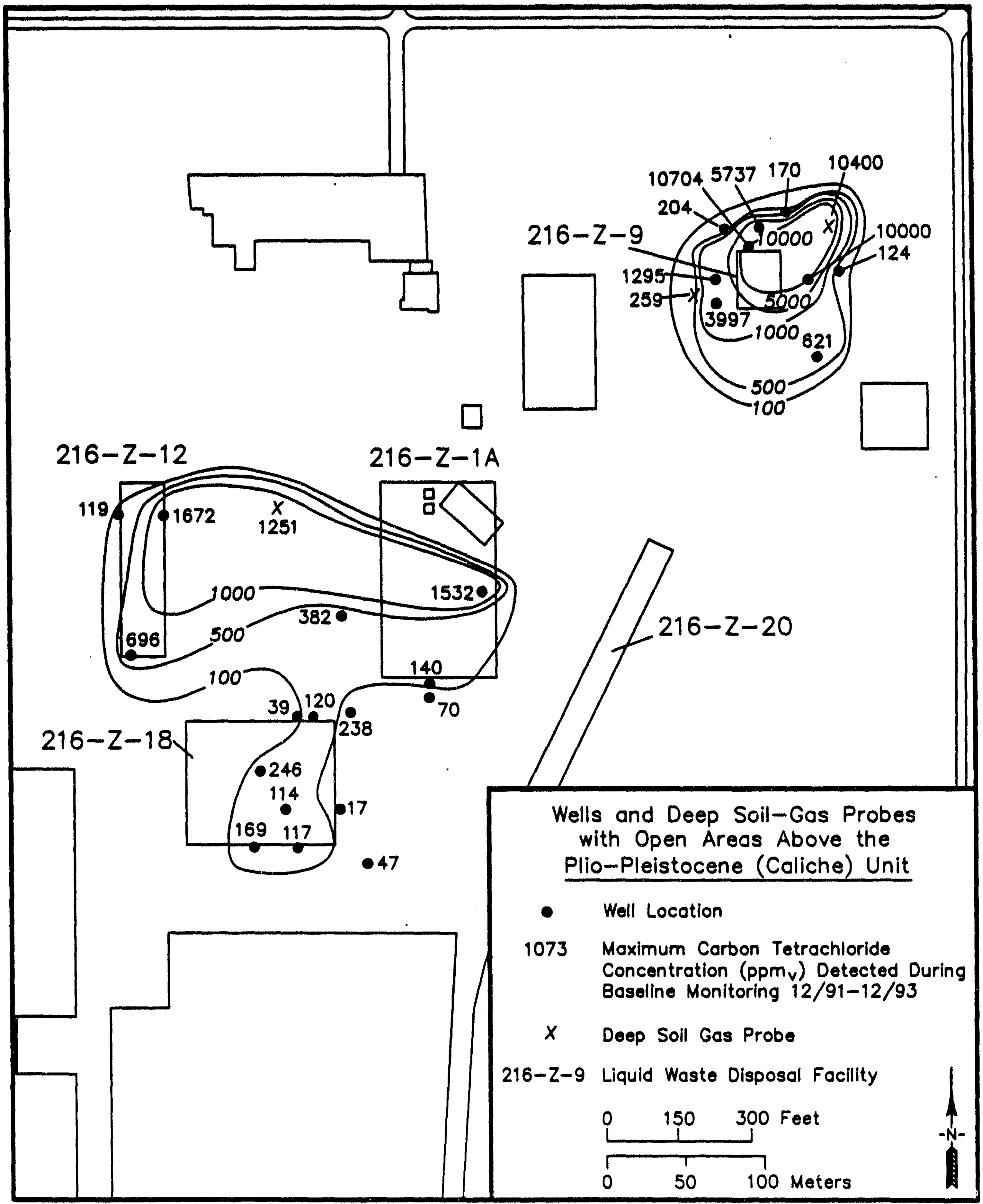

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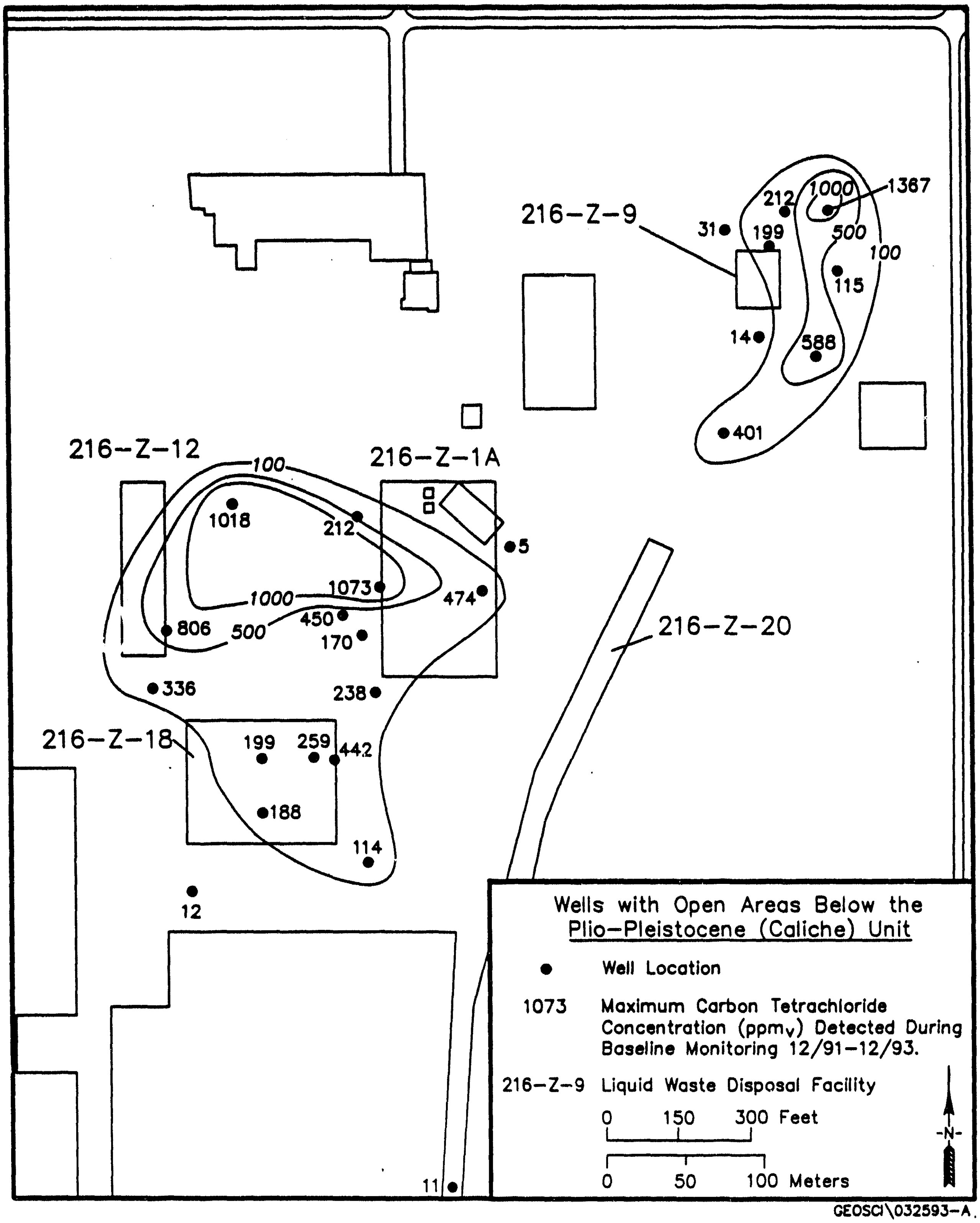
Figure 4-9. Maximum Carbon Tetrachloride Concentrations Recorded at Wells Open Below the Plio-Pleistocene Unit, December 1991 Through December 1993 (from Fancher 1994).



A vapor extraction system began operating at the 216-Z-1A Tile Field in February 1992, using existing wells perforated at the approximate 35-m depth (i.e., above the caliche). In general, the wells are perforated across the contact between finer grained and coarser grained units. Usually, the vapor extraction system has been extracting from 4 to 10 wells simultaneously. When the carbon tetrachloride concentration in an extraction well drops significantly, the vapor extraction system is switched to a different well to optimize production. Average carbon tetrachloride concentrations in the combined vapor stream drawn from wells within the tile field gradually increased from approximately 400 to 500 ppm_v in August 1992 to approximately 700 to 1,000 ppm_v in December 1992 at average flow rates ranging from 124 to 210 ft^3/min. The increase in carbon tetrachloride suggests that the vapor plume was steadily being drawn in toward the extraction wells by the vapor extraction system. During extraction from nine wells from February to June 1993, combined vapor stream concentrations fell to 200 to 500 ppm_v, indicating removal of the higher concentration vapor plume. The typical extraction flow rates ranged from 20 to 300 ft^3/min per extraction well. This same vapor extraction system began operating at the 216-Z-18 Crib during the summer of 1992. The extracted soil vapor concentrations from two wells (one open below the caliche) in the 216-Z-18 Crib has been a few hundred parts per million by volume carbon tetrachloride.

Characterization tests were conducted using the vapor extraction equipment to extract soil gas from a single open interval while measurements were made of the flow rate and vacuum. The carbon tetrachloride concentration in the extracted soil gas was analyzed using a photo-acoustic infrared sensor. Characterization testing data at the 216-Z-1A/216-Z-18 wellfield in June 1993 are presented in Table 4-3 (Rohay and Cameron 1994). The extent of the horizontal influence of the vacuum placed on each of the extraction wells is in the range of 100 ft, established during the pilot testing of the vapor extraction system (DOE-RL 1991, Appendix F).

A second vapor extraction system began operating at the 216-Z-9 Trench in March 1993 and was used to characterize several 216-Z-9 wells in the spring of 1993. As shown in Table 4-4, the concentrations of carbon tetrachloride in the extracted soil vapor from above the caliche in those wells ranged from 77 to 28,500 ppm_v (Rohay and Cameron 1994). Concentrations of carbon tetrachloride in soil gas extracted from above the caliche in the 216-Z-9 wellfield are at least an order of magnitude higher than concentrations extracted from above the caliche in the 216-Z-1A/216-Z-18 wellfield (Figure 4-10).

In June 1993, an overheating incident in the primary granular activated carbon canister at the 216-Z-9 Trench resulted in the temporary suspension of all active vapor extraction operations (Rohay 1993). Operations resumed at the 216-Z-1A/216-Z-18 site in November 1993 and at the 216-Z-9 site in February 1994. As of the end of May 1994, a total of 16,790 kg of carbon tetrachloride has been removed from the unsaturated zone using active vapor extraction, 5,030 kg from the 216-Z-1A/216-Z-18 wellfield, and 11,760 kg from the 216-Z-9 wellfield.

4.2.2.4 In Situ Soil-Gas Sampling. In situ soil-gas samples were collected during the drilling of unsaturated zone monitoring/vapor extraction wells at the ERA/VOC-Arid ID carbon tetrachloride site. In situ samples were collected using the SEAMIST (tradename of Eastman Cherrington Environmental, Santa Fe, New Mexico) soil-gas sampling system (Rohay and McLellan 1992) and the

Table 4-3. Results of 216-Z-1A/216-Z-18 Wellfield Characterization Tests (from Rohay and Cameron 1994).

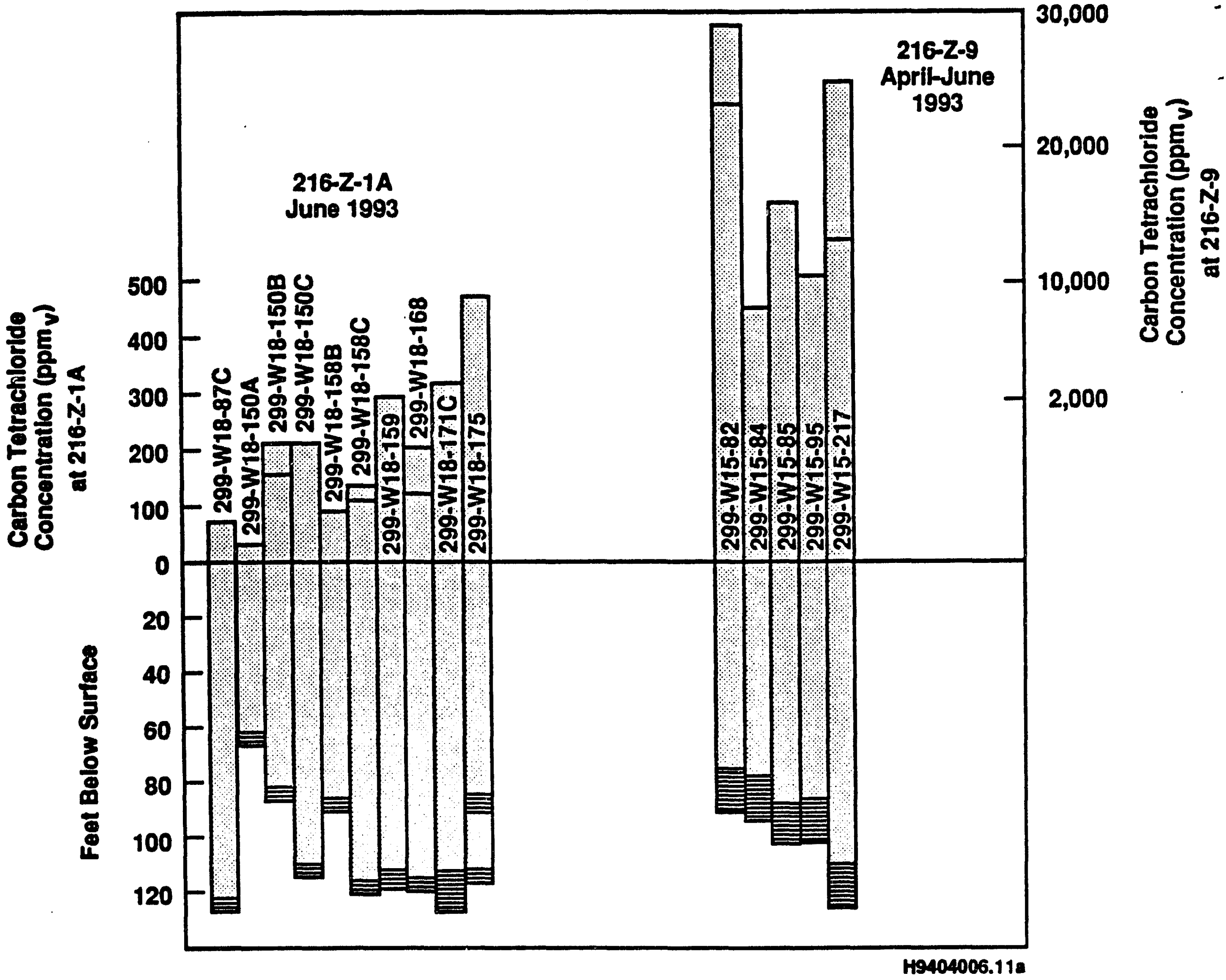
Date	Well number	Open interval (ft below ground surface)	Vacuum (in. H_2O)	Flow (ft^3/min)	Carbon tetrachloride concentration (ppm$_v$)
06/01/93	299-W18-175	84-91 112-117	132	68	475
06/01/93	299-W18-150 A[a]	62-67	131	32	33
06/01/93	299-W18-150 B[b]	82-87	132	28	219/157[c]
06/01/93	299-W18-150 C[d]	110-115	132	84	215
06/01/93	299-W18-166	121-126	130	16	5/82[c]
06/01/93	299-W18-158 A	72-77	31	64 leak	2
06/01/93	299-W18-158 B	86-91	131	40	86
06/01/93	299-W18-158 C	116-121	131	40	108/144[c]
06/01/93	299-W18-159	112-119	132	72	298
06/01/93	299-W18-168	115-120	139	27	131/212[c]
06/01/93	299-W18-163 A	67-77	141	11	2
06/01/93	299-W18-163 B	90-97	130	10	2
06/01/93	299-W18-163 C	112-117	124	8	5
06/01/93	299-W18-87 C	122.5-127.5	130	120	75
06/01/93	299-W18-171 C	112.5-127.5	130	296	325
06/01/93	299-W18-97	63-75	134	312	23
06/01/93	299-W18-10	180-211	130	80	147/221[c]

[a] Upper interval.
[b] Middle interval.
[c] Dual concentration values denote measurements taken at two different times during testing.
[d] Lower interval.

Table 4-4. Results of 216-Z-9 Wellfield Characterization Testing (from Rohay and Cameron 1994).

Date	Well number	Open interval (ft below ground surface)	Vacuum (in. H_2O)	Flow (ft^3/min)	Carbon tetrachloride concentration (ppm_v)
Before perforation					
03/31/93	299-W15-82	Area of bottom	128	23	1,333
04/14/93	299-W15-95	Area of bottom	Unknown	22	5,660
After perforation					
04/28/93	299-W15-82	73-88	116	203	22,350
04/28/93	299-W15-95	83-98	118	34	10,700
04/29/93	299-W15-84	75-90	102	75	8,475
04/30/93	299-W15-85	83-98	85	205	15,950
05/04/93	299-W15-217	106-121	56	75	13,474
05/05/93	299-W15-217	106-121	130	157	17,975
05/10/93	299-W15-217	106-121	119	186	24,367
05/11/93	299-W15-217	106-121	102	173	23,933
05/27/93	CPT-12	36-49	101	64	78
06/03/93	299-W15-82	73-88	69	253	28,500

Figure 4-10. Concentrations of Carbon Tetrachloride Observed During Characterization Testing at the 216-Z-1A/216-Z-18 and 216-Z-9 Wellfields, Spring 1993.



BoreSampler (WHC 1993b) during the FY 1992 and FY 1993 drilling activities (Last and Rohay 1993, Rohay et al. 1992a, 1993a). The samples were analyzed using a gas chromatography/electron capture detector.

It should be noted that barometric pressure has a strong influence on the movement and thus the concentration of VOCs in soil-gas measurements. Thus, the detection of VOC concentrations may not represent equilibrium conditions nor accurate concentrations in the vicinity of the sampling point.

A total of 36 SEAMIST soil-gas samples were collected from 5 wells installed in FY 1993 (Rohay et al. 1993a). Table 4-5 lists these results. The highest concentrations of carbon tetrachloride were detected in soil-gas samples from well 299-W15-218, just north of the 216-Z-9 Trench. Here concentrations increased from 45.39 ppm_v carbon tetrachloride at the 18.3-m depth to 20,910 ppm_v carbon tetrachloride at the 34-m depth (1 m above the caliche layer). Below this the concentrations dropped down to 29.75 ppm_v carbon tetrachloride at the 38.6-m depth and then increased again to 10,380 ppm_v carbon tetrachloride at the 57.8-m depth (3 m above the water table). Other high concentrations (over 1,000 ppm_v) of carbon tetrachloride have been observed in wells 299-W15-220 (1,511.6 ppm_v at 27.4 m) and 299-W18-252 (1419.61 ppm_v at 48.6 m). A total of 37 SEAMIST soil-gas samples were collected from 6 wells in FY 1992. The highest concentration of carbon tetrachloride observed was 7,125 ppm_v from the 24-m depth in well 299-W15-217 (Last and Rohay 1993).

4.2.3 Borehole Sediment Sampling

Sediment samples were collected from five new boreholes and two existing boreholes that were deepened during FY 1993 (Rohay et al. 1993a). Six previous boreholes were sampled in FY 1992 (Rohay et al. 1992a, Last and Rohay 1993). This brings the total number of boreholes that have been sampled to 11 new wells and 2 deepened existing wells. These wells were installed to act as both monitoring wells and/or as vapor extraction wells. The two deepened wells are located within the boundaries of the 216-Z-18 Crib and 216-Z-1A Tile Field, respectively. Three wells installed in FY 1992 are adjacent (within 10 m) to the boundaries of each carbon tetrachloride crib, and the remaining eight new wells are installed near (within 25 to 80 m) the boundaries of the cribs. Figure 4-11 illustrates the locations of these wells.

The two deepened crib monitoring wells (299-W18-96 and 299-W18-174) and the three near-crib monitoring/vapor extraction wells (299-W15-217, 299-W18-248, and 299-W18-249) were installed to identify the VOCs and co-contaminants present, the physical state of these constituents, their concentration, and their distribution in the immediate vicinity of the cribs. These wells were drilled only to the top of the Plio-Pleistocene unit and were completed as vapor-extraction wells, with a 4.6-m screened interval situated to span the contact between the Plio-Pleistocene laminated silts and lower Hanford formation sediments (Appendix F). Sediment samples were collected for chemical analyses approximately every 1.5 m.

Seven near-field unsaturated zone monitoring/vapor extraction wells (299-W15-216, 299-W15-218, 299-W15-219, 299-W15-220, 299-W18-246, 299-W18-247, and 299-W18-252) were installed around the perimeter of the three waste disposal facilities to further refine the conceptual model and to support

Table 4-5. Analytical Results from In Situ Soil-Gas Sampling of Five Boreholes in the Carbon Tetrachloride Disposal Site Area Using the SEAMIST System in FY 1993.

Well No. 299-W18-252

Depth (ft)	GC/ECD (ppm)	OVM (ppm)
48.86	0.83 Unk	0
	1.72 Unk	0
	.70 Unk	0
	1.73 CCL4	0
	1.48 Unk	0
64.6	*	3.5
85.68	1.19 Unk	0
	6.12 Unk	
	16.32 CCL4	
	7.82 Unk	
	1.02 Unk	
	4.08 Unk	
104.42	*	0
123.2	5.251 CCL4	0
138	36.410 CCL4	1.8
	5.133 Unk	
	0.177 CHCL3	
159.4	1419.61 CCL4	26
	3.057 Unk	
	0.134 Unk	
	1.623 Unk	
	0.074 Unk	
185.8	8.918 CCL4	0
202.24	0.475 Unk	2.5
	0.123 Unk	
	169.708 CCL4	
	14.818 Unk	
	0.012 CH2CL2	
	0.683 Unk	
	0.511 CHCL3	
	1.660 Unk	

Well No. 299-W15-220

Depth (ft)	GC/ECD (ppm)	OVM (ppm)
50.5	853.66 CCL4	174
70	*	76
90	1,511.6 CCL4	121.7
	11.09 CHCL3	
	11.16 Unk	
	0.14 1-2 DCA	
115	633.02 CCL4	121.7
	0.99 CHCL3	
	0.54 Unk	
	0.09 1-2 DCA	
142	149.0 CCL4	18.1
	0.97 CHCL3	
	2.12 Unk	
	0.12 Unk	
	0.10 Unk	
142	167.2 CCL4	18.1
	0.45 CHCL3	
	0.10 Unk	
	0.03 Unk	
160	108.356 CCL4	22.2
	0.045 Unk	
	1.305 CHCL3	
	0.022 1-2 DCA	
182	49.368 CCL4	8.2
	1.551 CHCL3	
	0.450 1-2 DCA	
182	50.160 CCL4	8.2
	0.020 Unk	
	1.435 CHCL3	
	0.006 1-2 DCA	

Well No. 299-W15-218

Depth (ft)	GC/ECD (ppm)	OVM (ppm)
59.9	45.39 CCL4	16.5
92	102.85 CCL4	46.6
111.8	16,660 CCL4	590
	18.7 CHCL3	
111.8	20,910 CCL4	602
	96.6 CHCL3	
	2.89 CH2CL2	
126.6	29.75 CCL4	73.6
139.5	10.2 CCL4	30.1
	7.905 CCL4	
158.9	155.04 CCL4	3.1
178.5	778.6 CCL4	0
189.7	10,380 CCL4	489
	0.68 CHCL3	

Well No. 299-W18-96

Depth (ft)	GC/ECD (ppm)	OVM (ppm)
86.7	8.1 CCL4	3.9
101.1	8.31 CCL4	5.5
121.8	98.09 CCL4	28.6
148.15	*	29.7

Well No. 299-W15-223

Vertical Depth (ft)	Length of Borehole (ft)	GCE/ECD (ppm)	OVM (ppm)
85	120	27.673 ppm CCL4	33
		2.293 ppb* CH2CL2	
		677.684 ppb Unk	
		148.980 ppb Unk	
		60.657 ppb Unk	
		19.667 ppb Unk	
98	138.6	10.597 ppm CCL4	—
104	147	36.774 ppm CCL4	0
		319.305 ppb CH3CL3	
		322.584 ppb C2H3CL	
		314.397 ppb Unk	
		187.787 ppb Unk	
		134.224 ppb Unk	
		109.571 ppb Unk	
		89.074 ppb Unk	
		85.816 ppb Unk	
		51.383 ppb Unk	
		7.120 ppb Unk	
110	155.6	11.138 ppm CCL4	1.9
119.9	169.5	116.654 ppm CCL4	752

* Well 299-W15-223 was the first well analyzed to ppb concentrations.

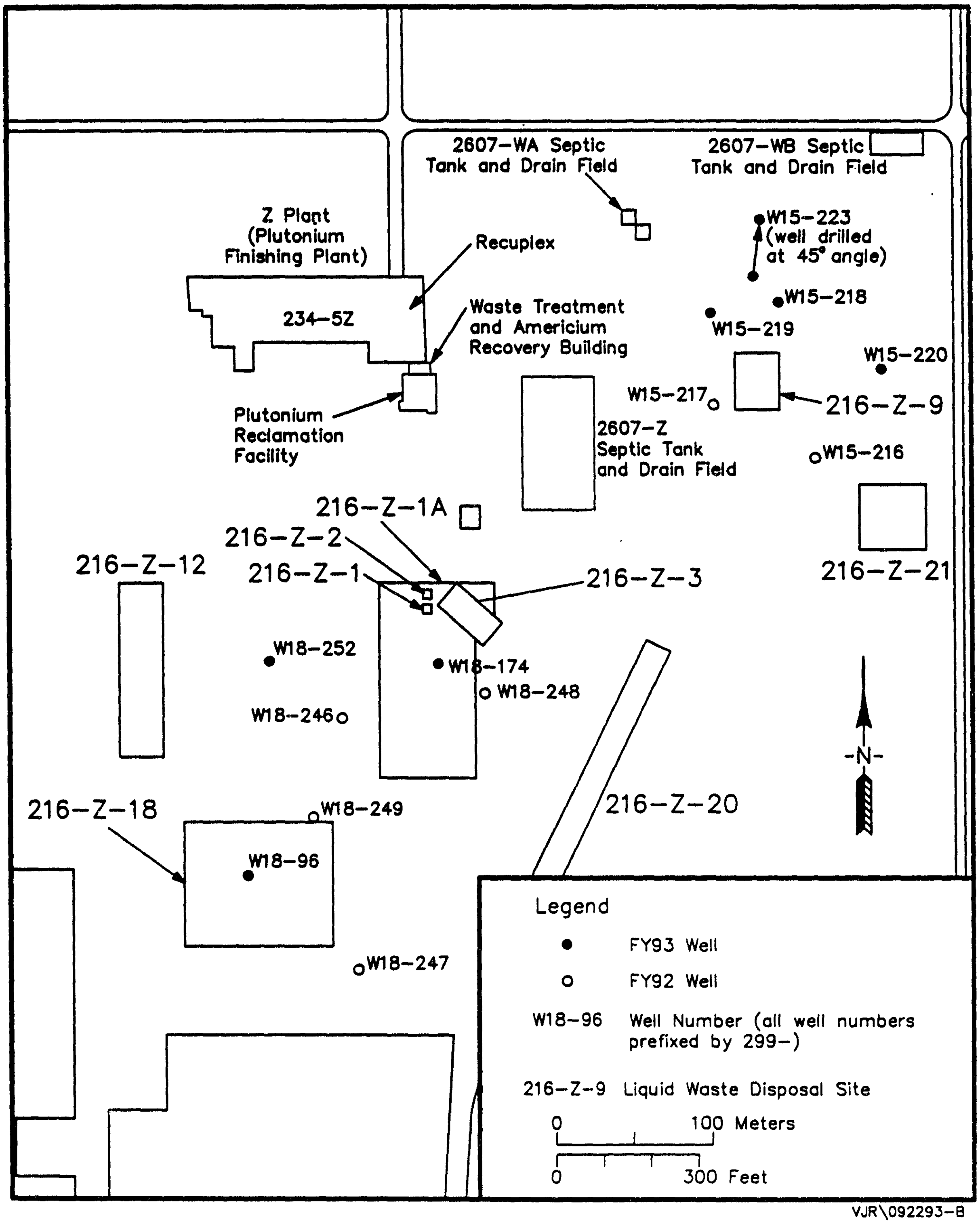
(GC/ECD) Gas Chromatograph/Electron Capture Detector

(OVM) Organic Vapor Monitor

* Results not received from laboratory.

Unk= Unknown

Figure 4-11. Location of FY 1992 and FY 1993 Unsaturated Zone Monitoring/ Vapor Extraction Wells at the ERA/VOC-Arid ID Carbon Tetrachloride Site.



vapor extraction system operations. Of principal interest was the nature and distribution of carbon tetrachloride and co-contaminants in the unsaturated zone. These boreholes were drilled approximately 6 m into the unconfined aquifer. Sediment samples were collected for chemical analyses approximately every 1.5 to 6 m, and groundwater samples were collected approximately every 1.5 m. The lower portion of the borehole was then grouted and the wells completed with two 3-m screened intervals: one just below and one just above the Plio-Pleistocene unit (Appendix F). Packers were then set to isolate the two intervals.

An eighth near-field monitoring/vapor extraction well (299-W15-223) was installed at a 45° angle to investigate the distribution of carbon tetrachloride beneath a recently installed asphalt parking lot. High near-surface soil-gas concentrations had previously been recorded here prior to the pavement of the parking lot (Last and Rohay 1993). This well was drilled using a sonic drill rig to the top of the Plio-Pleistocene caliche unit and was completed as a vapor extraction well, with a 6-m-long (4.3 vertical m) screened interval situated to span the contact between the Hanford formation sand and Plio-Pleistocene silt. Continuous core was recovered as drilling progressed, with subsamples collected for chemical analyses approximately every 1.5 m.

Details on the drilling and completion activities, materials encountered, and sampling and handling methods used can be found in Rohay et al. (1992a, 1993a). Construction details for these wells are summarized in Table 4-6. Table 4-7 lists the chemical and radiological analytes determined for sediment and groundwater samples from these wells. Constituents of potential interest not analyzed include DBP, DBBP, MBP, triglycerides, aluminum, rubidium, plutonium, americium, and strontium (WHC 1991, Rohay et al. 1992). These analyses were prohibitively expensive and, thus, were either not analyzed for or a less-expensive screening-type analysis (e.g., gross alpha, gross beta) was substituted. Results of these analyses are included in Appendix G.

The following discussions summarize the sediment and groundwater sample results, addressing the nature and distribution of contaminants found in the unsaturated zone and groundwater beneath and adjacent to each waste disposal facility. Note that these soil analyses represent total analyses and include constituents in the vapor phase, aqueous phase, nonaqueous phase (if present), and/or sorbed on the soil particles. Also note that active vapor extraction systems have been operating at each of the three carbon tetrachloride cribs, thus the concentration of volatile organics was likely affected in the vicinity of the cribs (Section 4.2.2.3).

4.2.3.1 216-Z-9 Trench. Chemical analyses of borehole samples are available from all six wells located in the vicinity of the 216-Z-9 Trench (Figure 4-11). Volatile organic analyses are available from all of these wells, while other chemical and radiological analyses were performed only on borehole samples from wells 299-W15-216 and 299-W15-217. Table 4-8 summarizes the maximum concentration of target analytes and other constituents of interest detected in the vicinity of the 216-Z-9 Trench.

Table 4-6. Well Construction Summary for the FY 1992 and FY 1993 Unsaturated Zone Monitoring/Vapor Extraction Wells.

Well number	Lambert coordinates		Pad elevation (ft)	Drill depth (ft)	Completed depth (ft)	Depth to water (ft)	Well diameter (in.)	Screened interval (ft)	Date completed
	North	East							
299-W15-216	135,561.129	566,793.635	661.42	210.0	184.6	193.7[a]	4	69.7-79.8 174.5-184.6	July 8, 1992
299-W15-217	135,595.174	566,730.801	668.71	123.4	122.2	NA	4	106-121	July 10, 1992
299-W15-218	135,661.168	566,771.023	665.36	206.1	195.3	198.97	4	98.5-113.5 180.4-195.3	April 28, 1993
299-W15-219	135,654.033	566,728.897	668.02	212	182.5	201.6	4	87.2-102.2 167.2-182.2	July 16, 1993
299-W15-220	135,618.444	566,834.927	657.73	201	185.3	191.58[b]	4	80-95.10 170.02-185.3	August 25, 1993
299-W15-223[c]	135,677.748	566,755.386	666.18	119.0	117.0	NA	3.5	102.7-117.0	October 1, 1993
299-W18-96	135,293.826	566,435.228	NA	149.2	132.31	NA	2	122.29-131.88	March 5, 1993
299-W18-174	135,437.384	566,558.208	NA	131.5	126.45	NA	4	106.45-126.45	May 3, 1993
299-W18-246	135,392.889	566,493.313	681.32	230.0	175.2	213.8	4	120.0-130.0 164.9-174.9	June 17, 1992
299-W18-247	135,232.042	566,503.493	678.09	227.2	227.2	211.7	4	119-129 162-172	May 6, 1992
299-W18-248	135,409.221	566,584.053	676.11	141.0	138.9	NA	4	123.2-138.6	June 3, 1992
299-W18-249	135,329.264	566,474.813	679.74	146.7	137.0	NA	4	121.7-136.7	July 31, 1992
299-W18-252	135,429.477	566,447.020	680.59	228.5	210.3	215.83	4	113.24-133.21 165.13-185.00	August 6, 1993

NA = not applicable.

[a] Perched water at 92.3 ft.

[b] Perched water at 106.10 ft.

[c] Drilled at a 45° angle bearing N7E. Coordinates give intersection of well with ground surface; depths are vertical feet below ground surface.

Table 4-7. Chemical and Radiological Analytes Determined in Sediment and Groundwater Samples.

Volatile organics[a]	Anions[a]	Semivolatile organics[a]	Metals[a]	Radionuclides
Methylene chloride[b]	Fluoride[b]	o-Creosol	Antimony	Soil Analytes
trans-1,2-Dichloroethylene	Chloride[b]	m-Creosol	Barium	^{60}Co
1,1-Dichloroethane	Nitrate ion[b]	p-Creosol	Beryllium	^{106}Ru
cis-1,2-Dichloroethylene	Nitrite ion	Decane	Cadmium[b]	^{125}Sb
Chloroform[b]	Bromide	Dodecane	Calcium[b]	^{137}Cs
1,1,1-Trichloroethane	Phosphate[b]	Tetradecane	Chromium[b]	^{212}Pb
Carbon tetrachloride[b]	Sulfate[b]	Napthalene	Cobalt	^{214}Pb
1,2-Dichloroethane		Pentachloro-phenol	Copper	^{226}Ra
Benzene		Phenol	Iron[b]	^{224}Ra
Trichloroethylene		Tributyl phosphate[b]	Magnesium[b]	Total alpha
Toluene			Manganese	Total beta
Tetrachloroethylene[b]			Nickel[b]	
Ethylbenzene			Potassium	Water Analytes
M+P-xylene			Silver	^{60}Co
O-xylene			Sodium	^{106}Ru
Acetone			Tin	^{125}Sb
n-Butyl benzene			Vanadium	^{137}Cs
Methyl ethyl ketone			Zinc	Total alpha
Methyl iso butyl ketone			Soil Analytes	Total beta
			Cyanide Mercury Lead	

[a] Unless specifically designated, analyses for these constituents were performed for both the sediment and groundwater samples.

[b] Target constituents believed disposed to the facilities of interest (WHC 1991).

Table 4-8. Maximum Soil Concentrations of Target Constituents from Wells near the 216-Z-9 Trench.

Analyte	Units	Detection Level	Max. Soil Conc.	Well Number	Depth (m)
Target Volatile Organics					
Methylene Chloride	ppb		1171	299-W15-220	30.6
CHCl3	ppb		730	299-W15-218	39.6
CCl4	ppb		37817	299-W15-217	34.7
TCE	ppb		13	299-W15-217	34.7
PCE	ppb		28	299-W15-217	34.7
MEK	ppb		NR		
Other Volatile Organics					
cis-1,2-DCE	ppb		10	299-W15-218	39.6
1,1-DCA	ppb		18	299-W15-217	34.7
1,2-DCA	ppb		25	299-W15-218	24.4
1,1,1-TCA	ppb		3	299-W15-217	34.7
Benzene	ppb		3	299-W15-217	16.5 24.6
Toluene	ppb		>1329	299-W15-219	61.0
Ethylbenzene	ppb		4	299-W15-217	35.2
M+P-Xylene	ppb		~9	299-W15-217	35.2
O-Xylene	ppb		16	299-W15-218	59.4
Acetone	ppb		NR		
n-Butyl Benzene	ppb		~2000 (d)	299-W15-219	45.7
Chlorobenzene	ppb		~70 (d)	299-W15-223	20.7
Target Semivolatile Organics					
TBP	ug/Kg	58	62(c)	299-W15-217	24.6
DPB			NA		
DBBP			NA		
MBP			NA		
Triglycerides (lard oil)			NA		
Other Semivolatile Organics					
Decane	ug/Kg	54	ND		
Dodecane	ug/Kg	31	ND		
Tetradecane	ug/Kg	52	ND		
Phenol	ug/Kg	49	220(c)	299-W15-217	30.9
Unknown Oxyhydrocarbon	ug/Kg		28000	299-W15-217	6.3
Target Metals					
Aluminum			NA		
Iron	ug/Kg	2000	31000000	299-W15-217	7.8
Cadium	ug/Kg	1000	ND		
Magnesium	ug/Kg	10000	7700000	299-W15-217	37.1
Chromium	ug/Kg	2000	21000	299-W15-217	24.6
Nickel	ug/Kg	3000	20000	299-W15-217	24.6
Target Anions/Cations					
Chloride	ug/Kg	400	54000	299-W15-217	24.6
Fluoride	ug/Kg	200	2600	299-W15-217	37.1
Calcium	ug/Kg	10000	140000000	299-W15-217	37.1
Nitrate	ug/Kg	400	1600000	299-W15-217	37.1
Sulfate	ug/Kg	1000	69000	299-W15-217	24.6
Phosphate	ug/Kg	800	ND		
Target Radionuclides					
Plutonium			NA		
Americium			NA		
Strontium-90			NA		
Uranium			NA		
Gamma Emitters					
Pb-212	pCi/g		1.01	299-W15-217	35.3
Pb-214	pCi/g		1.73	299-W15-217	37.1
Ra-226	pCi/g		1.66	299-W15-217	37.1
Ra-224	pCi/g		1.01	299-W15-217	35.3
Gross Alpha	pCi/g		11.1	299-W15-217	37.1
Gross Beta	pCi/g		27.5	299-W15-217	16.6

(c) below limit of quantitation
(d) non-calibrated estimate
NA not analyzed
ND not detected
NR not reported

The highest carbon tetrachloride soil concentration found to date (37,817 ppb) was recovered from well 299-W15-217 at a depth of 34.7 m. Wells 299-W15-218 and 299-W15-219 have yielded the second highest carbon tetrachloride soil concentrations (15,794 ppb at 33.5 m and 11,688 ppb at 34.9 m, respectively). All of these maximum carbon tetrachloride soil concentrations are associated with the interbedded sands and silts of the Hanford formation lower fine unit and/or laminated silts of the Plio-Pleistocene unit, which lie directly above the caliche layer. Figure 4-12 illustrates the distribution of maximum carbon tetrachloride concentrations found in these fine units around the 216-Z-9 Trench. Figure 4-13 illustrates the relationship between the concentration and distance from the trench center. Note that the concentrations of carbon tetrachloride decrease dramatically (orders of magnitude) away from the trench.

The maximum concentrations of carbon tetrachloride found in wells away from the trench are not associated with the Hanford lower fine or Plio-Pleistocene laminated silt units. Well 299-W15-216 yielded maximum concentrations of 67 ppb carbon tetrachloride at the 15-m depth (near the top of the Hanford fine unit). Well 299-W15-220 yielded maximum concentrations of 1,132 ppb carbon tetrachloride at the 27.6-m depth (near the bottom of the Hanford fine unit).

Chloroform and tetrachloroethylene (PCE) are found throughout the lower portion of well 299-W15-217 (Hanford fine unit, Plio-Pleistocene laminated silts, caliche, and below). However, the highest soil concentration of chloroform (730 ppb) was recovered from well 299-W15-219 at a depth of 39.6 m, just below the caliche layer.

The maximum concentration of methylene chloride (1,171 ppb) has been found in well 299-W15-220 at the 30.6 m depth, just above the Plio-Pleistocene laminated silts. Note, however, that methylene chloride is a common laboratory contaminant and, thus, these results may not be representative of actual unsaturated zone soil concentrations.

Minor concentrations of trichloroethylene (TCE); PCE; and their degradation products, trans-1,2-dichloroethylene (trans-1,2-DCE), 1,1-dichloroethane (1,1-DCA), and 1,1,1-trichloroethane (1,1,1-TCA), were detected in well 299-W15-217, nearest the 216-Z-9 Trench. PCE and cis-1,2-DCE were detected in well 299-W15-218 (second closest well to the trench) at a depth associated with or just below the caliche. Only PCE was detected in well 299-W15-216 (away from the trench) at a depth associated with the Hanford fine unit.

Minor concentrations of benzene, toluene, and/or xylene (BTX) compounds were found in all the wells. Although these compounds are found throughout the lower portion of the unsaturated zone in these wells, the highest concentrations appear to be associated with the capillary fringe zone, located within 3 to 6 m above the water table. Note that the elevation of the water table in this area has been decreasing since 1984.

The vertical distribution of selected volatile organics in well 299-W15-217 (nearest the trench) is shown in Figure 4-14. Similar vertical profiles are presented for each well in Appendix H.

Figure 4-12. Distribution of Maximum Carbon Tetrachloride Concentrations Observed in Sediment Samples from the Hanford Formation Lower Fine Unit and/or the Plio-Pleistocene Unit near the 216-Z-9 Trench.

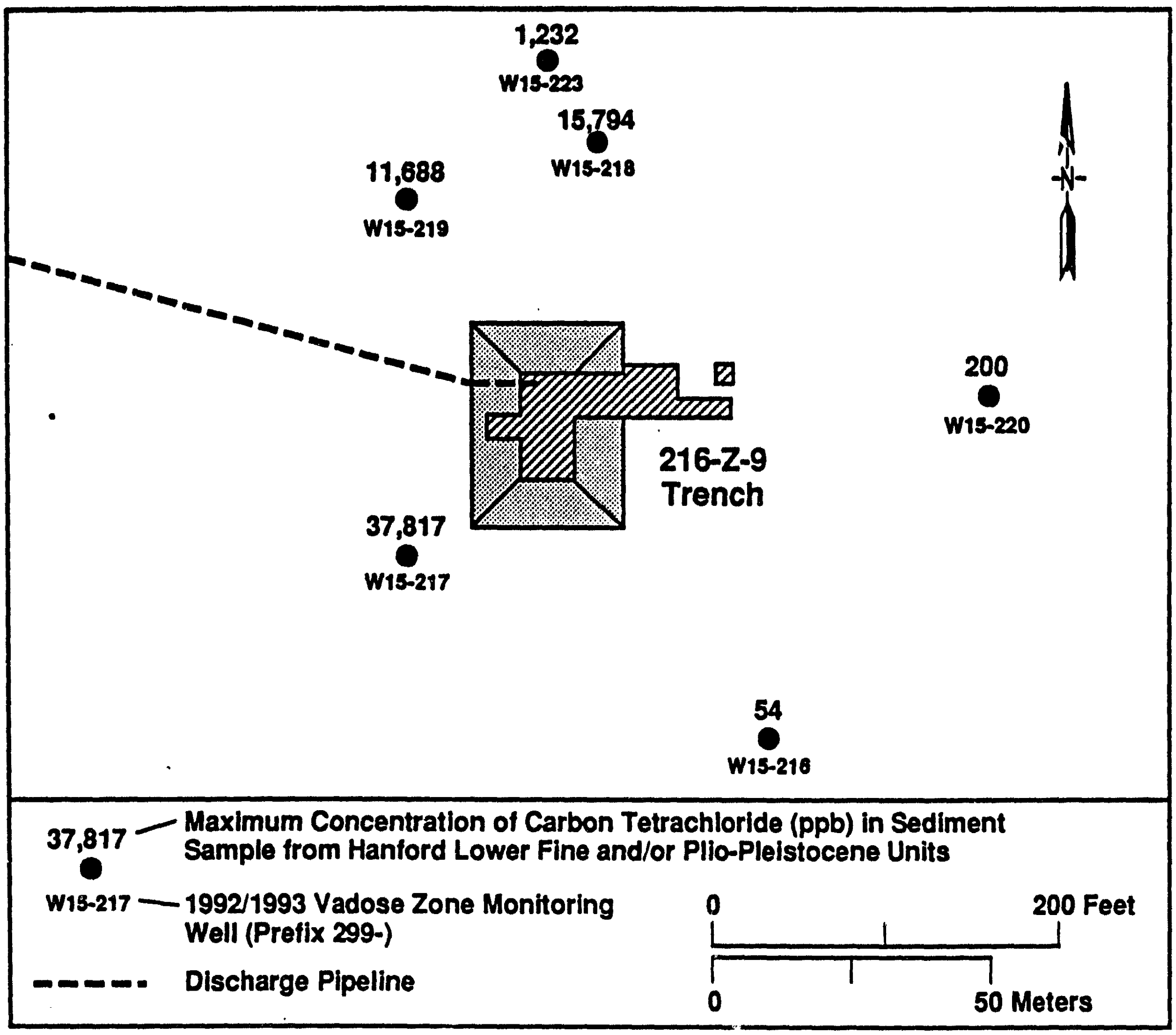


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Figure 4-13. Relationship Between Maximum Carbon Tetrachloride Concentrations in Soil Samples and Distance from the 216-Z-9 Trench.

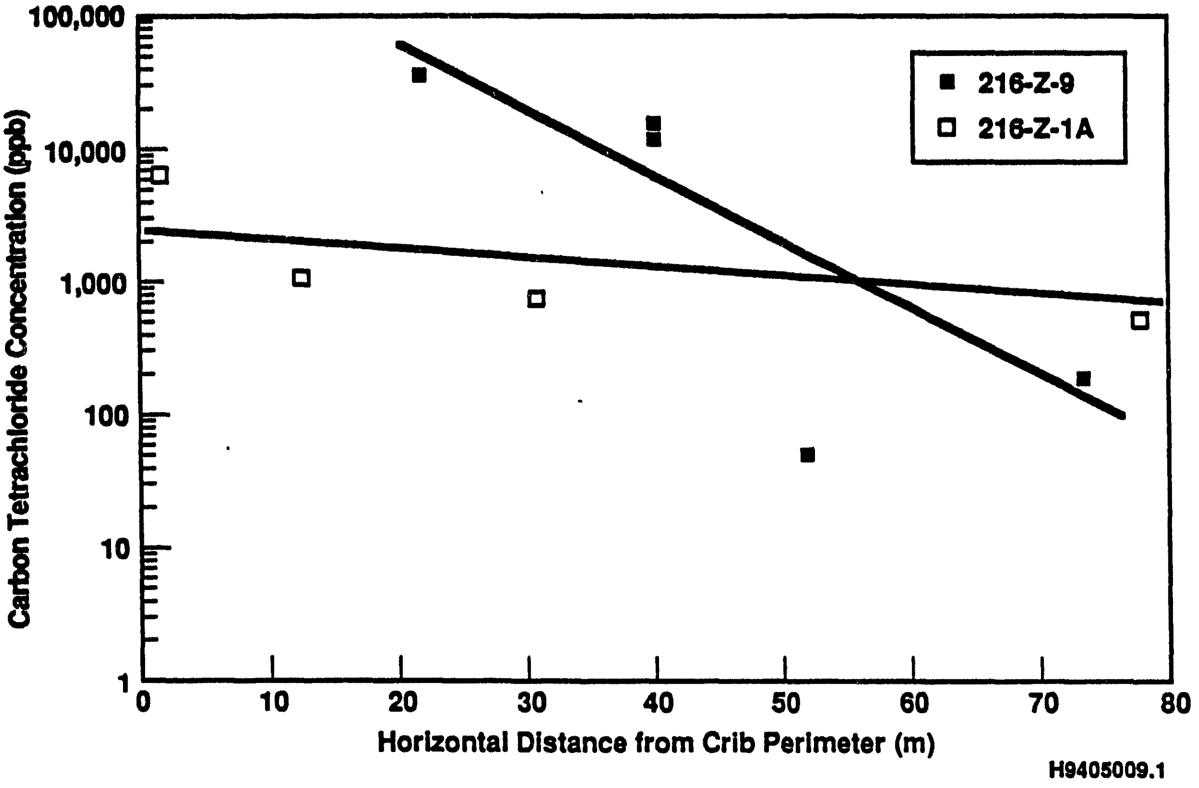
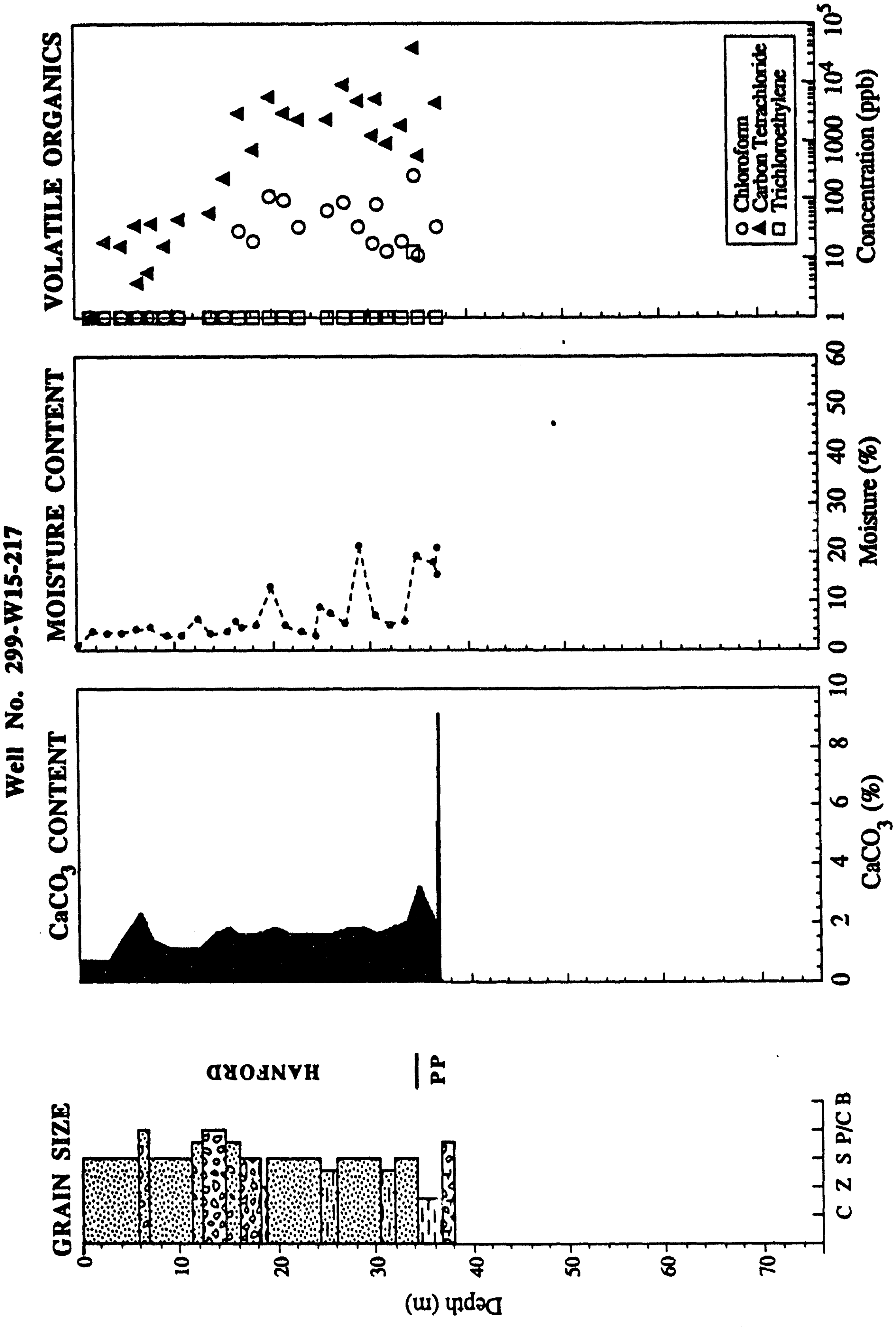


Figure 4-14. Vertical Carbon Tetrachloride (and Selected Volatile Organic Compounds) Concentration Profiles for Well 299-W15-217.



Probably the most significant findings of the semivolatile analyses were the detection of tributyl phosphate (TBP) in one sample at the 24.6-m depth in well 299-W15-217 and undetermined oxyhydrocarbons (possibly related to lard oil) at the 6.3-m depth. These have been the only detections of these compounds to date (although it should be noted that the no additional analyses for these compounds near the 216-Z-9 Trench were conducted during FY 1993). Phenol was also detected in one sample from this well. Several other phenolic compounds, shown as being detected in the analysis tables in Appendix G, are laboratory surrogates added to the sample to track the analytical technique.

Also worthy of note are the high concentrations of nitrate found in well 299-W15-217 below the 25-m depth. This suggests the presence of aqueous nitrate wastes disposed to this trench.

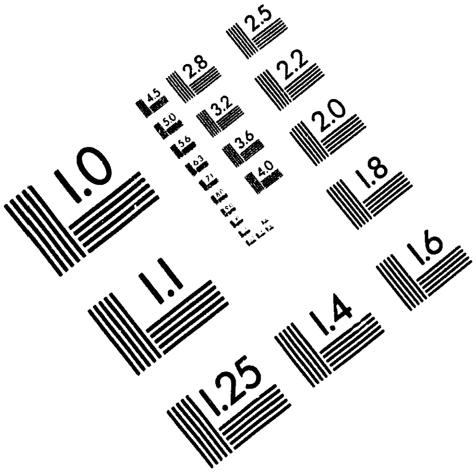
Soil samples were collected from the 216-Z-9 Trench in 1973 to determine the concentrations and distribution of plutonium. Subsequently, the upper 30 cm of soil was removed. Samples collected in 1973 from a depth of 2.4 m contained ^{239}Pu concentrations of 0.03 to 0.1 g plutonium per liter of soil and ^{241}Am concentrations of 200 to 550 μCi/L of soil (Smith 1973).

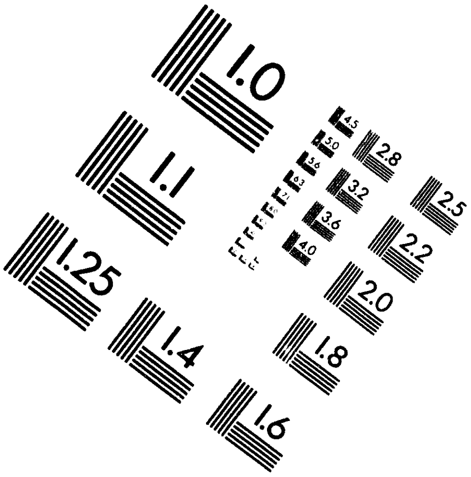
4.2.3.2 216-Z-1A Tile Field. Borehole samples were analyzed from two additional wells drilled near the 216-Z-1A Tile Field in FY 1993 (Figure 4-11). Well 299-W18-174 is an existing well located within the tile field boundaries and was deepened from its previous depth of 15.1 m to the top of the caliche (39.6 m). Well 299-W18-252 is located approximately 78 m west of the tile field. Analytical results of borehole samples are also available from two wells drilled in FY 1992 (299-W18-246 and 299-W18-248). Well 299-W18-246 is located approximately 30 m west of the tile field, and well 299-W18-248 is located approximately 5 m east of the tile field, juxtaposed to well 299-W18-7.

Volatile organic analyses and other chemical and radiological analyses are available from all of these wells, except well 299-W18-252 where only volatile organic analyses were performed. Table 4-9 summarizes the maximum concentration of target analytes and other detected constituents in the vicinity of the 216-Z-1A Tile Field.

The maximum concentration of carbon tetrachloride found beneath the 216-Z-1A Tile Field (6,561 ppb) was from well 299-W18-174, located in the head end of the tile field. This maximum concentration was from the Plio-Pleistocene laminated silts just above the caliche layer. It is interesting that carbon tetrachloride was found in quantifiable concentrations throughout the extended portion of the borehole, except between the depths of 27.6 m and 34 m. This zone of less than quantifiable concentrations corresponds well with a gravel unit located near the base of the Hanford formation (Appendix B). Active vapor extraction operations may have removed the volatile organics from this relatively permeable zone.

The maximum concentrations of carbon tetrachloride found in each well are associated with the interbedded sands and silts of the Hanford formation lower fine unit, laminated silts of the Plio-Pleistocene, and/or the top of the caliche. The distribution of these maximum concentrations around the 216-Z-1A Tile Field is shown in Figure 4-15. Figure 4-13 illustrates the relationship between the concentration and distance from the tile field center. Note that the concentration of carbon tetrachloride drops off an





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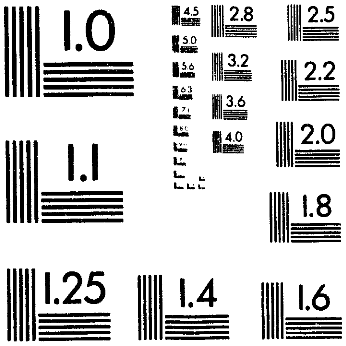

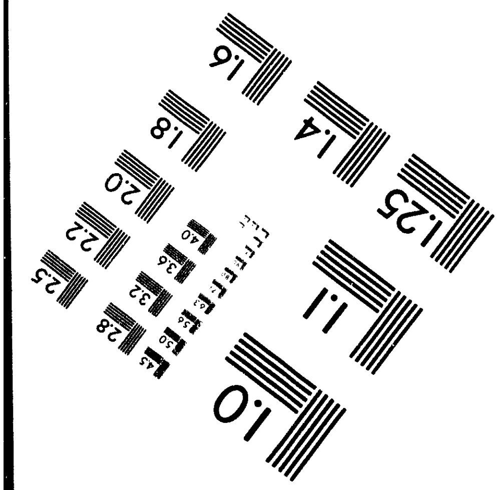

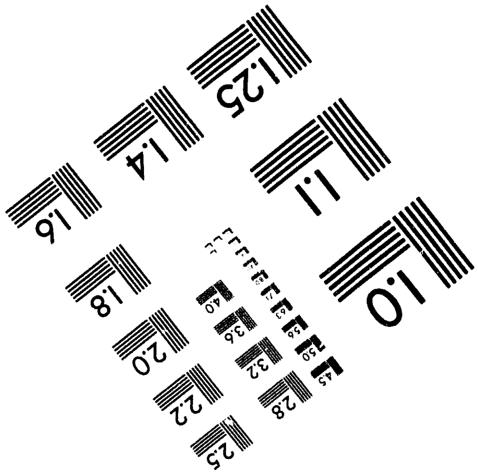

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Table 4-9. Maximum Soil Concentrations of Target Constituents from Wells near the 216-Z-1A Tile Field.

Analyte	Units	Detection Level	Max. Soil Conc.	Well Number	Depth (m)
Target Volatile Organics					
Methylene Chloride	ppb		2264 (a)	299-W18-248	19.8
$CHCl_3$	ppb		135	299-W18-174	39.9
CCl_4	ppb		6561	299-W18-174	38.7
TCE	ppb		68	299-W18-174	39.3
PCE	ppb		50	299-W18-174	39.3
MEK	ppb		180 (d)	299-W18-174	17.1
Methyl Iso Butyl Ketone	ppb		156 (d)	299-W18-174	22.7
Other Volatile Organics					
trans-1,2-DCE	ppb		~150	299-W18-248	19.8
1,1-DCA	ppb		~100	299-W18-248	19.8
cis-1,2-DCE			~80	299-W18-248	19.8
1,1,1-TCA	ppb		NR		
Benzene	ppb		<25	299-W18-248	
Toluene	ppb		626	299-W18-252	60.8
Ethylbenzene	ppb		<25	299-W18-248	
M+P-Xylene	ppb		<25	299-W18-248	
O-Xylene	ppb		<25	299-W18-248	
Acetone	ppb		ND		
Target Semivolatile Organics					
TBP	ug/Kg	58	ND		
DPB			NA		
DBBP			NA		
MBP			NA		
Triglycerides (lard oil)			NA		
Other Semivolatile Organics					
Decane	ug/Kg	54	ND		
Dodecane	ug/Kg	31	ND		
Tetradecane	ug/Kg	52	ND		
Phenol	ug/Kg	49	880	299-W18-246	44.6
Unknown Oxyhydrocarbon	ug/Kg		NR		
Target Metals					
Aluminum			NA		
Iron	ug/Kg	2000	230000000	299-W18-248	6.0
Cadium	ug/Kg	1000	ND		
Magnesium	ug/Kg	10000	21000000	299-W18-246	44.6
Chromium	ug/Kg	2000	100000	299-W18-248	18.2
Nickel	ug/Kg	3000	17000	299-W18-246	43.3
Target Anions/Cations					
Chloride	ug/Kg	400	20000	299-W18-246	17.2
Fluoride	ug/Kg	200	16000	299-W18-174	38.1 & 39.3
Calcium	ug/Kg	10000	230000000	299-W18-248	42.7
Nitrate	ug/Kg	400	250000	299-W18-174	17.1
Sulfate	ug/Kg	1000	45000	299-W18-246	17.2
Phosphate	ug/Kg	800	1000	299-W18-174	17.1
Target Radionuclides					
Plutonium			NA		
Americium-241	pCi/g wetwt		1.92E+03	299-W18-174	14.6
Strontium-90			NA		
Uranium			NA		
Gamma Emitters					
Co-60					
Ru-106					
Sb-125					
Cs-137	pC/g wetwt		<6.56E-01	299-W18-174	14.6
Pb-212	pCi/g		1.82	299-W18-246	43.1
Pb-214	pCi/g		2.94	299-W18-246	44.6
Ra-226	pCi/g		2.81	299-W18-246	44.6
Ra-224	pCi/g		1.89	299-W18-246	43.1
Gross Alpha	pCi/g		29.4	299-W18-246	44.6
Gross Beta	pCi/g		27.5	299-W18-248	16.6
Other Radionuclides					
Np-237	pCi/g wetwt		4.00E+01	299-W18-174	14.6
Pa-233	pCi/g wetwt		3.67E+01	299-W18-174	14.6

(a) A concentration of 19854 ppb was reported for one sample from well 299-W18-246. However, this value was suspect du to varied CH_2Cl_2 impurities in the purge and trap methanol, and/or other possible influences from around the drill site.

(d) non calibrated estimate, Suspect

NA not analyzed

ND not detected

NR not reported

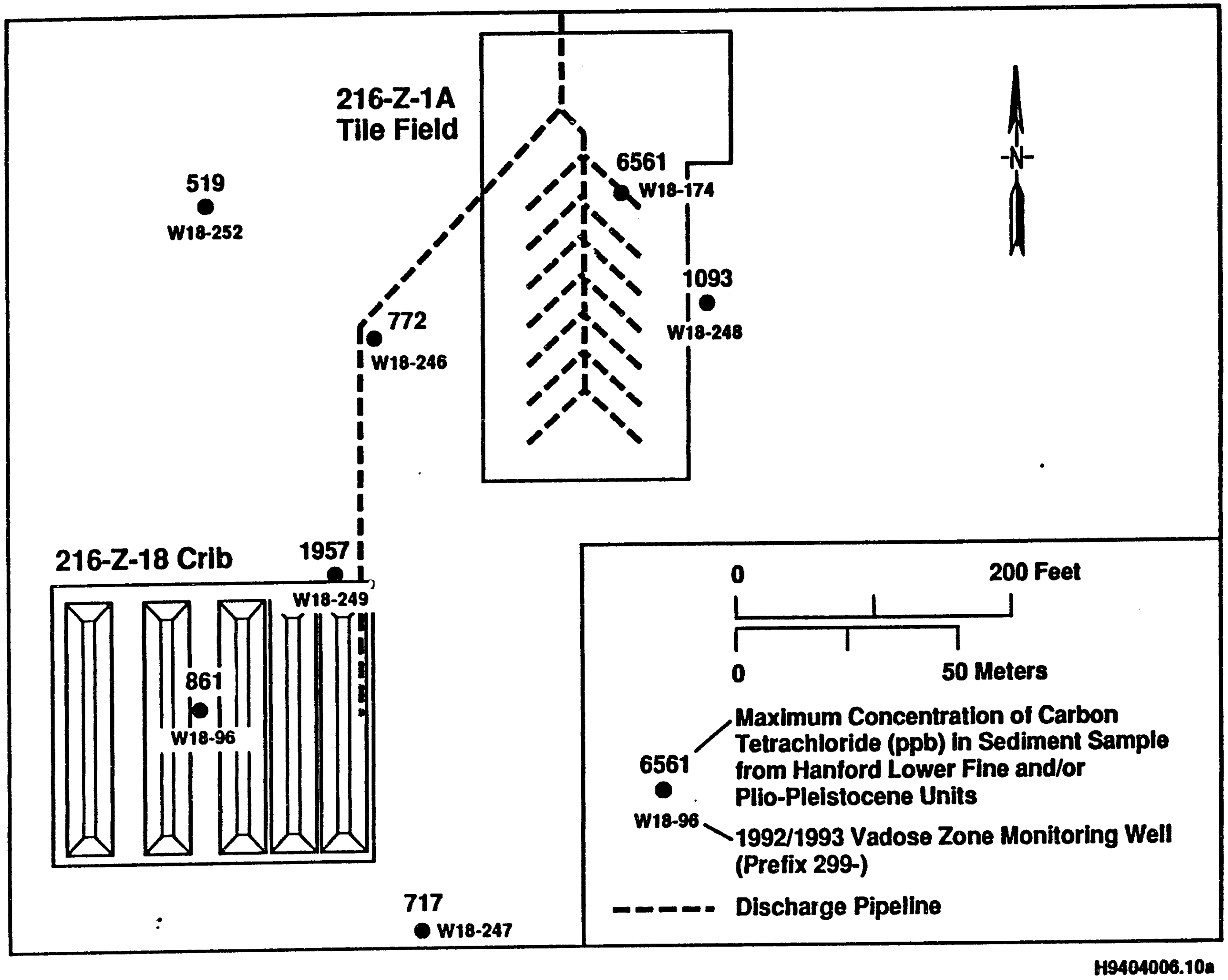


Figure 4-15. Distribution of Maximum Carbon Tetrachloride Concentrations Observed in Sediment Samples from the Hanford Formation Lower Fine Unit and/or the Plio-Pleistocene Unit near the 216-Z-1A Tile Field.

order of magnitude to 519 ppb carbon tetrachloride at well 299-W18-252, 78 m from the tile field. This is a more gradual decrease than that seen around the 216-Z-9 Trench.

Low concentrations (≤135 ppb) of chloroform have been detected in isolated locations from soil samples around the 216-Z-1A Tile Field. These isolated concentrations have been found either high in the soil column (17- to 20-m depth), or near the Hanford lower fine unit/caliche or Plio-Pleistocene laminated silt/caliche interface, or associated with the capillary fringe just above the water table.

The maximum concentration of methylene chloride observed in a sediment sample was 2,264 ppb at a depth of 19.8 m in well 299-W18-248 (Table 4-9). The highest observed concentration of carbon tetrachloride in this well was 1,093 ppb at a depth of 41.1 m (Last and Rohay 1993). Soil-gas concentrations near the water table (58- to 62-m depth) in the adjacent well (299-W18-7), monitored by Savannah River Site personnel using a photo-acoustic infrared sensor, also showed higher concentrations of methylene chloride than carbon tetrachloride (Figure 4-16).

Minor concentrations of TCE, and PCE have been detected in each well near the 216-Z-1A Tile Field except well 299-W18-252. It is interesting to note that while both these compounds were found throughout the soil column at well 299-W18-246 (adjacent to the tile field), they are conspicuously absent from well 299-W18-174 (in the head end of the tile field), except for small concentrations at the 18-m depth and higher concentrations near the bottom of the Plio-Pleistocene laminated silts. The relative absence of TCE and PCE in samples from 299-W18-174 may be a result of VOC removal by active vapor extraction operations at the 216-Z-1A Tile Field.

The degradation products, trans-1,2-DCE (~150 ppb), 1,1-DCA (~100 ppb), and cis-1,2-DCE (~80 ppb), have been found only in well 299-W18-248. However, the greater concentrations and distribution in this well suggests that the TCE and PCE disposed to 216-Z-1A Tile Field might be older or at least more degraded than that disposed to the 216-Z-9 Trench and/or the 216-Z-18 Crib.

Concentrations of toluene have been detected in all four wells, but no other BTX compounds have been detected. The distribution of toluene appears to be localized at about the 20-m depth and/or near the interbedded sands and silts of the Hanford formation lower fine unit or laminated silts of the Plio-Pleistocene unit in all wells except well 299-W18-252. Here, concentrations of toluene are found nearly throughout the entire soil column, with the maximum concentration found 8 m above the current water table. Again, it should be noted that the water table has dropped over 5 m since decommissioning of the 216-U-10 Pond in 1984.

Methyl ethyl ketone (MEK) and methyl iso butyl ketone were both identified in analytical results from well 299-W18-174, at depths ranging from 16.2 m to 34 m. However, these results were noncalibrated estimates and are suspect. Some MEK impurity was also found in the purge and trap of one sample.

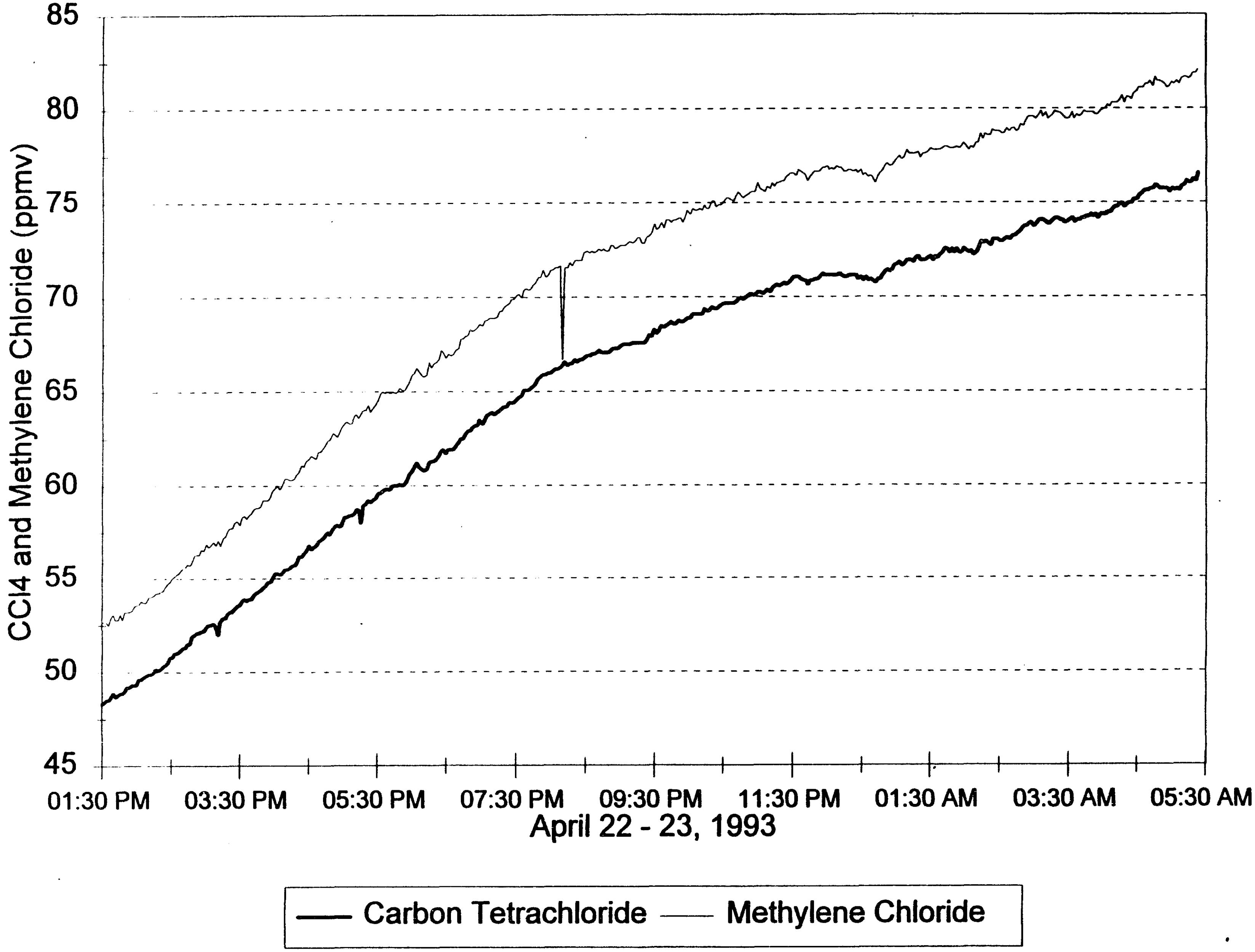


Figure 4-16. Soil-Gas Concentrations of Carbon Tetrachloride and Methylene Chloride Observed in Well 299-W18-7, April 22-23, 1993.

Figure 4-17 illustrates the vertical distribution of selected volatile organics from well 299-W18-174 in the head end of the tile field. Note that data are available only for that portion of the well that was deepened in FY 1993. Similar diagrams are provided for the remaining wells in Appendix H.

None of the target semivolatile organics have been identified in any of these wells. Phenol was detected in samples from well 299-W18-246 and in one sample from well 299-W18-174 (16.2 m). As discussed earlier, several other phenolic compounds were listed in the analyses and are shown in the analysis tables in Appendix G. These have, however, been determined to be laboratory surrogates added to the sample to track the analytical technique.

The lateral and vertical extent of plutonium and americium contamination beneath the 216-Z-1A Tile Field was determined through sediment sampling and analysis from 16 wells (including 299-W18-174) installed for a study in the mid-1970's (Price et al. 1979). The highest measured concentration of $^{239/240}$Pu (about 4 x 10^4 nCi/g) and ^{241}Am (about 2.5 x 10^3 nCi/g) at the tile field occurs in sediments located immediately beneath the central distributor pipe, and most of the plutonium and americium contamination appears to be contained within the first 15 m of sediments beneath the bottom of the disposal facility. The concentration of plutonium and americium generally decreases with depth; an increase in concentration is generally associated with an increase in the silt content of the sediments or with boundaries between sedimentary units. The maximum vertical penetration of plutonium and americium contamination (defined by the 10^{-2} nCi/g isopleth) is approximately 30 m below the bottom of the tile field, or about 30 m above the water table (Price et al. 1979).

4.2.3.3 216-Z-18 Crib. Well 299-W18-96 was the only new well installed at the 216-Z-18 Crib in FY 1993 (Figure 4-11). This was an existing well that is located within the crib boundaries, between the third and fourth trenches (Figure 4-15). It should be noted that the fifth (westernmost) trench in this crib was never used (Owens 1981). Soil samples were collected as the well was deepened from 25.3 m to 45.5 m (top of caliche). Borehole soil samples have also been analyzed from well 299-W18-249, located approximately 3 m north of the crib and juxtaposed to the distal end of the first trench, and well 299-W18-247, located approximately 40 m southeast of the 216-Z-18 Crib (Figure 4-15).

Table 4-10 summarizes the maximum concentration of target analytes and other constituents of interest detected in these wells. Some variation in the sample concentrations between these wells may be the effect of the different drilling methods used. Well 299-W18-247 was drilled using a sonic drilling rig and continuous core barrel methods, while wells 299-W18-96 and 299-W18-249 were drilled using a conventional cable-tool drill rig with drive-barrel and split-spoon sampling methods.

Concentrations of carbon tetrachloride were found throughout the soil column of all three wells. The maximum concentration (1,957 ppb) was observed at well 299-W18-249, located just outside the 216-Z-18 Crib. The maximum concentrations found in well 299-W18-96, located within the crib, and in well 299-W18-247, located away from the crib, were less the one-half this value at 861 ppb and 717 ppb, respectively (Figure 4-15). All maximum concentrations of carbon tetrachloride were found in association with the Plio-Pleistocene laminated silts and/or top of the caliche.

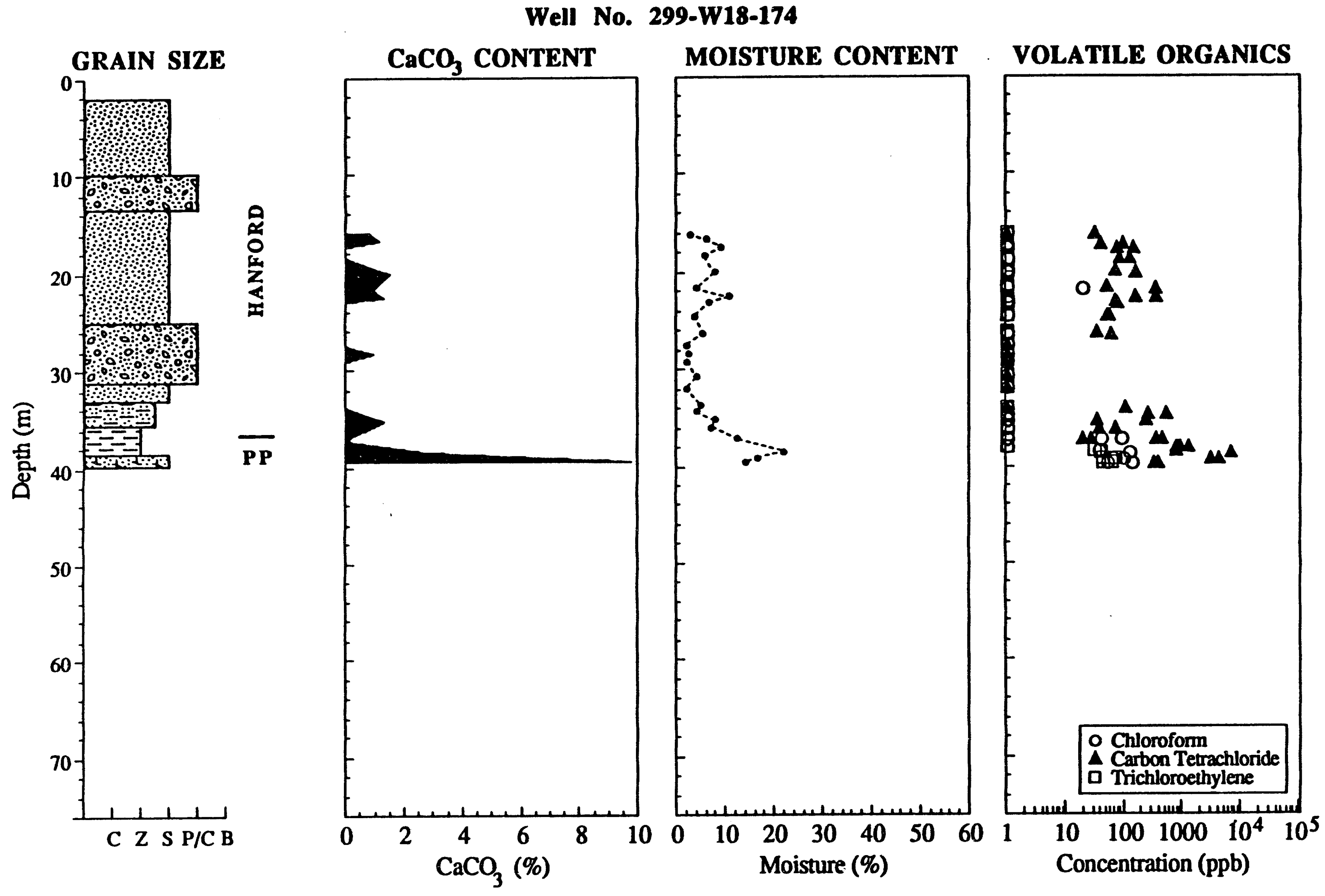


Figure 4-17. Vertical Carbon Tetrachloride (and Selected Volatile Organic Compounds) Concentration Profiles for Well 299-W18-174.

Table 4-10. Maximum Concentration of Target Constituents from Wells near the 216-Z-18 Crib.

Analyte	Units	Detection Level	Max. Soil Conc.	Well Number	Depth (m)
Target Volatile Organics					
Methylene Chloride	ppb		89996	299-W18-249	30.2
CHCl3	ppb		44	299-W18-96	41.0
CCl4	ppb		1957	299-W18-249	44.2
TCE	ppb		8	299-W18-249	30.2
PCE	ppb		6	299-W18-249	30.2
MEK	ppb		NR		
Other Volatile Organics					
trans-1,2-DCE	ppb		<30	299-W18-96	27.4
1,1-DCA	ppb		<40	299-W18-96	41.0
cis-1,2-DCE			<30	299-W18-96	27.4
1,1,1-TCA	ppb		103	299-W18-249	30.6
Benzene	ppb		11	299-W18-249	30.6
Toluene	ppb		3427	299-W18-247	17.0
Ethylbenzene	ppb		61	299-W18-247	17.1
M+P-Xylene	ppb		266	299-W18-247	17.1
O-Xylene	ppb		150	299-W18-247	17.1
n-Butyl Benzene	ppb		~13 (e)	299-W18-96	38.3
Acetone	ppb		NR		
Target Semivolatile Organics					
TBP	ug/Kg	58	ND		
DPB			NA		
DBBP			NA		
MBP			NA		
Triglycerides (lard oil)			NA		
Other Semivolatile Organics					
Decane	ug/Kg	54	110(c)	299-W18-249	44.7
Dodecane	ug/Kg	31	110(c)	299-W18-249	44.7
Tetradecane	ug/Kg	52	29(c)	299-W18-249	44.7
Phenol	ug/Kg	49	700	299-W18-247	47.2
Unknown Oxyhydrocarbon	ug/Kg		NR		
Target Metals					
Aluminum			NA		
Iron	ug/Kg	2000	35000000	299-W18-249	18.2
Cadium	ug/Kg	1000	ND		
Magnesium	ug/Kg	10000	8500000	299-W18-249	44.7
Chromium	ug/Kg	2000	28000	299-W18-247	47.2
Nickel	ug/Kg	3000	20000	299-W18-96	39.8
Target Anions/Cations					
Chloride	ug/Kg	400	22000	299-W18-96	25.6
Fluoride	ug/Kg	200	4700	299-W18-96	25.6
Calcium	ug/Kg	10000	80000000	299-W18-247	45.6
Nitrate	ug/Kg	400	4400000	299-W18-96	25.6
Sulfate	ug/Kg	1000	28000	299-W18-249	11.4
Phosphate	ug/Kg	800	ND		
Target Radionuclides					
Plutonium			NA		
Americium	pCi/g		1.29E-02	299-W18-96	38.3
Strontium-90	pCi/g		8.02E-03	299-W18-96	27.9
Uranium-238	pCi/g		5.47E-05	299-W18-96	37.6
Gamma Emitters					
Co-60	pCi/g		3.48E-02	299-W18-96	41.6
Ru-106	pCi/g		2.28E-01	299-W18-96	37.6
Sb-125	pCi/g		1.10E-01	299-W18-96	37.6
Cs-137	pCi/g		7.57E-03	299-W18-96	27.9
Pb-212	pCi/g		1.76E+00	299-W18-96	26.2
Pb-214	pCi/g		1.45E+00	299-W18-96	26.2
Ra-226	pCi/g		4.07E+00	299-W18-247	45.5
Ra-224	pCi/g		1.83E+00	299-W18-96	26.2
Gross Alpha	pCi/g		1.30E+01	299-W18-249	44.7
Gross Beta	pCi/g		2.71E+01	299-W18-96	43.8

(c) below limit of quantitation
(e) non-calibrated estimate
NA not analyzed
ND not detected
NR not reported

The active vapor extraction system began operating at the 216-Z-18 Crib in May 1992. It was used to extract soil gas from two wells, 299-W18-10 and 299-W18-97, immediately east of the crib (Figure 3-3) during May and June 1992, after well 299-W18-247 was completed but prior to drilling of wells 299-W18-249 and 299-W18-96. However, it is unlikely that the vapor extraction system operations affected sampling results from these two wells. The radius of influence of these two wells (particularly 299-W18-10, which is open below the Plio-Pleistocene unit) is believed to be less than the distance to either well 299-W18-96 or 299-W18-149.

Slight amounts of chloroform, TCE, and PCE were found in well 299-W18-249, while only chloroform was found in the other two wells. High concentrations of methylene chloride were reported in well 299-W18-249 and lesser amounts in well 299-W18-96. However, these may be related to laboratory contamination rather than actual unsaturated zone contamination. Virtually none of the TCE/PCE degradation products (i.e., trans-1,2-DCE, 1,1-DCA, and cis-1,2-DCE) observed at the 216-Z-9 and 216-Z-1A waste disposal facilities were detected in samples from the 216-Z-18 Crib, except for 1,1,1-TCA that was found at a maximum concentration of 103 ppb in well 299-W18-249.

Relatively high concentrations of BTX compounds (2,961 to 3,427 ppb toluene, 34 to 61 ppb ethylbenzene, 42 to 266 ppb M+P-xylene, and 116 to 150 ppb O-xylene) were found in wells 299-W18-249 and 299-W18-247, respectively. The highest concentration of toluene found in well 299-W18-96 was only 94 ppb. Note that the higher concentrations were found in the well farthest from the crib. This suggests that the source of these BTX compounds may be located southeast of the crib.

Figure 4-18 illustrates the vertical distribution of selected volatile organics relative to the stratigraphy and moisture content of well 299-W18-96, located near the center of the 216-Z-18 Crib. Similar diagrams for the remaining wells are provided in Appendix H.

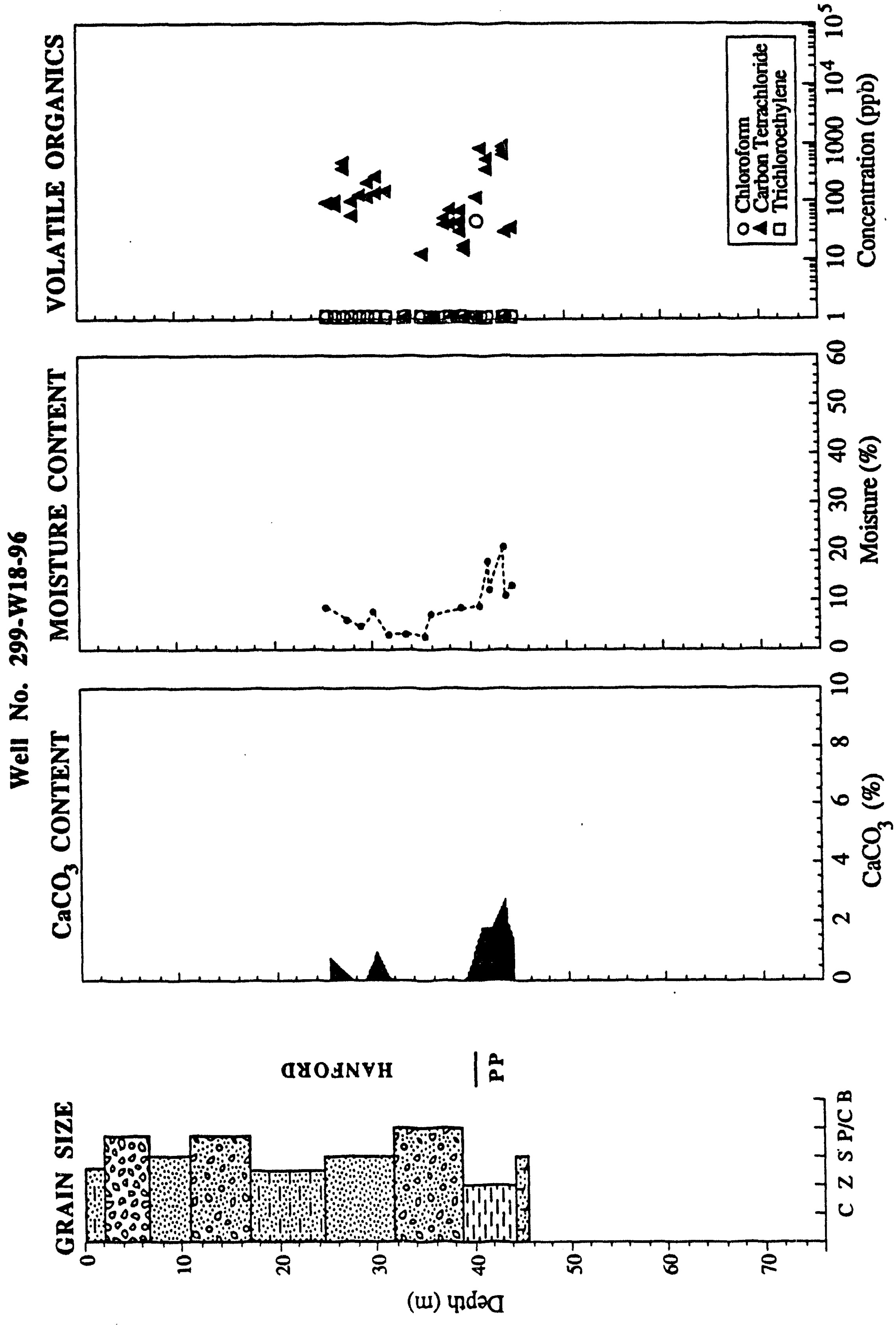
Although TBP was not detected in these samples, a variety of other semivolatile organics were identified, if not quantified. These included decane, dodecane, and tetradecane in samples from depths of 30.6 and 44.7 m in well 299-W18-249, juxtaposed to the crib, and phenol at several depths in well 299-W18-247. Other phenolic compounds reported in the analysis tables (Appendix G) are simply laboratory surrogates added to the sample to track the analytical technique.

Also noteworthy is that cadmium was detected, at the 1,000-μg/kg detection level, in the 47.2-m sample from well 299-W18-247. This is the only sediment sample where cadmium was detected. It is also interesting to note that cadmium was also detected in one groundwater sample from this well, although at a much lower concentration (15 μg/L).

4.3 GROUNDWATER CONTAMINATION

This section describes the lateral and vertical distribution of volatile organic contaminants, primarily carbon tetrachloride, within the groundwater of the unconfined aquifer. The lateral distribution of existing groundwater contamination is presented at two levels of detail: the 200 West Area and the ERA/VOC-Arid ID carbon tetrachloride area.

Figure 4-18. Vertical Carbon Tetrachloride (and Selected Volatile Organic Compounds) Concentration Profiles for Well 299-W18-96.



4.3.1 Lateral Distribution in the 200 West Area

The unconfined aquifer beneath the 200 West Area contains overlapping contaminant plumes of both chemical compounds and radionuclides as a result of liquid discharges to the soil column through liquid waste disposal facilities. Dissolved groundwater plumes that appear to be associated with the carbon tetrachloride discharges include carbon tetrachloride, chloroform, and plutonium.

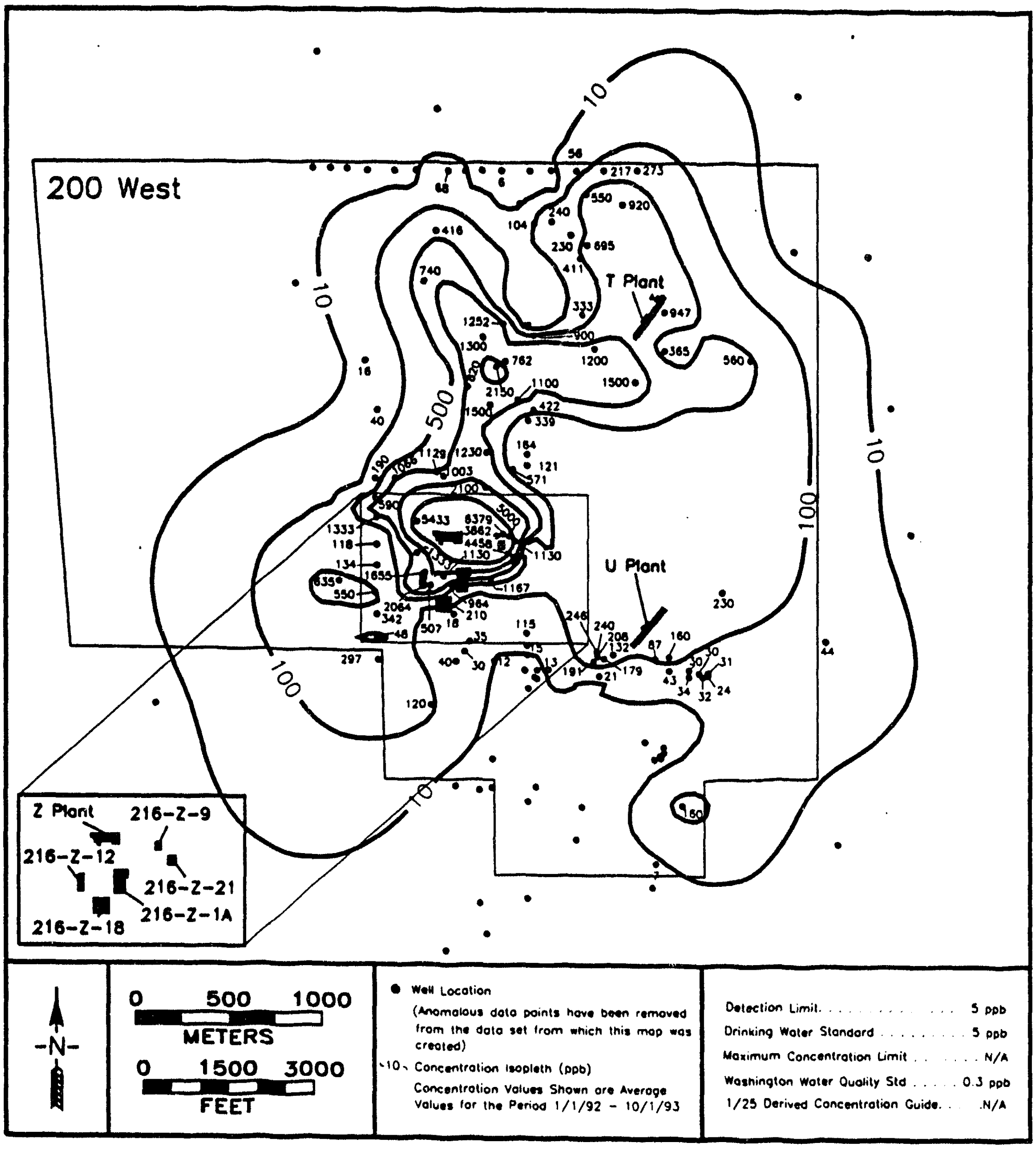
4.3.1.1 Carbon Tetrachloride. The plume of dissolved carbon tetrachloride extends over 10 km^2 in the unconfined aquifer underlying the 200 West Area (Figure 4-19). The highest average concentration during 1992-1993 was 6,379 µg/L (ppb) in well 299-W15-218, 45 m north of the 216-Z-9 Trench (Figure 4-19). The zone of higher concentrations (>1,000 µg/L) is surrounded by a widely distributed, low-concentration halo.

The groundwater concentration data collected in FY 1993 (October 1, 1992 - October 1, 1993) were combined with previous carbon tetrachloride data (January 1, 1992 - September 30, 1992) to update the plume map from 1991 (January 1988 - May 1991) and 1992 (January 1988 - October 1992) (Rohay and Johnson 1991 and Last and Rohay 1993, respectively). The data were combined because of the limited amount of data available for each sampling period. Average values were used for wells with multiple sampling results (Appendix I). The drinking water standard for carbon tetrachloride is 5 µg/L (EPA 1976), which is also the detection limit for the standard gas chromatograph/mass spectrometry analytical method used on these samples. The minimum contour shown in Figure 4-19 is 10 µg/L.

Although all the monitoring wells used to construct the groundwater plume map are screened in the upper 10 m of the aquifer, the well network includes both Resource Conservation and Recovery Act (RCRA)-type wells and older wells of uncertain integrity. Uncertainties in contaminant concentrations associated with the older wells include the possibility of preferential pathways along the outside of the casing, the mix of submersible and positive displacement piston pumps, and the variety in the type and length of perforated or screened intervals. In addition, another uncertainty is introduced by the placement of the pump intake in relation both to the distribution of the contaminant within the aquifer and to the continuing drop in the water table (1 to 2 ft/yr). Groundwater samples were collected using a bailer from FY 1992 and FY 1993 vapor extraction wells during drilling.

The distribution of the carbon tetrachloride plume appears to be controlled, at least in part, by the variation in hydraulic conductivity within the unconfined aquifer (Figure 3-17). The area of highest carbon tetrachloride concentrations (>4,000 µg/L) lies northwest of the discharge area, which is consistent with the local gradient of the water table away from the disposal facilities (Figures 3-18 and 3-21) and the location of the disposal facilities within the zone of highest hydraulic conductivity (>1,000 ft/d). This zone of highest hydraulic conductivity trends northeast-southwest, coincident with the distribution of relatively higher concentrations both to the northeast and the southwest of the core of the plume. Further movement of the core of the plume to the northwest may be limited by a zone of low conductivity (<5 ft/d). The zone of low hydraulic conductivity in the southern part of the 200 West Area corresponds to an area where the plume is absent.

Figure 4-19. Carbon Tetrachloride Concentration Contours in the 200 West Area Groundwater, 1992-1993.



Comparison of the 1991, 1992, and 1993 maps indicates that the centroid of the dissolved carbon tetrachloride plume has not migrated significantly during that time. In fact, the zone of highest concentrations (>4,000 µg/L) still includes the 216-Z-9 Trench, which has been inactive since 1962, suggesting that the carbon tetrachloride discharged has been providing a continuous source of contamination to the groundwater.

Analytical results from individual wells can be used to construct concentration trends and to infer plume movement. For example, carbon tetrachloride concentrations in well 699-38-70 at the eastern edge of the plume have remained relatively constant at low levels since 1987, indicating little plume movement (Figure 4-20). Concentrations in well 699-39-79 at the western perimeter increased by an order of magnitude between March 1987 and August 1988, suggesting the arrival of the plume at that time (Evans et al. 1992, Dresel et al. 1993). Concentrations in well 699-39-79 have remained relatively constant since 1988 (Figure 4-20). Carbon tetrachloride concentrations appear to be rising in two wells (299-W6-2 and 299-W7-4) on the northern edge of the plume and in two wells (299-W19-15 and 299-W19-16) near the southern perimeter of the plume, indicating plume movement in those directions, also (Figure 4-20).

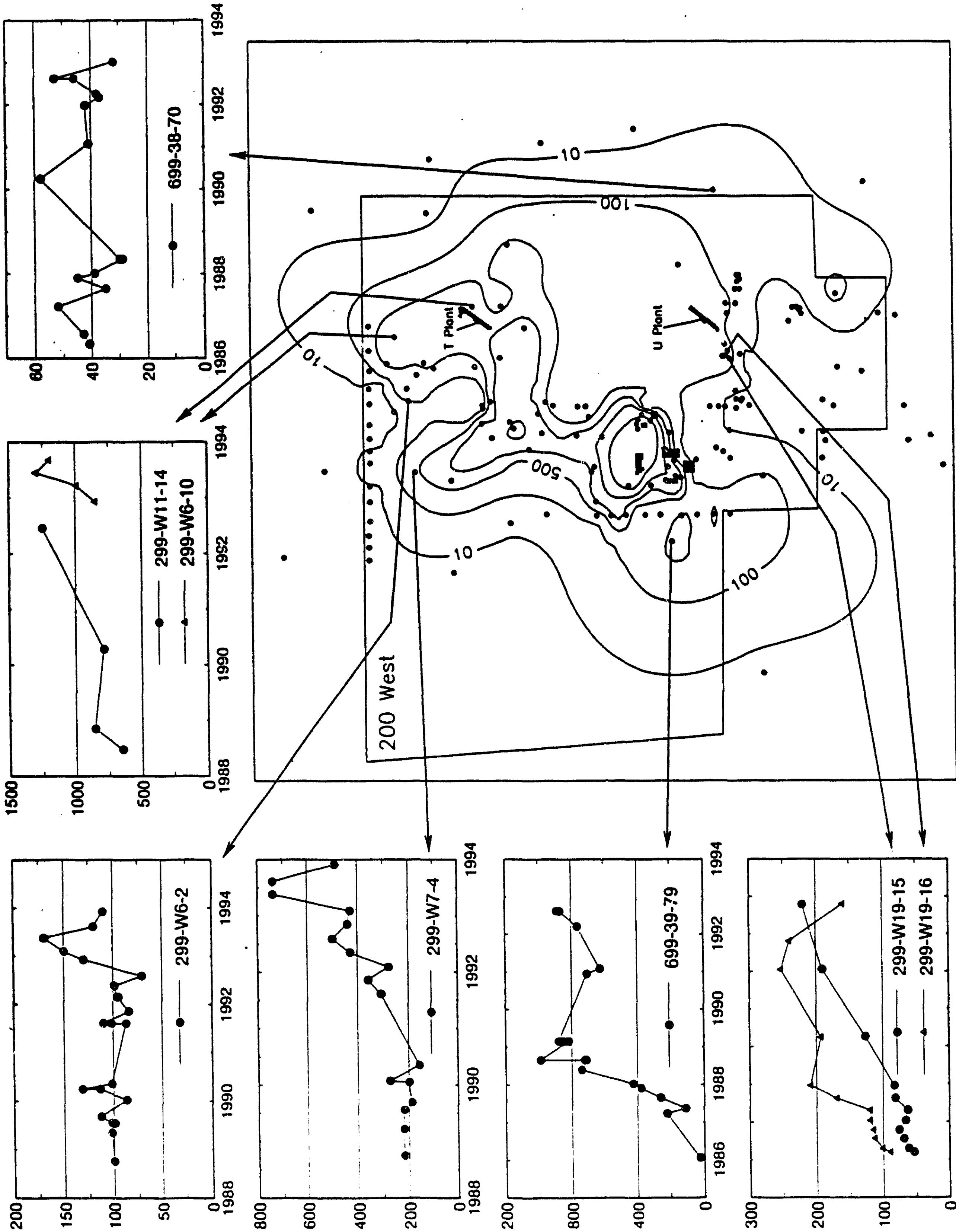
The highest concentration of dissolved carbon tetrachloride observed since 1987 was 8,700 µg/L detected in a 1990 sample from well 299-W15-16 west of Z Plant. Concentrations in this well fluctuated between 6,650 and 8,700 µg/L between October 1988 and April 1990, dropped to 4,450 µg/L in August 1991, and increased to 6,700 µg/L by August 1992; the average concentration in well 299-W15-16 between January 1, 1992 and October 1, 1993 was 5,433 µg/L. The analytical scatter may be a result of difficulties associated with analysis of exceptionally high-level samples that require dilution (Evans et al. 1992).

The distribution of the mass of carbon tetrachloride within the 1993 dissolved plume is illustrated in Figure 4-21. Based on average values of groundwater concentrations between 1988 and 1991, approximately 25% of the total mass was estimated to be contained within about 2% of the areal extent of the plume, defined by the 3,000 µg/L contour (Rohay and Johnson 1991). The 1,000 µg/L contour included about 10% of the area of the plume and nearly 60% of the mass (Rohay and Johnson 1991).

Based on the 1991 concentration contours, the upper 10 m of the aquifer was estimated to contain 5,250 to 15,740 kg of dissolved carbon tetrachloride (at 10% and 30% porosity, respectively), which accounts for approximately 1% to 2% of the estimated inventory discharged to the three waste disposal facilities (Rohay and Johnson 1991). In making this estimate, it was assumed that no carbon tetrachloride had partitioned from the dissolved phase onto the aquifer particles.

4.3.1.2 Chloroform. The areal extent of dissolved chloroform in the unconfined aquifer appears to be more limited than carbon tetrachloride (Figure 4-22). The highest average concentration during 1992-1993 was 976 µg/L in well 299-W15-216 south of the 216-Z-9 Trench. Concentrations in a nearby well, 299-W15-8, were 1,540 µg/L in May 1990 (Dresel et al. 1993). (The drop in water levels have precluded additional sampling in this well.)

Figure 4-20. Trend Plot of Carbon Tetrachloride Concentrations (μg/L) in Selected Wells in the 200 West Area (after Dresel et al. 1993).



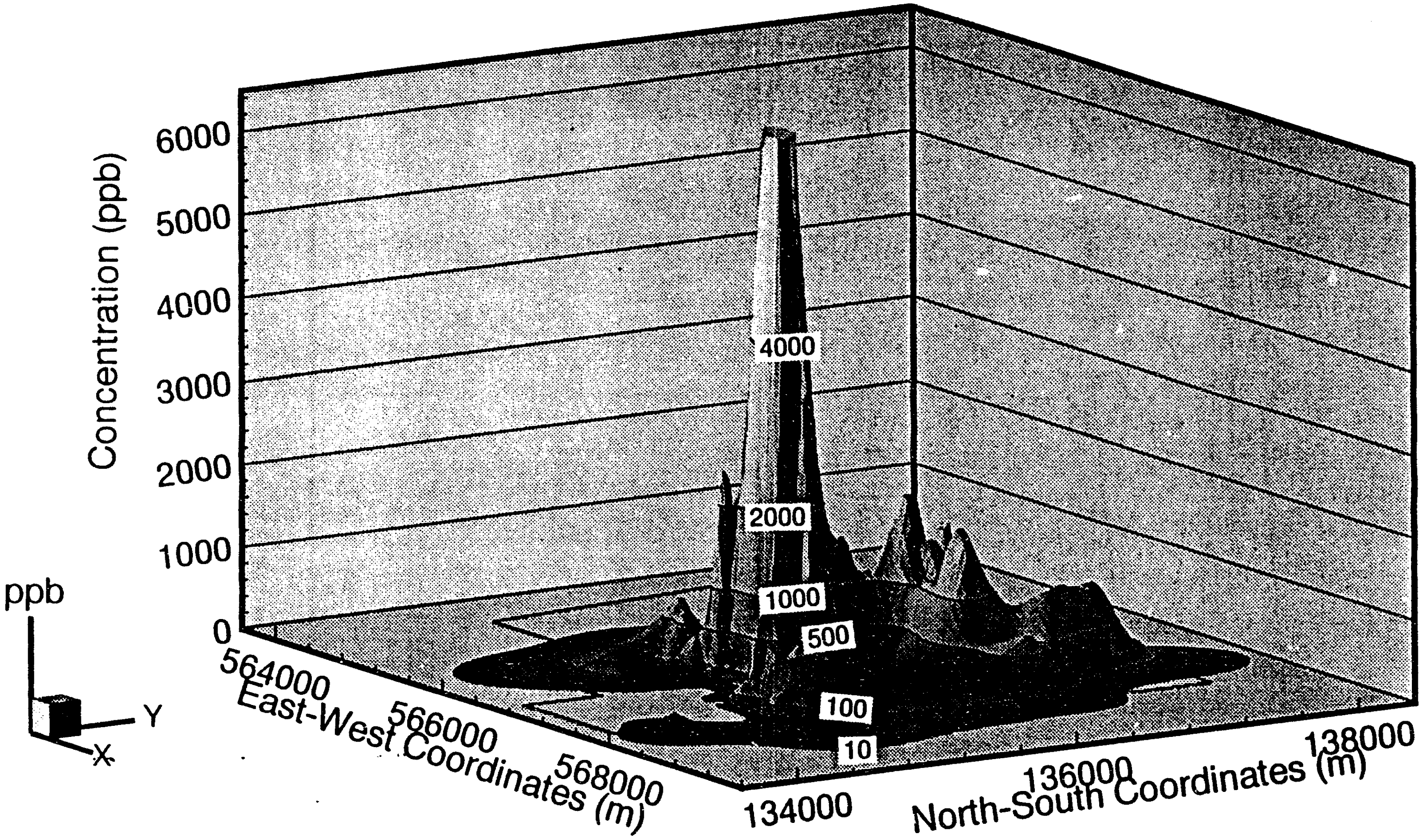
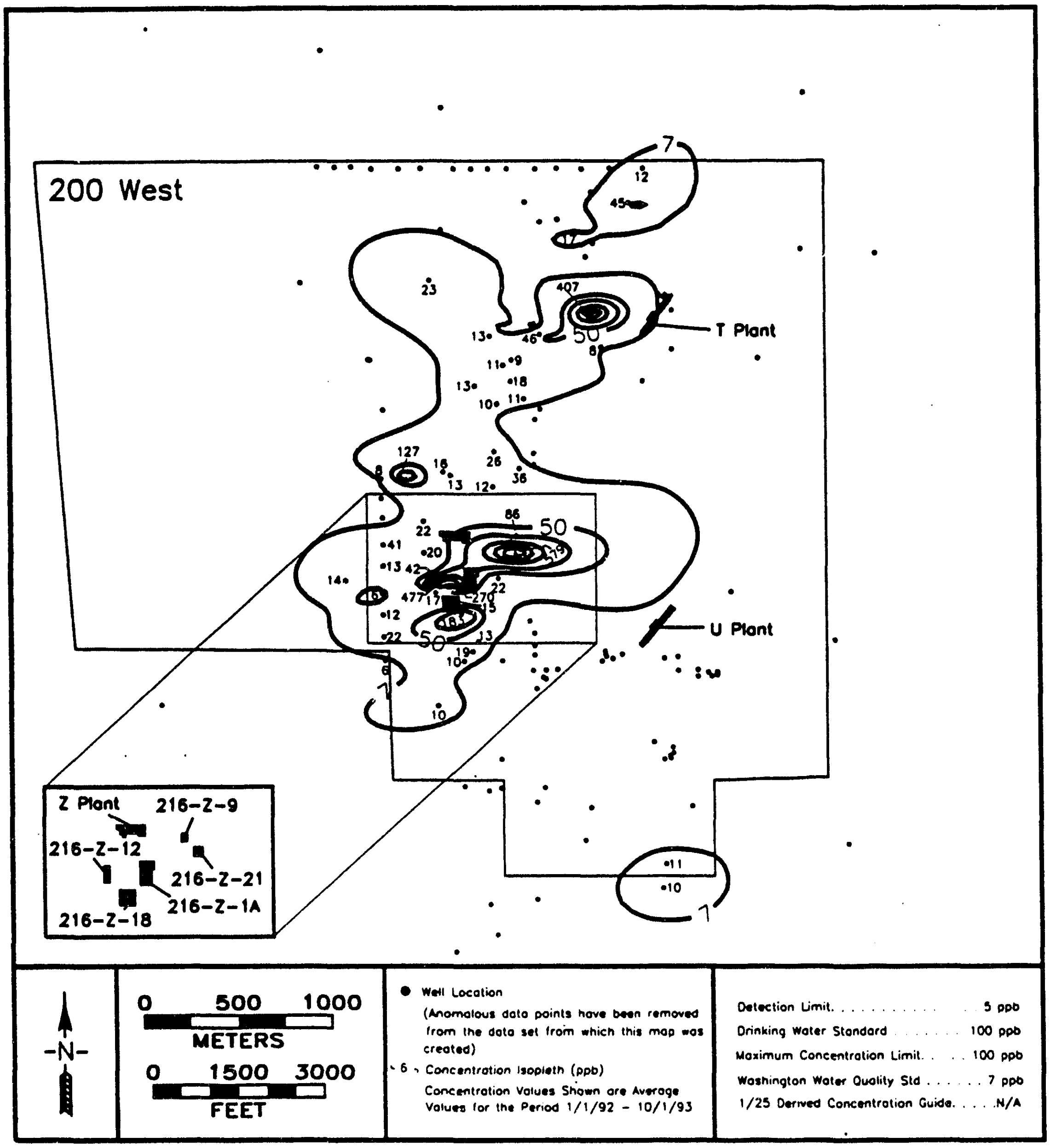


Figure 4-21. Distribution of Mass of Carbon Tetrachloride Within Dissolved Groundwater Plume, 1992-1993.

Figure 4-22. Chloroform Concentration Contours in the 200 West Area Groundwater, 1992-1993.



The chloroform may be present as a degradation product of carbon tetrachloride. The past and current presence of sanitary drainage fields in the 216-Z-9 area suggest that anaerobic bacterial degradation processes may be responsible (Dresel et al. 1993). A second area of relatively high concentrations (407 µg/L) is centered on well 299-W11-30 west of T Plant. The drinking water standard for chloroform is 100 µg/L (EPA 1976).

Chlorinated wastewater is discharged to the sanitary tile fields throughout the 200 West Area. However, sources such as chlorinated drinking water would be expected to contribute relatively low concentrations (on the order of 15 µg/L) to groundwater (DOE-RL 1992a).

Based on average values of groundwater concentrations between January 1988 and April 1992, and assuming 20% porosity, the mass of dissolved chloroform in the upper 10 m of the unconfined aquifer was estimated to be 240 kg, approximately 5% of the mass of carbon tetrachloride (DOE-RL 1992a).

4.3.1.3 Plutonium and Americium. Plutonium-239/240 has been detected above the drinking water standard (1 pCi/L) in only one groundwater well in the 200 West Area, 299-W15-8 on the south of the 216-Z-9 Trench. Plutonium-239/240 was first measured in this well in 1990 at a concentration of 8.3 pCi/L. Plutonium-238 was also detected at a concentration of 0.14 pCi/L. This well was resampled in 1991 and yielded concentrations of 1.9 and 0.03 pCi/L for $^{239/240}$Pu and ^{238}Pu, respectively. Americium-241 was measured at a concentration of 5.9 pCi/L. Filtered samples from the same 1991 sampling event yielded no detectable plutonium, confirming that the transuranics were associated with particulate material and are thus in a relatively immobile form (Evans et al. 1992, Dresel et al. 1993). Additional samples could not be collected in 1992 because of the drop in water level.

Well 299-W15-8 was drilled in 1954, approximately 6 months prior to initiation of discharge of plutonium- and americium-bearing liquids to the 216-Z-9 Trench and was deepened to the unconfined aquifer in 1966, 4 1/2 years after discharges to this site ceased. Well 299-W15-8 is approximately 17 m south of the trench. The age of the well and its proximity to the trench suggest that it may have been a preferential pathway for movement of liquid wastes to the groundwater along the outside of the casing. A spectral gamma log of the well indicates transuranic contamination along the casing, supporting the preferential pathway explanation (Johnson 1993a).

4.3.2 Lateral Distribution at the ERA/VOC-Arid ID Carbon Tetrachloride Area

Groundwater samples were collected during drilling of seven vapor extraction wells at the ERA/VOC-Arid ID carbon tetrachloride site in 1992 and 1993. Between January and May 1992, three wells (299-W15-216, 299-W18-247, 299-W18-246) were drilled 4.5 m (15 ft) into the unconfined aquifer, and groundwater samples were collected at 1.5-m (5-ft) intervals using a bailer. Between February and August 1993, four wells (299-W15-218, 299-W15-219, 299-W15-220, and 299-W18-252) were drilled 1.5 m (5 ft) into the saturated zone and sampled for groundwater using a bailer. All seven wells were backfilled into the unsaturated zone and completed as unsaturated zone extraction wells at the time of drilling (Figure 4-11). The 1992 wells were analyzed for VOCs; a suite of cations, ions, and chemical compounds; and radionuclides. The 1993 groundwater samples were analyzed for VOCs only.

Groundwater samples collected from four wells near the 216-Z-9 Trench all contained carbon tetrachloride, chloroform, and methylene chloride. Both trichloroethylene (TCE) and tetrachloroethylene (PCE) were present in trace amounts (Table 4-11). Carbon tetrachloride concentrations ranged from 6,379 µg/L in well 299-W15-218 north of the trench to 915 µg/L in well 299-W15-220, east of the trench. Trace amounts (up to 1.2 µg/L) of 1,1-dichloroethane and acetone (up to ~19 µg/L) were also detected in well 299-W15-216. Minor amounts of fission products (e.g., up to 29.5 pCi/L ^{106}Ru) were detected in well 299-W15-216; analyses for radionuclides were not conducted in the other three wells.

Both carbon tetrachloride and PCE were discharged to the 216-Z-9 Trench (Rohay and Johnson 1991). Through reductive dechlorination, carbon tetrachloride can be degraded to chloroform and to methylene chloride by denitrifying bacteria. The presence of both degradation products, and the past and current presence of sanitary drainage fields in the 216-Z-9 area, suggest that anaerobic bacterial degradation processes are responsible (Dresel et al. 1993). Tetrachloroethylene can also be degraded by microbes to TCE.

Table 4-11. Maximum Groundwater Concentrations (µg/L) of Volatile Organic Compounds in 1992/1993 Wells at the ERA/VOC-Arid ID Carbon Tetrachloride Site.

Well number	Carbon tetra-chloride	Chloroform	Methylene chloride	Trichloro-ethylene (TCE)	Tetrachloro-ethylene (PCE)
216-Z-9 Trench					
299-W15-216	4,479	976	630	0.9	2.6
299-W15-218	6,379	499	16	1.4	5.7
299-W15-219	3,862	862	38	1.1	3.3
299-W15-220	915	459	32	0.6	1.1
216-Z-1A					
299-W18-246	1,009	3,600[a]	672[a]	2.5	1.0
299-W18-252	1,130	46	<5	2.2	0.6
216-Z-18					
299-W18-247	418	183	1.9	1.0	Observed

[a] The maximum concentrations of chloroform and methylene chloride are at least an order of magnitude higher than those found in the other five groundwater samples collected from this well. Thus, this might be the result of some unrecognized sampling or analysis error. The second highest concentrations detected are 361 and 97 µg/L, respectively.

Groundwater samples from wells 299-W18-246 and 299-W18-252, which are 59.6 m apart and both west of the 216-Z-1A Tile Field, had comparable concentrations of carbon tetrachloride (Table 4-11). However, the concentrations of chloroform and methylene chloride were at least an order of magnitude lower in well 299-W18-252, the well farther from the tile field. Again, trace amounts of TCE and PCE were present.

In well 299-W18-246, trace amounts of 1,1-DCA were observed; methyl ethyl ketone (MEK), at concentrations up to approximately 9 µg/L, was found for the first time; and benzene, toluene, and xylene (BTX) compounds, up to 2.9 µg/L, were also found, along with acetone at concentrations up to approximately 144 µg/L. The same fission products found beneath the 216-Z-9 Trench were also found in the groundwater beneath the 216-Z-1A Tile Field but at slightly higher levels (e.g., up to 55.3 pCi/L ^{106}Ru) in samples from well 299-W18-246. Groundwater samples from 299-W18-252 were not analyzed for radionuclides.

The groundwater samples from well 299-W18-247, southeast of the 216-Z-18 Crib, yielded lower maximum concentrations of carbon tetrachloride than in the other wells and lower maximum concentrations of chloroform and methylene chloride than in all the other wells except 299-W18-252. Concentrations of TCE and PCE appear to be relatively consistent throughout the carbon tetrachloride crib area. Maximum concentrations of the BTX compounds remained approximately the same as those near the 216-Z-1A Tile Field (up to 1.2 µg/L). However, the maximum concentrations of acetone and MEK increased (up to ~1,050 and ~93 µg/L, respectively). High concentrations of MEK (over 1,000 µg/L) were observed from a single bailed sample from the 216-Z-18 Crib (well 299-W18-9) in 1991 (Rohay and Johnson 1991). Concentrations of the fission products also increased slightly (e.g., up to 68.5 pCi/L ^{106}Ru).

Other major co-contaminants, tributyl phosphate (TBP), dibutyl phosphate (DBP), dibutyl butyl phosphonate (DBBP), and triglycerides (lard oil), have not been detected in groundwater. The groundwater samples from 1992 carbon tetrachloride wells (299-W15-216, 299-W18-246, 299-W18-247) were analyzed for TBP, which was not detected (Last and Rohay 1993). Sampling data for TBP and DBP acquired for other programs between 1987 and 1990 at wells in the vicinity of the carbon tetrachloride cribs as well as from wells within the core of the 200 West Area carbon tetrachloride plume were all below detection limits for TBP and DBP (Rohay and Johnson 1991). Analyses for DBBP and triglycerides have not been performed. The apparent absence of TBP and DBP in 200 West Area groundwater is attributed to biodegradation of these organic constituents and/or because they have a moderate affinity for sediments (Ames and Serne 1991). Lard oil is expected to remain at shallow depths in the soil (Dresel et al. 1993).

4.3.3 Vertical Distribution of Carbon Tetrachloride

Deep interval sampling in well 299-W15-6, which has a 52-m-long perforated interval within the unconfined aquifer, was conducted in 1991 (Rohay and Johnson 1991). Results suggested that there is deeply distributed carbon tetrachloride and chloroform within the aquifer, at least near the 216-Z-9 Trench. Bailed samples were taken at the surface and bottom of the well, and pumped samples (after purging) were taken from approximately 3 m below the surface and near the bottom of the well after installation of a packer to isolate the lower section of the perforated interval. The bailed and pumped samples from the bottom of the interval in 1991 contained 3,784 and 2,651 µg/L of carbon tetrachloride, respectively. The lower concentration obtained with the pumped sample suggests that the contamination may be localized in the immediate vicinity of the borehole rather than widespread in the deeper part of the aquifer (Johnson 1993a). In 1993, the vertical extent of groundwater contamination was re-examined in this well. The 1993 testing included introduction of a tracer into the well to evaluate whether leakage along the annulus of the well is contaminating the sample from the packed-off zone (Ford 1993). Preliminary results of this testing indicate that there is groundwater flow along the annulus; thus, the well annulus may be providing a preferential pathway for contaminants to reach the deep portions of the unconfined aquifer.

There is also a suggestion of carbon tetrachloride at depths below the water table in well 299-W18-17 at the 216-Z-20 Crib. A sample, representative of the 6- to 9-m depth, collected in 1990 contained 2,000 µg/L carbon tetrachloride; a sample pumped from 1.5 m below the water table in 1991 contained 1,004 µg/L carbon tetrachloride. However, the mechanism by which the contaminants reached these depths is uncertain (Rohay and Johnson 1991). This well was remediated in 1993 and is sealed above the Plio-Pleistocene unit (Johnson 1993b).

It should be noted that two wells west of the carbon tetrachloride disposal facilities are screened at the bottom of the aquifer (299-W18-22, 465 m southwest of the 216-Z-18 Crib, and 299-W15-17, 400 m northwest of the 216-Z-1A Tile Field). Carbon tetrachloride is below detection levels in samples from these wells, although it is present in groundwater samples from companion wells screened at the water table (Rohay and Johnson 1991).

5.0 CONCEPTUAL MODEL

This chapter presents current hypotheses concerning the source term, environmental setting, unsaturated zone contamination, unsaturated zone transport, groundwater contamination, sorption, and biological degradation of carbon tetrachloride and associated contaminants at the ERA/VOC-Arid ID carbon tetrachloride site. This information represents an update to the conceptual model of the site as presented in Rohay and Johnson (1991); Last and Rohay (1991, 1993); and Last et al. (1991). Figure 5-1 illustrates many of the concepts discussed in the following sections.

5.1 SOURCE TERM

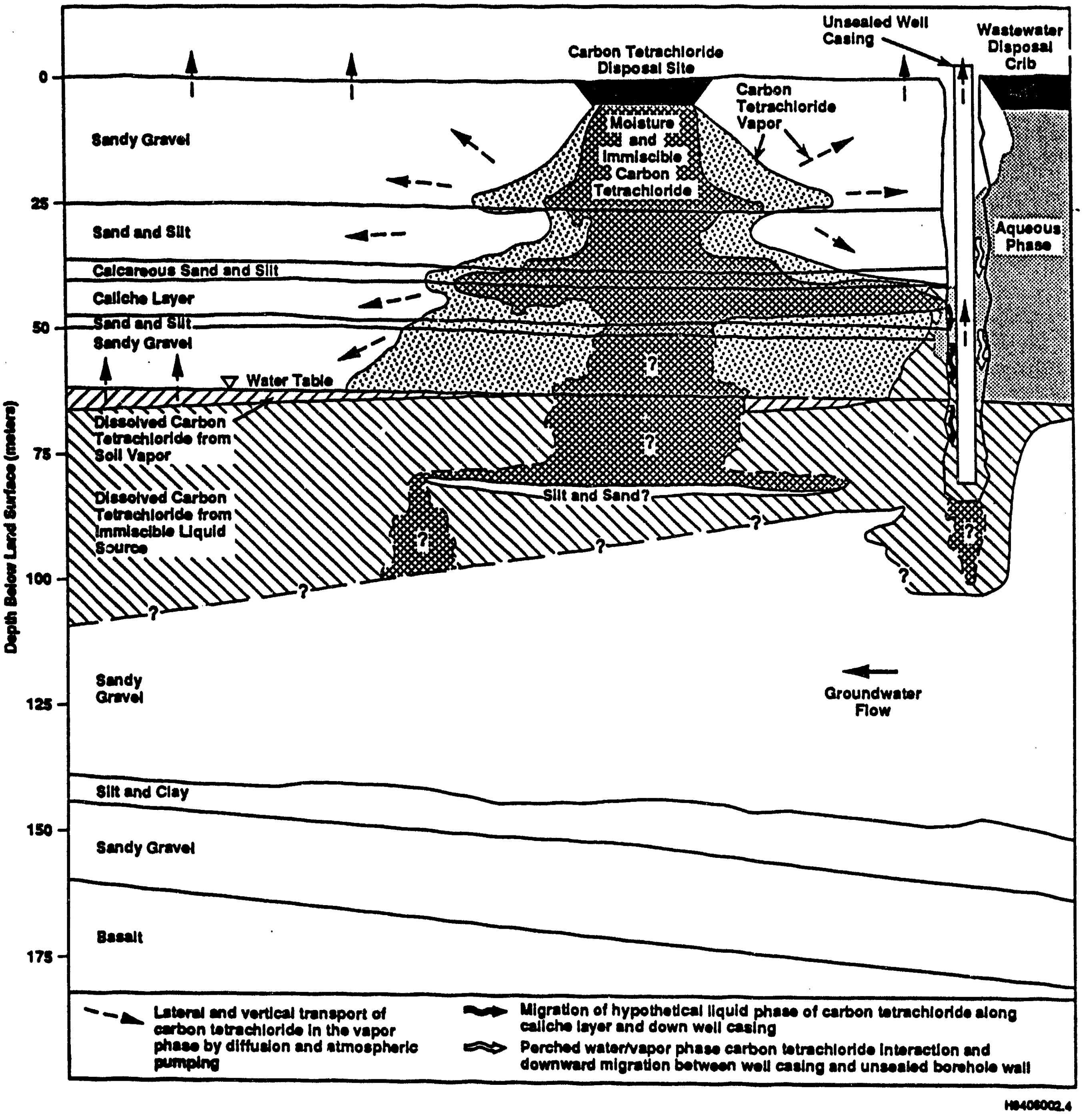
Between 1955 and 1973, a total of 363,000 to 580,000 L (577,000 to 922,000 kg) of liquid carbon tetrachloride, in mixtures with other organic and aqueous, actinide-bearing liquids, was discharged to the soil column at three subsurface disposal facilities (cribs) near Z Plant in the 200 West Area. The organic solutions consisted of 50% to 85% by volume carbon tetrachloride mixed with either tributyl phosphate (TBP), dibutyl butyl phosphonate (DBBP), or lard oil. These organic solutions made up only approximately 4% to 8% of the total volume of liquid waste discharged to the disposal facilities. The predominant wastes discharged were acidic, high-salt (sodium nitrate), aqueous wastes containing the above organic solutions in saturation amounts (<1%). The organic solutions were periodically discharged to the predominantly water-wetted soil column in small (100- to 200-L) batches. Thus, carbon tetrachloride was introduced to the unsaturated zone as an aqueous phase and also as a dense, nonaqueous-phase liquid (DNAPL).

5.2 ENVIRONMENTAL SETTING

The unsaturated zone underlying the carbon tetrachloride disposal sites ranges in thickness from 60 to 71 m and consists primarily of uncemented to partially consolidated gravel, sand, and silt deposits of the Pleistocene Hanford and late Miocene to Pliocene Ringold formations. Between these two units, the relatively impermeable Plio-Pleistocene unit, typically containing an increase in calcium carbonate content ("caliche layer"), occurs at approximately 35 to 40 m below the surface and ranges in thickness from 1 to 13 m. Perched groundwater has been encountered in this zone, and airflow through it has been observed to be significantly impeded.

The uppermost aquifer beneath the 200 West Area is unconfined and lies within a semi-indurated gravel sequence. Hydraulic conductivity values at the top of the aquifer vary by several orders of magnitude. The present direction and rate of groundwater flow in the vicinity of the 200 West Area are largely influenced by a groundwater mound caused by former soil-column disposal of large volumes of waste water as part of Hanford Site operations. As this mound dissipates, the water table elevation drops 0.3 to 0.6 m/yr under the carbon tetrachloride site.

Figure 5-1. Schematic Illustration of Carbon Tetrachloride and Waste Water Migration Beneath the 216-Z-9 Trench.



5.3 UNSATURATED ZONE CONTAMINATION

Carbon tetrachloride is found throughout the 65-m-thick unsaturated zone underlying the three primary disposal facilities. Laterally, the highest concentrations of carbon tetrachloride are consistently located in the vicinity of the 216-Z-9 Trench. Vertically, the highest concentrations are associated with fine-grained, relatively impermeable units (the Hanford lower fine and Plio-Pleistocene units), located at depths of 35 to 40 m below ground surface.

The highest near-surface vapor concentration measured during a soil-gas survey was 72 ppm_v carbon tetrachloride just north of this trench. Maximum vapor concentrations observed at wellheads and deep soil-gas probes, which were measured twice a week for 25 months, exceeded 10,000 ppm_v total VOCs at monitoring locations above the Plio-Pleistocene unit and immediately north of the 216-Z-9 Trench. At similar locations above the Plio-Pleistocene unit in the 216-Z-1A/216-Z-18 area, maximum concentrations were an order of magnitude lower. However, maximum concentrations from monitoring ports below the Plio-Pleistocene unit were approximately 1,000 ppm_v at both locations.

The highest carbon tetrachloride concentration in the sediment samples collected during drilling of 13 new wells was 37.8 ppm from a well at the 216-Z-9 Trench. Carbon tetrachloride concentrations exceeded 10 ppm in samples from two other wells in the 216-Z-9 area. In contrast, the highest carbon tetrachloride concentration in a sediment sample from the 216-Z-1A/216-Z-18 area was 6.6 ppm from a well inside the 216-Z-1A Tile Field. At both locations, all of the maximum carbon tetrachloride sediment concentrations are associated with the interbedded sands and silts of the Hanford formation lower fine unit, laminated silts of the Plio-Pleistocene unit, and/or the top of the caliche.

The highest carbon tetrachloride concentrations in the in situ soil-gas samples collected during drilling exceeded 10,000 ppm_v in wells at the 216-Z-9 Trench. Carbon tetrachloride concentrations in soil vapor extracted using the vapor extraction systems exceeded 25,000 ppm_v carbon tetrachloride from intervals above the Plio-Pleistocene unit at the 216-Z-9 Trench. Extracted soil-gas concentrations from the 216-Z-1A/216-Z-18 wellfield are an order of magnitude lower.

Soil that is saturated with liquid carbon tetrachloride will have an associated equilibrium soil-gas concentration of 120,000 ppm_v at 20 °C. As a rule-of-thumb, for soils saturated with an organic contaminant, standard soil vapor extraction will produce a gas stream containing one-tenth to one-half the expected concentration (Johnson et al. 1990). Therefore, vapor extraction concentrations greater than 12,000 ppm_v of carbon tetrachloride may indicate that the soil is saturated and a separate carbon tetrachloride phase is probably present near the extraction well. Extracted soil-gas concentrations at the 216-Z-9 Trench are in excess of 12,000 ppm_v, suggesting that a separate carbon tetrachloride phase is present above the Plio-Pleistocene layer.

Soil that is not saturated with carbon tetrachloride will have soil-gas concentrations related to the quantity of contaminant dissolved in the soil moisture and adsorbed to the solid soil matrix. A linear isotherm was used to determine a vapor-phase partitioning coefficient using carbon tetrachloride concentrations from sediment samples and from corresponding soil-gas measurements (Rohay and Cameron 1994) (Figure 5-2). This isotherm had the following form:

$$C_s\ (\mu g/kg) = 0.73\ C_v\ (ppm_v)$$

where:

C_s = solid-phase concentration (mass of contaminant sorbed on soil particles plus mass dissolved in soil moisture per mass of soil)

C_v = vapor-phase equilibrium concentration.

The maximum soil-gas carbon tetrachloride concentrations found to date are 30,000 ppm_v at the 216-Z-9 wellfield and 1,700 ppm_v at the 216-Z-1A/216-Z-18 wellfield. Subsurface inventories were calculated using these concentrations, the vapor-phase partitioning coefficient, a contaminated depth of 20 m, and a contaminated area of 60,000 m^2 for the 216-Z-9 wellfield and 240,000 m^2 for the combined 216-Z-1A/216-Z-18 and 216-Z-12 wellfields. These calculations predict carbon tetrachloride inventories of 50,000 kg (6.7% of inventory) beneath the 216-Z-9 wellfield surface and 10,000 kg (1.3% of inventory) beneath the combined 216-Z-1A/216-Z-18 and 216-Z-12 wellfield surface. However, disposal records indicate significantly greater quantities of carbon tetrachloride were discharged to these sites. The discrepancy between the estimated amount of carbon tetrachloride discharged and the predicted remaining carbon tetrachloride inventory could be most easily accounted for if a separate carbon tetrachloride phase were present beneath each of the disposal sites (Rohay and Cameron 1994).

Nonaqueous-phase liquid carbon tetrachloride has not been observed in the unsaturated zone.

As of the end of May 1994, a total of 16,790 kg of carbon tetrachloride (2% of the discharged inventory) had been removed from the unsaturated zone using active vapor extraction, 5,030 kg from the 216-Z-1A/216-Z-18 wellfield and 11,760 kg from the 216-Z-9 wellfield.

In the far field, carbon tetrachloride vapor has been detected in wells under construction throughout much of the 200 West Area since 1987. Most of the reported detections have been from below the Plio-Pleistocene caliche layer, often in the capillary fringe zone just above the water table. The distribution of wells with detections below the caliche layer matches fairly well with the distribution of carbon tetrachloride dissolved in the groundwater.

5.4 UNSATURATED ZONE TRANSPORT

Once discharged to the crib, the liquid wastes infiltrated into the underlying soils and migrated under their own hydraulic gradients. An average infiltration rate or recharge rate into the soil column can be estimated for each crib from the area of the crib bottom and average annual discharges. These range from 1 to 10 $L/m^2/d$ (Table 5-1). Average infiltration rates from percolation tests in the 216-Z-20 and 216-Z-21 crib areas have been reported

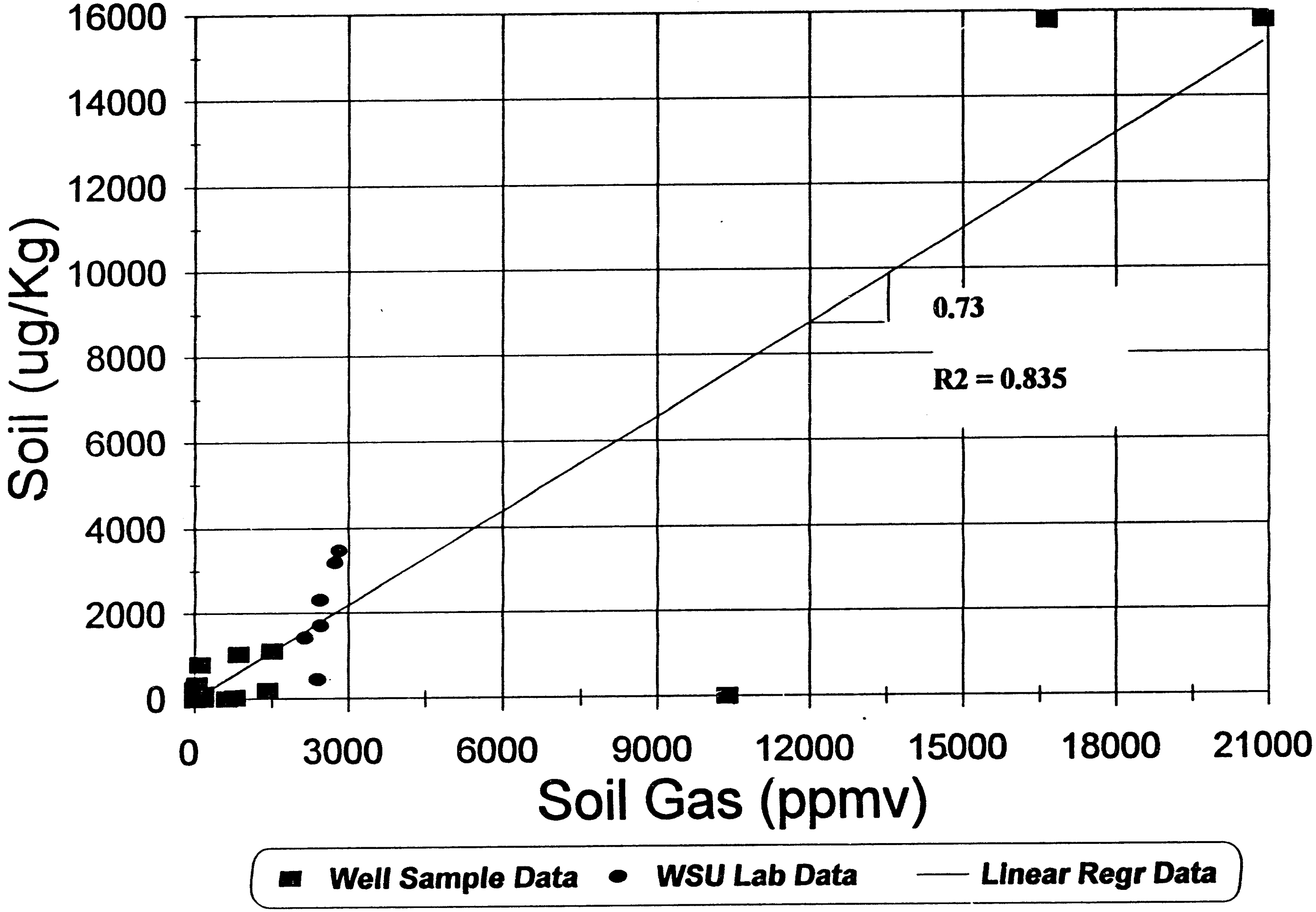


Figure 5-2. Vapor-Phase Partitioning Isotherm.

Table 5-1. Pore Column Volume Estimates for the Carbon Tetrachloride Cribs.

Waste disposal facility	North-south length (m)	East-west length (m)	Bottom area (m^2)	Depth to water (m)	Average annual discharge (L)	Infiltration rate ($L/m^2/d$)	Porosity (%)	Column pore volume (L)	Total discharge volume (L)	% Pore volume
216-Z-1A	84	35	2,940	57	1.15E+06	1.07	30	5.03E+07	6.21E+06	12
216-Z-9	18.3	9.1	167	57.6	6.08E+05	10.00	30	2.88E+06	4.09E+06	142
216-Z-18	63	12	756	59	9.74E+05	3.53	30	1.34E+07	3.86E+06	29

as ranging from 1,900 to 2,850 $L/m^2/d$ (Last and Rohay 1993). Thus, the field-measured infiltration rate of the soil column far exceeds the estimated recharge rate from the cribs. Assuming that the behavior of the liquid wastes discharged was similar to that of water used in the percolation tests, it is doubtful that the soil column ever became fully saturated or that the cribs exceeded the infiltration capacity, at least for any appreciable period of time. Crawley (1969), however, did report that a buildup of liquid waste was suspected in the head end of the 216-Z-1A Tile Field. This suggests that the infiltration capacity of that first one-third of the crib had been exceeded by the discharge volumes perhaps as a result of plugging of the soil pores by fine particulates or other solids. It should also be noted that the 216-Z-1A Tile Field had received other liquid wastes from 1949 to 1959, so the soil column was already partially saturated.

As a first approximation, the likelihood that carbon tetrachloride in an aqueous or nonaqueous phase reached the groundwater can be estimated by comparing the total volume discharged to the column pore volume beneath each crib (i.e., bottom area of crib multiplied by depth to water multiplied by porosity; assuming 30% porosity). Results of such calculations indicate that the 216-Z-1A and 216-Z-18 waste disposal facilities received only 12% and 29% of their estimated column pore volumes, respectively, while the 216-Z-9 Trench received 142% of its column pore volume (Table 5-1). It must be noted that these are only rough estimates and that the wastes were discharged over periods of years rather than at one time. If the porosity were smaller or if the entire column pore volume were not used (e.g., if the wastes migrated down preferential pathways such as unsealed wells or if the wastes did not spread out evenly over the crib floor), the values would be higher. Conversely, if the waste plume spread out laterally, increasing its column pore volume, these values would be smaller. In any case, the 216-Z-9 Trench is more likely to have had waste fluids containing carbon tetrachloride reach the groundwater strictly by downward percolation.

Numerical flow simulations suggest that carbon tetrachloride may have migrated to the water table from the 216-Z-9 Trench irrespective of whether an unsealed borehole or other pathway may have been present (Piepho et al. 1993). However, as Piepho et al. (1993) point out, this result should be viewed as tenuous because no data on nonaqueous-phase liquid residual saturation were available and several simplifications were applied that require further investigation. Also, the physical properties of pure carbon tetrachloride were used rather than those of the carbon tetrachloride organic mixtures. The three phase flow simulations (water, separate liquid-phase organic, and air) suggest that most of the free liquid carbon tetrachloride that has not evaporated should now be located in the Hanford formation lower fine and Plio-Pleistocene units or in the groundwater (Piepho et al. 1993).

Numerical simulations of waste water migration beneath the 216-Z-9 Trench suggest some horizontal spreading of the aqueous plume may have occurred at the Hanford coarse-grained unit/fine-grained unit boundary, but that little lateral spreading may have occurred below that (Last and Rohay 1993). Piepho et al. (1993) also indicate that horizontal spreading in the unsaturated zone appears to be minimal even though anisotropy was assumed. Wright et al. (1994) inferred a near-vertical moisture plume beneath the carbon tetrachloride cribs, with some spreading occurring only on the Hanford formation lower fine/Plio-Pleistocene unit surfaces.

Because liquid carbon tetrachloride is immiscible with water and the soil column is assumed to be water wetted, the carbon tetrachloride would move under its own hydraulic gradient. Wright et al. (1994) concluded, based on their measurements, that the hydraulic conductivity of liquid carbon tetrachloride through subsurface soil samples was much higher than that of water or of an aqueous carbon tetrachloride solution, and that the differences were greater in the finer grained sample.

As nonaqueous-phase liquid carbon tetrachloride moves down through the soil column under its own hydraulic gradient, some of the liquid carbon tetrachloride will become discontinuous and will be held up in the soil pores. This is referred to as residual saturation. Based on studies of carbon tetrachloride hydraulic conductivities in soil samples, Conca et al. (1992) concluded that the retention of liquid-phase carbon tetrachloride was about half that of water or an aqueous-phase carbon tetrachloride solution. Thus, if the field moisture content of the soil were 5% under a given unsaturated flow condition, it can be estimated to retain 2.5% carbon tetrachloride under the same conditions. It should be noted that these are strictly empirically derived estimates, based on two samples, and should be viewed with some caution.

A rough estimate of how far the organic nonaqueous-phase liquid may have traveled downward through the soil column as a continuous organic liquid phase (i.e., at saturations greater than the residual) can be calculated by assuming a single residual saturation of 2.5% for the entire pore column volume and by assuming that the organic was evenly distributed across the crib bottom area. Table 5-2 lists the relative depth of nonaqueous-phase liquid migration for each facility. Note that the migration depth calculated for the 216-Z-9 Trench is over an order of magnitude greater than that of the other two cribs and is potentially below the water table. It also seems plausible that much of the organic nonaqueous-phase liquid may have been retained in the soil column because of the residual saturation. It should be noted, however, that DNAPL characteristically moves nonuniformly through the unsaturated zone (Cohen et al. 1993).

Table 5-2. Estimated Depth of Organic Migration Beneath the Carbon Tetrachloride Cribs.

Waste disposal facility	North-south length (m)	East-west length (m)	Bottom area (m^2)	Depth to water (m)	Total organic discharge (L)	Residual saturation (%)	Depth of migration (m)
216-Z-1A	84	35	2,940	57	1.75E+05	2.5	2
216-Z-9	18.3	9.1	167	57.6	8.30E+05 to 3.00E+05	2.5	20 to 72
216-Z-18	63	12	756	59	1.10E+05	2.5	6

Volatilization of carbon tetrachloride from aqueous- and nonaqueous-phase liquids within the unsaturated zone results in vapor-phase carbon tetrachloride in soil pores. Due to the density of the carbon tetrachloride vapor, the density of the contaminated vapor phase is significantly greater than uncontaminated vapor in the unsaturated zone (Table 5-3). This contrast in densities can result in density-driven advective flow, which would move carbon tetrachloride vapor downward and laterally from the disposal facilities. As the contaminated vapor moves into uncontaminated areas, it may partition into the soil moisture and adsorbed phases and act to establish equilibrium. The carbon tetrachloride vapor may also provide a continuous source of contamination to the groundwater. The higher vapor-phase carbon tetrachloride concentrations above the Plio-Pleistocene layer suggest that density-driven advective vapor flow may be significant.

Carbon tetrachloride vapors in the unsaturated zone, which equilibrate with perched water and/or with waste water from other sources, may then be transported to the water table in dissolved form.

Carbon tetrachloride may volatilize from the dissolved groundwater plume. The contaminant vapors would then move upward by diffusion but may become temporarily trapped below the Plio-Pleistocene layer until they find a vertical pathway upward. The distribution of carbon tetrachloride vapor below the caliche throughout much of the 200 West Area underlain by the groundwater plume suggests that these vapors may have volatilized from the groundwater.

Atmospheric pressure fluctuations appear to constitute a significant release mechanism for carbon tetrachloride vapor out of the unsaturated zone both through the soil surface and through boreholes perforated or otherwise open to the unsaturated zone. The soil-surface flux of carbon tetrachloride measured in 1992 and 1993 using the EMFLUX soil-gas technology ranged from 1.4 to 922.7 ng/m^2/min (0.0007 to 0.48 g/m^2/yr) in the 216-Z-9 Trench area. The average soil-surface flux for the area overlying the groundwater plume in 1990 was estimated to be 285 ng/m^2/min (0.15 ng/m^2/yr), or 1,800 kg/yr (WHC 1993a). It is estimated that, between 1955 and 1990, 18% of the total carbon tetrachloride inventory was lost to the atmosphere through natural soil flux (WHC 1993a). The wells breathe in response to atmospheric pressure changes and other meteorological phenomena. The carbon tetrachloride flux from a single borehole is estimated to range from several grams to several tens of grams per hour during an exhalation event (Rohay and Cameron 1992). The carbon tetrachloride released from wells in the vicinity of the cribs between

Table 5-3. Physical Properties of Carbon Tetrachloride.

Property	Units	Pure CCl_4	85 CCl_4:15 TBP by volume	50 CCl_4:50 DBBP by volume	50 CCl_4:50 lard oil by volume	Water
Liquid density	g/mL at 20 °C	1.59[a]				1.00[a]
	g/mL at 25 °C		1.51	1.27	1.25	
Viscosity	centipoise at 24 °C		5.75	4.50	10.50	
	centipoise at 20 °C	0.97[b]				1.00[b]
Interfacial tension with air	dynes/cm at 24 °C		31.0	32.0	33.0	
Interfacial tension with water	dynes/cm at 24 °C		23	11	18	
	dynes/cm at 20 °C	45.0[b]				
Interfacial tension with 5 M sodium nitrate	dynes/cm at 24 °C		11	19	7	
Vapor pressure	cm H_2O at 24 °C, 30.1 in. Hg	130	100	52	60	
Saturated vapor concentration	mg/L at 20 °C	754[a]				
	ppm_v at 20 °C	120,000[a]				
Saturated vapor density	g/L at 25 °C, 1 atm	6.29[b]				dry air = 1.204[b]
Relative vapor density[c]	--	1.515[b]				
Air diffusion coefficient	cm^2/s at 20 °C	.0797[b]				
Henry's Law constant	atm - m^3/mol at 25 °C	3.02 E-02[b]				
Solubility in water	mg/L at 20 °C, 1 atm	800[a,b]				
Dielectric constant	--	2.2[a]				78.5[a]

From Last and Rohay (1993).

[a] Rohay and Johnson (1991).

[b] Cohen et al. (1993).

[c] Weight of compound-saturated air relative to weight of moist air.

CCl_4 = carbon tetrachloride.

DBBP = dibutyl butyl phosphonate.

TBP = tributyl phosphate.

1955 and 1990 is estimated to be 22,200 kg, or 3% of the discharged inventory (WHC 1993a). Thus, an estimated 21% of the total carbon tetrachloride inventory may have been lost to the atmosphere via the soil surface and borehole flux since soil column disposal was initiated (WHC 1993a).

WHC (1993a) estimated that 12% of the original carbon tetrachloride inventory was retained in the unsaturated zone air, water, and soil, leaving 65% unaccounted for, which might be attributed to residual saturation of nonaqueous-phase liquid wastes in the unsaturated or saturated zones and/or biodegradation.

Another potential indicator of the distribution of the organic phase is the distribution of the associated radionuclide contaminants. Transuranics (primarily ^{239}Pu and ^{241}Am) discharged to the disposal sites may have been carried in association with the organic-complexant liquid phase. The behavior of the transuranics in such a mixture as the DNAPL moves through the soil column is unknown. Typically, when plutonium and americium are released as solutes, they are retained in the upper few meters of the soil column (Johnson 1993b). However, at the 216-Z-1A Crib, these radionuclides were discharged as co-contaminants with the DNAPL-complexant mixture and are found at depths up to 30 m below the bottom of the field (Price et al. 1979). This behavior has been previously attributed to the destruction of the sorptive capacity of the soils by the acidic waste stream. However, the abundant amounts of calcium carbonate in the soil column could have easily neutralized the acid. For example, at a pH of 1 (0.1 M), which is slightly more acidic than the discharged aqueous waste stream (pH of 2.5), the total volume of aqueous waste discharged to the 216-Z-1A Crib would have contained approximately 500 kmol of acid. The first few meters of the soil column beneath this crib contain more than enough calcium carbonate to neutralize this amount of acid (Johnson 1993b). Thus, it seems more probable that the greater depth distribution of transuranics in this crib is due to migration with the solvent-complexant phase. Beneath the 216-Z-1A Tile Field, increases in concentrations of plutonium and americium with depth are generally associated with an increase in the silt content of the sediments or with boundaries between sedimentary units. In addition, the lateral spread of radionuclides beyond the perimeter of the tile field was limited to a 9-m-wide zone (Price et al. 1979). Because similar solvent-chemical conditions existed for disposal at the other carbon tetrachloride sites, similar depth distributions of significant transuranic concentrations could be encountered wherever DNAPL still exists.

Older, poorly sealed wells, which penetrate either the Plio-Pleistocene unit and/or the water table, may provide a vertical conduit for fluids. Nonaqueous-phase liquid carbon tetrachloride and aqueous-phase dissolved carbon tetrachloride that intercept the borehole in the subsurface may migrate downward along the outside casing of the well. In addition, these fluids may be channeled along preferential pathways, such as fractures or large, interconnected pores, within the unsaturated zone.

Due to its low dielectric constant, carbon tetrachloride can increase the permeability of the subsurface materials and thereby strongly influence its own migration pathway. Solutions with high dielectric constants, such as water (Table 5-3), will cause alumino-silicate clays to swell. A liquid with a low dielectric constant, such as carbon tetrachloride, causes clays to shrink, and therefore increases the permeability of the soil through the introduction of cracks and fissures (Rohay and Johnson 1991). Although clay-sized particles which include alumino-silicate clay minerals occur throughout the unsaturated zone, the Plio-Pleistocene unit typically contains a higher percentage (6% to 14%) (Wright et al. 1994). This dielectric phenomenon may be responsible for increasing the introduction of carbon tetrachloride into and/or through this finer grained unit.

5.5 GROUNDWATER CONTAMINATION

The plume of dissolved carbon tetrachloride extends over 10 km^2 in the unconfined aquifer underlying the 200 West Area. The zone of highest concentrations (4,000 to 7,000 μg/L) still includes the 216-Z-9 Trench, suggesting that the carbon tetrachloride discharged there has been providing a continuous source of contamination to the groundwater. Although the centroid of the plume has not migrated significantly, the perimeter of the plume appears to be migrating laterally to the south, west, and north. Nearly 60% of the mass of carbon tetrachloride is contained within about 10% of the area of the plume (Rohay and Johnson 1991).

Carbon tetrachloride has been detected at or less than 1% of its theoretical solubility limit in water (800,000 μg/L). Chlorinated hydrocarbon solvents are commonly observed to be at concentration levels in groundwater well below their aqueous solubility limits, even when the aquifer is believed to contain separate phase liquid (Anderson et al. 1992). Possible explanations proposed by Anderson et al. (1992) include the preferential formation of thin flat pools rather than vertical fingers of DNAPL, which would reduce the cross-sectional contact area between the oncoming groundwater and the DNAPL; dilution of small aqueous plumes by dispersion downgradient from the source; and dilution of thin and/or narrow aqueous plumes by uncontaminated water in monitoring wells screened over lengths of several meters, large relative to the dimensions of the plume. In addition, the wells monitor the top of the aquifer and may not sample carbon tetrachloride present at depth.

An estimated 2% of the total carbon tetrachloride inventory can be accounted for in the top 10 m of the unconfined aquifer beneath the 200 West Area (Rohay and Johnson 1991). In making this estimate, it was assumed that no carbon tetrachloride had partitioned from the dissolved phases into the aquifer particles. However, a distribution coefficient (K_d) of 0.0 to 0.2 mL/g was suggested as likely for carbon tetrachloride aqueous solutions on Hanford soil based on batch K_d experiments (Last and Rohay 1993). Assuming a K_d of 0.2 mL/g in the upper 10 m of the aquifer would indicate that the mass of carbon tetrachloride sorbed onto the aquifer solids is 3.6 times the mass dissolved in the pore fluids. Assuming that 5,250 kg to 15,740 kg is dissolved in the groundwater (Rohay and Johnson 1991), an additional 18,900 kg to 56,660 kg could be sorbed onto the aquifer solids, which would account for an additional 2% to 8% of the carbon tetrachloride inventory.

At one well northeast of the 216-Z-9 Trench, groundwater samples indicate that there is deeply distributed carbon tetrachloride 52 m beneath the water table. However, the well itself, which lacked an annular seal until 1987, may have provided the preferential pathway for the downward migration of contaminants. Column pore volume estimates and numerical model simulations suggest that at the 216-Z-9 Trench, nonaqueous-phase liquid carbon tetrachloride may have reached the water table by downward migration through the soil column, irrespective of whether poorly sealed wells provided a preferential pathway.

Some separate, liquid-phase carbon tetrachloride/organic mixture may be present in the form of residual saturation or, perhaps, as a perched, dense, nonaqueous-phase-liquid pocket within the aquifer. This could provide a continuous source for groundwater contamination, for example, at the 216-Z-9 Trench. However, nonaqueous-phase liquid has not been observed.

These transport and inventory partitioning estimates have been made using pure liquid-phase carbon tetrachloride properties. However, the carbon tetrachloride was not discharged as a pure liquid but as a mixture with other organics (TBP, DBBP, and lard oil). The liquid properties (density, viscosity, interfacial tension, and vapor pressure) of three representative mixtures, 85:15 carbon tetrachloride:TBP, 50:50 carbon tetrachloride:DBBP, and 50:50 carbon tetrachloride:lard oil, are presented in Table 5-3. The organic composites (even the carbon tetrachloride:lard oil mixture) were found to be denser and more viscous than water (Last and Rohay 1993). Vapor pressure of the carbon tetrachloride:DBBP and carbon tetrachloride:lard oil mixtures is only half that of the pure carbon tetrachloride and the carbon tetrachloride: TBP mixture. The interfacial tension between the 50:50 carbon tetrachloride: lard oil mixture and a 5 M sodium nitrate solution was found to be low, suggesting that the fluids may be somewhat miscible, allowing them to mix and behave more as an aqueous fluid (Last and Rohay 1993).

5.6 SORPTION

It has been estimated that 6% of the original carbon tetrachloride inventory is contained (sorbed) in the soil (WHC 1993a). This estimate was based on a calculated distribution coefficient (K_d) for aqueous-phase carbon tetrachloride of 0.192 mL/g and assumed partitioning estimates. This value is consistent with batch K_d experiments which resulted in estimated K_d values for carbon tetrachloride aqueous solutions on Hanford soil that range between 0.0 and 0.2 mL/g (Last and Rohay 1993). It was noted in WHC (1993a) that the level of uncertainty in the soil inventory estimates was large and that additional measurements of soil mineralogy and soil-water-partitioning coefficients would help refine the analysis of the unsaturated zone inventory.

5.7 BIODEGRADATION

WHC (1993a) suggested that a portion of the 65% of the inventory unaccounted for in their residual inventory estimates might be explained by subsurface biodegradation of the carbon tetrachloride. Microbiological analyses of sediment samples from well 299-W15-217 at the 216-Z-9 Trench and well 299-W18-246 at the 216-Z-1A Tile Field have shown increased viable counts (on the order of 1 to 6.6 colony-forming units) of culturable, aerobic, heterotrophic bacteria within the Hanford formation lower fine and the Plio-Pleistocene units (Last and Rohay 1993). These microorganisms were metabolically active, displaying activity levels on the order of 32.8% to 62.2% $^{14}CO_2$ within the vicinity of these carbon tetrachloride disposal sites. The relationship between these microorganisms and any biodegradation of the carbon tetrachloride, however, has not been determined. Lenhard et al. (1992) reported that microbial degradation of carbon tetrachloride has been demonstrated with a number of bacteria; however, the conditions that favor biodegradation are predominantly anaerobic or microaerophilic and, thus, biodegradation in the predominantly aerobic unsaturated zone at the 200 West Area may be rather limited.

In the groundwater under denitrifying conditions, the carbon tetrachloride will degrade to carbon dioxide and chloroform. Given the right microcosm, this degradation process can occur after only 3 weeks. Under methanogenic conditions, the carbon tetrachloride can completely degrade to carbon dioxide. Considerable variation has been observed in carbon tetrachloride degradation even in similar samples, suggesting that microbial populations and their associated activities can be heterogeneous.

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APPENDIX A

WASTE STREAM DESCRIPTIONS, DISPOSAL FACILITY DESCRIPTIONS, AND ESTIMATED DISPOSAL INVENTORIES AT THE ERA/VOC-ARID ID SITE

APPENDIX A

WASTE STREAM DESCRIPTIONS, DISPOSAL FACILITY DESCRIPTIONS, AND ESTIMATED DISPOSAL INVENTORIES AT THE ERA/VOC-ARID ID SITE

This appendix provides a description of the various waste streams discharged to the 216-Z-9 Trench, 216-Z-1A Tile Field, and 216-Z-18 Crib, the three primary carbon tetrachloride disposal sites. Also described are the waste disposal facilities and their estimated inventories.

WASTE STREAMS

Three principal waste streams were discharged to the 216-Z-9, Z-1A, and Z-18 facilities: aqueous wastes, organic wastes, and "lard oil."

Aqueous Wastes

Aqueous wastes amounted to approximately 95% of the total waste discharges to the primary carbon tetrachloride waste disposal facilities. These wastes have been characterized as an acidic, high-salt (5 to 6 M) sodium nitrate ($NaNO_3$) solution containing low levels of plutonium and other transuranic elements. Primary constituents consisted of nitric acid, fluoride, and phosphate (DOE-RL 1992). Waste from the Recuplex solvent column extraction consisted of aluminum, magnesium, sodium, calcium, and other metallic nitrate salts. These aqueous wastes were accumulated in a large stainless steel tank and were periodically batch neutralized to a pH of 2.5 by the addition of sodium hydroxide. Organic liquids, consisting of carbon tetrachloride, tributyl phosphate (TBP), and dibutyl butyl phosphonate (DBBP), were found in saturation amounts in the aqueous phase (Rohay and Johnson 1991).

Organic Wastes

Two organic streams were used in the Recuplex/Plutonium Reclamation Facility (PRF) processes: a TBP-based solvent and a DBBP-based solvent. The TBP-based solvent consisted of carbon tetrachloride and TBP. The Recuplex process primarily used a ratio (by volume) of 85:15 carbon tetrachloride to TBP, while the PRF process used a ratio (by volume) of 80:20 carbon tetrachloride to TBP (Rohay and Johnson 1991). Tetrachloroethylene (also referred to as perchloroethylene [PCE]) and tetrabromoethane were also used, at times, in combination with carbon tetrachloride at Recuplex (Rohay and Johnson 1991). Ionizing radiation and nitric acid would eventually degrade the TBP to dibutyl phosphate (DBP). The degraded solvent was periodically discharged, in batches, to the soil column and replaced with a fresh batch of solvent. Each batch of TBP-based solvent amounted to approximately 200 L (Rohay and Johnson 1991). The DBBP-based solvent stream was used for batch rework of aqueous liquid from the primary extraction column that exceeded plutonium concentration discharge specifications and/or for the americium recovery processes (Rohay and Johnson 1991). The Recuplex process used a ratio (by volume) of 50:50 carbon tetrachloride to DBBP, while the PRF process used a ratio (by volume) of 70:30 carbon tetrachloride to DBBP. The DBBP-based solvent was then stripped of plutonium and discharged, again to the soil column and in batch mode. Each batch of DBBP-based solvent amounted to approximately 100 L.

"Lard Oil"

A lubricating/cutting oil (also referred to as fabrication ["fab"] or "lard" oil), a mixture consisting of a 75:25 ratio (by volume) of carbon tetrachloride to lard oil, was used as a lubricant on plutonium cutting and milling tools. Also, carbon tetrachloride was used to clean the cutting oil from the millings and work surfaces (Rohay and Johnson 1991). The used lubrication oil, consisting of a new estimated ratio of 50:50 carbon tetrachloride to lard oil, was discharged to the same waste disposal facilities as the organic and aqueous wastes.

LIQUID WASTE DISPOSAL FACILITIES AND ASSOCIATED INVENTORIES

The physical design of the disposal facilities and their estimated inventories are described below. Additional detail is provided in Rohay and Johnson (1991) and Last et al. (1991).

216-Z-9 Trench

The 216-Z-9 Trench is an enclosed, underground trench (or chamber), covered by a 0.23-m-thick concrete pad. The base of the trench is 18.3 m long by 9.1 m wide by 6.1 m deep. All concrete surfaces are lined with acid-resistant brick. The 36.5- by 27.4-m concrete trench cover is supported by six 7-m-tall concrete columns (Rohay and Johnson 1991). Waste was transferred by gravity to the trench via one of two 3.8-cm stainless steel pipelines that terminated approximately 5 m above the bottom of the trench. Figure A-1 is a schematic drawing of this facility.

The 216-Z-9 Trench operated from July 1955 through June 1962 and received all the organic and aqueous wastes discharged to the soil from the Recuplex process. The 216-Z-9 Trench received no other wastes. Table A-1 provides the estimated waste discharge history, and Table A-2 provides an estimated waste constituent inventory for this facility.

216-Z-1A Tile Field

The 216-Z-1A Tile Field is similar in design to that of a common septic tank drain field. The tile field was constructed in 1949 to receive overflow liquid waste from three adjacent cribs: 216-Z-1, -2, and -3. Construction of the tile field was initiated with a 5.8-m-deep excavation, having floor dimensions of approximately 35 by 84 m (Price et al. 1979). The floor of the excavation sloped (1%) slightly to the south and was covered by a 1.2-m-thick layer of cobbles. A herringbone pattern of 20-cm-dia. vitrified clay pipe was placed on the cobble layer (Figure A-2). The piping system was then overlaid with 15 cm of cobbles and 1.5 m of sand and gravel.

Figure A-1. Map and Schematic Cross Section Through the 216-Z-9 Trench.

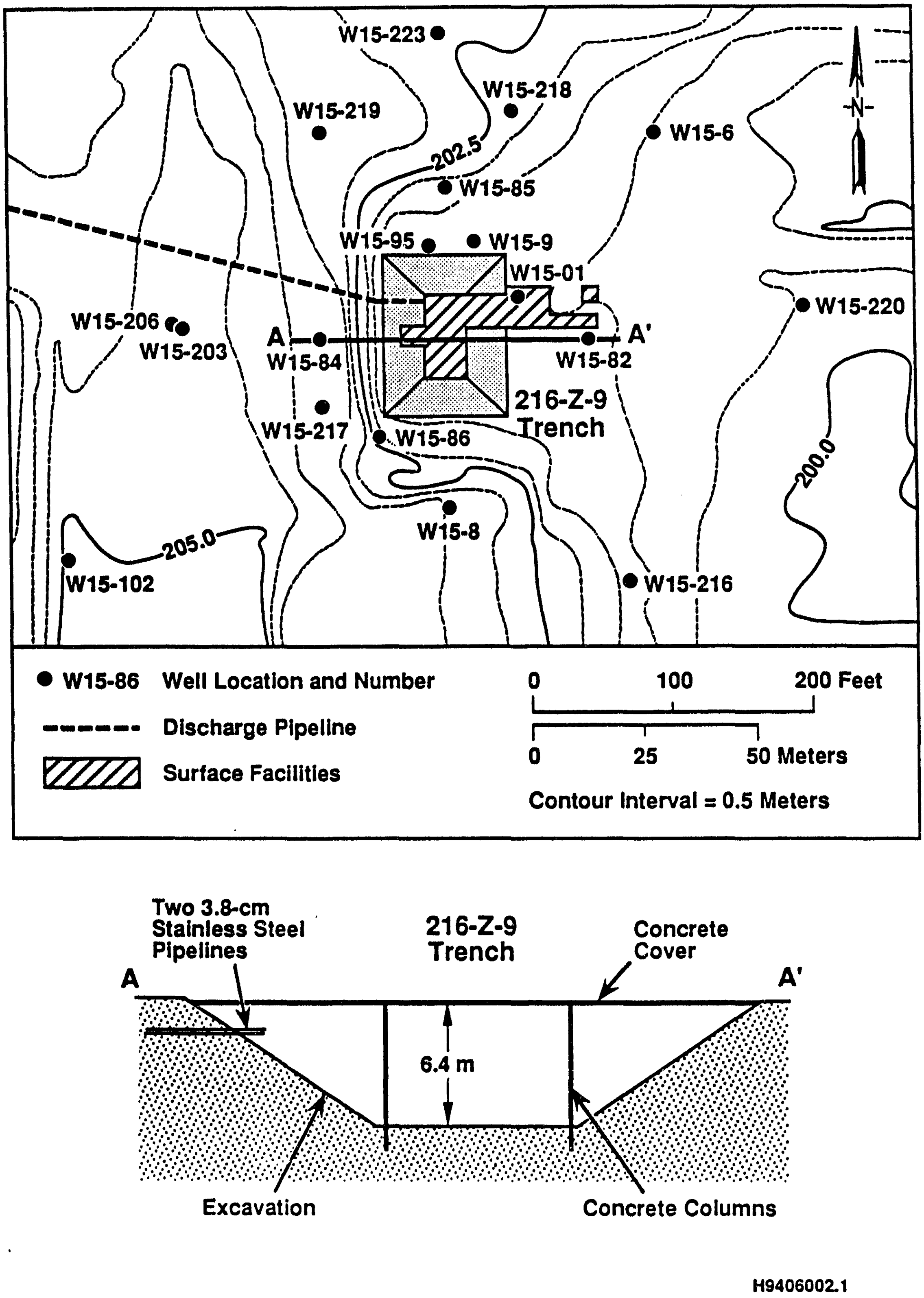


Table A-1. Estimated Waste Discharge History for the 216-Z-9 Trench.

Year	Total liquid discharged (L)	Total aqueous waste discharged (L)	Total TBP waste discharged (L)	Total DBBP waste discharged (L)	Total "lard oil" waste discharged (L)
1955	2.60E+05	2.55E+05	3.01E+03	1.51E+03	6.02E+02
1956	4.60E+05	4.14E+05	2.73E+04	1.36E+04	5.46E+03
1957	5.40E+05	4.94E+05	2.73E+04	1.36E+04	5.46E+03
1958	7.00E+05	6.55E+05	2.65E+04	1.32E+04	5.29E+03
1959	5.60E+05	5.13E+05	2.78E+04	1.39E+04	5.56E+03
1960	6.20E+05	5.72E+05	2.81E+04	1.41E+04	5.62E+03
1961	7.70E+05	7.07E+05	3.73E+04	1.86E+04	7.46E+03
1962	1.80E+05	1.65E+05	8.71E+03	4.36E+03	1.74E+03
Total	4.09E+06	3.77E+06	1.86E+05	9.30E+04	3.72E+04

Based on information from Owens (1981), DOE-RL (1992), Rohay and Johnson (1991), and Piepho et al. (1993).

Table A-2. Estimated Waste Constituent Inventory for the 216-Z-9 Trench.

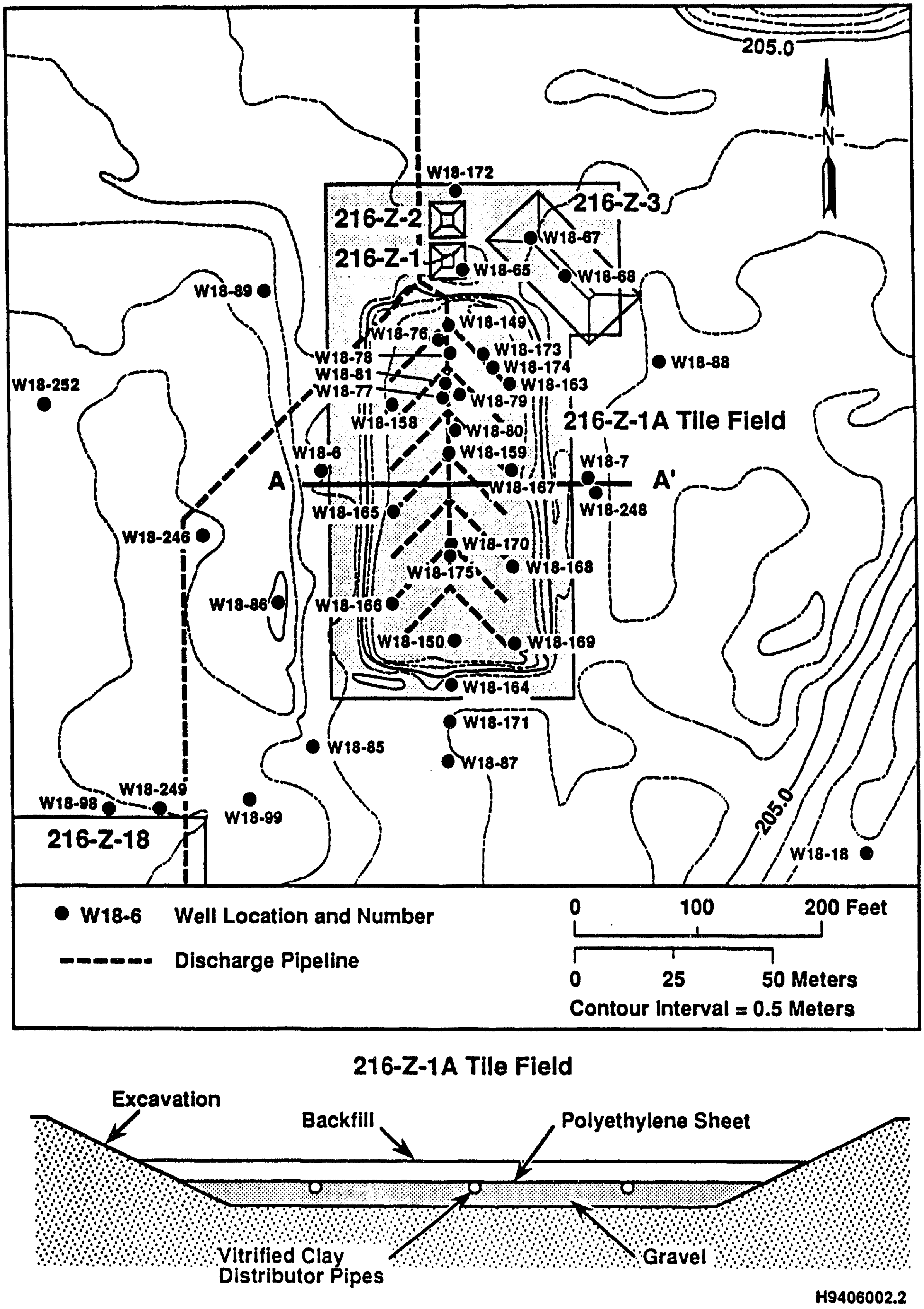
Year	Total liquid discharged (L)	Total aqueous waste discharged (L)	Total plutonium discharged (g)	Total TBP discharged (L)	Total DBBP discharged (L)	Total "lard oil" discharged (L)	Total carbon tetra-chloride discharged (L)
1955	2.60E+05	2.55E+05	6.45E+02	4.52E+02	7.53E+02	1.51E+02	3.76E+03
1956	4.60E+05	4.14E+05	2.25E+03	4.09E+03	6.82E+03	1.36E+03	3.41E+04
1957	5.40E+05	4.94E+05	5.19E+03	4.09E+03	6.82E+03	1.36E+03	3.41E+04
1958	7.00E+05	6.55E+05	7.04E+03	3.97E+03	6.62E+03	1.32E+03	3.31E+04
1959	5.60E+05	5.13E+05	5.34E+03	4.17E+03	6.96E+03	1.39E+03	3.48E+04
1960	6.20E+05	5.72E+05	5.68E+03	4.22E+03	7.03E+03	1.41E+03	3.51E+04
1961	7.70E+05	7.07E+05	8.79E+03	5.59E+03	9.32E+03	1.86E+03	4.66E+04
1962	1.80E+05	1.65E+05	3.42E+03	1.31E+03	2.18E+03	4.36E+02	1.09E+04
Total	4.09E+06	3.77E+06	3.84E+04[a]	2.79E+04	4.65E+04	9.30E+03	2.33E+05[b]

[a] 58 kg was removed in the 1976-1978 mining operation. This was 54% higher than originally estimated and led to a 54% correction factor to the inventory estimates, resulting in a total inventory estimate of 106 kg, with 48 kg still remaining (Ludowise 1978).

[b] Total carbon tetrachloride inventory estimates range from 8.3E+04 to 3.00E+05 L.

Based on information from Owens (1981), DOE-RL (1992), Rohay and Johnson (1991), and Piepho et al. (1993).

Figure A-2. Map and Schematic Cross Section Through the 216-Z-1A Tile Field.



The tile field was used in this configuration from 1949 to 1959. The waste stream discharged to the three cribs and overflowing to the tile field consisted of neutral to basic (pH 8 to 10) process waste and analytical and development laboratory waste from the Z Plant via the 241-Z-361 settling tank.

Prior to reactivation of the 216-Z-1A Tile Field in 1964, a sheet of 0.05-cm-thick polyethylene and a 30-cm-thick layer of sand and gravel were added and the liquid waste discharge piping was routed directly to its central distributor pipe. Between 1964 and 1969, a 5-cm-dia. stainless steel pipe was progressively inserted inside the central distributor pipe to divide the tile field into three operational sections (216-Z-1AA, -1AB, and -1AC). During that period, the tile field received the aqueous and organic waste from the PRF. No other waste disposal facility received PRF wastes during that period, except on two brief occasions while modifications were made to the piping system. On those two occasions, the waste was discharged to the adjacent 216-Z-1 and -2 Cribs. Table A-3 provides the estimated waste discharge history, and Table A-4 provides an estimated waste constituent inventory for the 216-Z-1A Tile Field.

216-Z-18 Crib

The 216-Z-18 Crib operated as a replacement for the 216-Z-1A Tile Field, receiving aqueous and organic wastes from the PRF between 1969 and 1973. This drain-field-type crib consists of five parallel trenches, each 63 m long by 3 m wide and ranging from 4.5 to 5.5 m deep (Figure A-3). The floor of each trench was covered with approximately 0.3 m of gravel. Two parallel, 7.6-cm-dia., fiberglass-reinforced epoxy distributor pipes were placed on the gravel layer within each trench. A central pipe, consisting of a 7.6-cm-dia. steel pipe, connects each trench. Another layer of approximately 0.3 m of gravel was placed over the distributor pipes in each trench. The gravel was covered by a membrane barrier (polyethylene) that was then covered with approximately 15 cm of sand and backfilled to grade. The westernmost trench never received any waste (Owens 1991). Table A-5 provides the estimated waste discharge history, and Table A-6 provides an estimated waste constituent inventory for the 216-Z-18 Crib.

Table A-3. Estimated Waste Discharge History for the 216-Z-1A Tile Field.

Year	Total liquid discharged (L)	Total aqueous waste discharged (L)	Total TBP waste discharged (L)	Total DBBP waste discharged (L)	Total "lard oil" waste discharged (L)
1949	6.00E+04	6.00E+04	NR	NR	NR
1950	1.00E+05	1.00E+05	NR	NR	NR
1951	1.00E+05	1.00E+05	NR	NR	NR
1952	1.00E+05	1.00E+05	NR	NR	NR
1953	1.00E+05	1.00E+05	NR	NR	NR
1954	1.00E+05	1.00E+05	NR	NR	NR
1955	1.00E+05	1.00E+05	NR	NR	NR
1956	1.00E+05	1.00E+05	NR	NR	NR
1957	1.00E+05	1.00E+05	NR	NR	NR
1958	1.00E+05	1.00E+05	NR	NR	NR
1959	4.00E+04	4.00E+04	NR	NR	NR
1960	Inactive	--	--	--	--
1961	Inactive	--	--	--	--
1962	Inactive	--	--	--	--
1963	Inactive	--	--	--	--
1964	4.40E+05	4.20E+05	1.01E+04	7.75E+03	1.86E+03
1965	9.20E+05	8.79E+05	2.11E+04	1.62E+04	3.89E+03
1966	1.50E+06	1.43E+06	3.45E+04	2.64E+04	6.34E+03
1967	1.19E+06	1.14E+06	2.74E+04	2.10E+04	5.04E +03
1968	1.00E+06	9.55E+05	2.30E+04	1.76E+04	4.22E+03
1969	1.55E+05	1.48E+05	3.56E+03	2.73E+03	6.55E+02
Total	6.21E+06	5.97E+06	1.20E+05	9.18E+04	2.20E+04

NR = Not reported.

Based on information from Owens (1981), DOE-RL (1992), Rohay and Johnson (1991), and Piepho et al. (1993).

Table A-4. Estimated Waste Constituent Inventory for the 216-Z-1A Tile Field.

Year	Total liquid discharged (L)	Total plutonium discharged (L)	Total TBP discharged (L)	Total DBBP discharged (L)	Total "lard oil" discharged (L)	Total carbon tetra-chloride discharged (L)
1949	6.00E+04	3.00E+00	NR	NR	NR	NR
1950	1.00E+05	5.00E+00	NR	NR	NR	NR
1951	1.00E+05	5.00E+00	NR	NR	NR	NR
1952	1.00E+05	5.00E+00	NR	NR	NR	NR
1953	1.00E+05	5.00E+00	NR	NR	NR	NR
1954	1.00E+05	5.00E+00	NR	NR	NR	NR
1955	1.00E+05	5.00E+00	NR	NR	NR	NR
1956	1.00E+05	5.00E+00	NR	NR	NR	NR
1957	1.00E+05	5.00E+00	NR	NR	NR	NR
1958	1.00E+05	5.00E+00	NR	NR	NR	NR
1959	4.00E+04	2.00E+00	NR	NR	NR	NR
1960	Inactive	--	--	--	--	--
1961	Inactive	--	--	--	--	--
1962	Inactive	--	--	--	--	--
1963	Inactive	--	--	--	--	--
1964	4.40E+05	1.43E+04	2.02E+03	2.33E+03	9.29E+02	1.44E+04
1965	9.20E+05	1.10E+04	4.23E+03	4.86E+03	1.94E+03	3.02E+04
1966	1.50E+06	1.66E+04	6.90E+03	7.93E+03	3.17E+03	4.93E+04
1967	1.19E+06	6.99E+03	5.48E+03	6.31E+03	2.52E+03	3.92E+04
1968	1.00E+06	7.60E+03	4.60E+03	5.29E+03	2.11E+03	3.28E+04
1969	1.55E+05	8.16E+02	7.13E+02	8.19E+02	3.27E+02	5.09E+03
Total	6.21E+06	5.74E+04	2.39E+04	2.75E+04	1.10E+04	1.71E+05

NR = Not reported.

Based on information from Owens (1981), DOE-RL (1992), Rohay and Johnson (1991), and Piepho et al. (1993).

Figure A-3. Map and Schematic Cross Section Through the 216-Z-18 Crib.

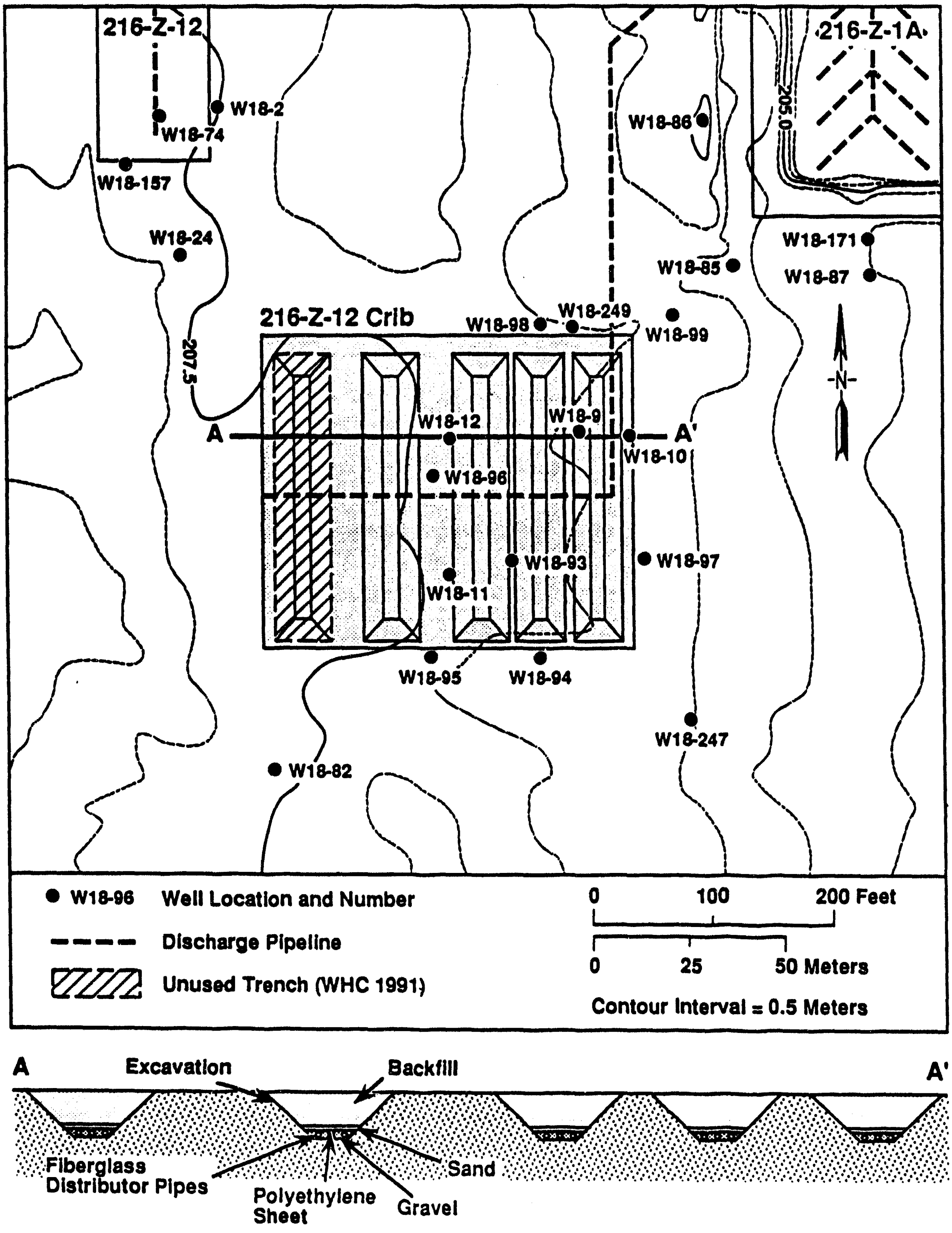


Table A-5. Estimated Waste Discharge History for the 216-Z-18 Crib.

Year	Total liquid discharged (L)	Total aqueous waste discharged (L)	Total TBP waste discharged (L)	Total DBBP waste discharged (L)	Total "lard oil" waste discharged (L)
1969	5.72E+05	5.50E+05	1.21E+04	9.44E+03	NR
1970	7.99E+05	7.69E+05	1.69E+04	1.32E+04	NR
1971	8.84E+05	8.51E+05	1.87E+04	1.46E+04	NR
1972	1.24E+06	1.19E+06	2.63E+04	2.05E+04	NR
1973	3.66E+05	3.52E+05	7.75E+03	6.04E+03	NR
Total	3.86E+06	3.72E+06	8.18E+04	6.37E+04	NR

NR = Not reported.

Based on information from Owens (1981), DOE-RL (1992), Rohay and Johnson (1991), and Piepho et al. (1993).

Table A-6. Estimated Waste Constituent Inventory for the 216-Z-18 Crib.

Year	Total liquid discharged (L)	Total plutonium discharged (g)	Total TBP discharged (L)	Total DBBP discharged (L)	Total "lard oil" discharged (L)	Total carbon tetrachloride discharged (L)
1969	5.72E+05	4.27E+03	2.42E+03	2.83E+03	NR	1.63E+04
1970	7.99E+05	5.01E+03	3.38E+03	3.96E+03	NR	2.28E+04
1971	8.84E+05	5.53E+03	3.74E+03	4.38E+03	NR	2.52E+04
1972	1.24E+06	6.87E+03	5.25E+03	6.14E+03	NR	3.53E+04
1973	3.66E+05	1.27E+03	1.55E+03	1.81E+03	NR	1.04E+04
Total	3.86E+06	2.30E+04	1.64E+04	1.91E+04	NR	1.10E+05

NR = Not reported.

Based on information from Owens (1981), DOE-RL (1992), Rohay and Johnson (1991), and Piepho et al. (1993).

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APPENDIX B

GEOLOGY OF THE ERA/VOC-ARID ID SITE: 1994 UPDATE

APPENDIX B
GEOLOGY OF THE ERA/VOC-ARID ID SITE: 1994 UPDATE

This appendix provides a detailed description of the lithology (i.e., composition, grain size, sorting, porosity, cementation) and stratigraphic relationships between geologic units beneath the Carbon Tetrachloride Expedited Response Action/Volatile Organic Compound - Arid Integrated Demonstration (ERA/VOC-Arid ID) site. These refined interpretations are based on evaluation of the following types of data: (1) driller's logs, (2) particle-size analyses, (3) calcium carbonate ($CaCO_3$) analyses, (4) moisture-content analyses, (5) geologist's logs, and (6) gross gamma logs. These data were evaluated in accordance with characteristics identified by Bjornstad (1985) and DOE (1988) and to distinguish between primary geologic units. Interpretations and nomenclature were based on those by WHC (1991, 1992); Rohay et al. (1993); and Singleton and Lindsey (1994). The quality and quantity of borehole data vary greatly from borehole to borehole and are subject to multiple interpretations. In addition, many of the boreholes have not been accurately surveyed, so elevation of the various geologic contacts may be off a few meters.

The subsurface geology of the ERA/VOC-Arid ID site consists of a thick accumulation (>150 m) of clastic sedimentary deposits overlying bedrock of the Miocene Columbia River Basalt Group. These suprabasalt sediments include lithologic units assigned to the late Miocene to Pliocene Ringold Formation, the Plio-Pleistocene unit, and the Pleistocene Hanford formation (informal name). A thin veneer of Holocene eolian sand locally overlies the Hanford formation. Figure B-1 illustrates the general stratigraphy and nomenclature for the units beneath the site. Each of these principal geologic units is described below. The estimated elevation of the interpreted geologic contacts used throughout this appendix are provided in Table B-1. Figure B-2 is the location map of wells used at the ERA/VOC-Arid ID site, and Figures B-3 through B-6 give the detailed cross sections through the site.

ELEPHANT MOUNTAIN MEMBER

The Columbia River Basalt Group (Swanson et al. 1979) forms the bedrock beneath the site and contains the regionally extensive confined aquifer system. The Elephant Mountain Member of the Saddle Mountains Basalt is the uppermost unit in the ERA/VOC-Arid ID area and is continuous beneath the site. Hydrologically, the Elephant Mountain Member acts as an aquiclude, confining the Rattlesnake Ridge aquifer beneath it and forming the base of the unconfined, suprabasalt aquifer system. The surface of this unit dips gently to the southwest toward the axis of the Cold Creek syncline (Figure B-7).

Figure B-1. Generalized Stratigraphy and Nomenclature of the ERA/VOC-Arid ID Site.

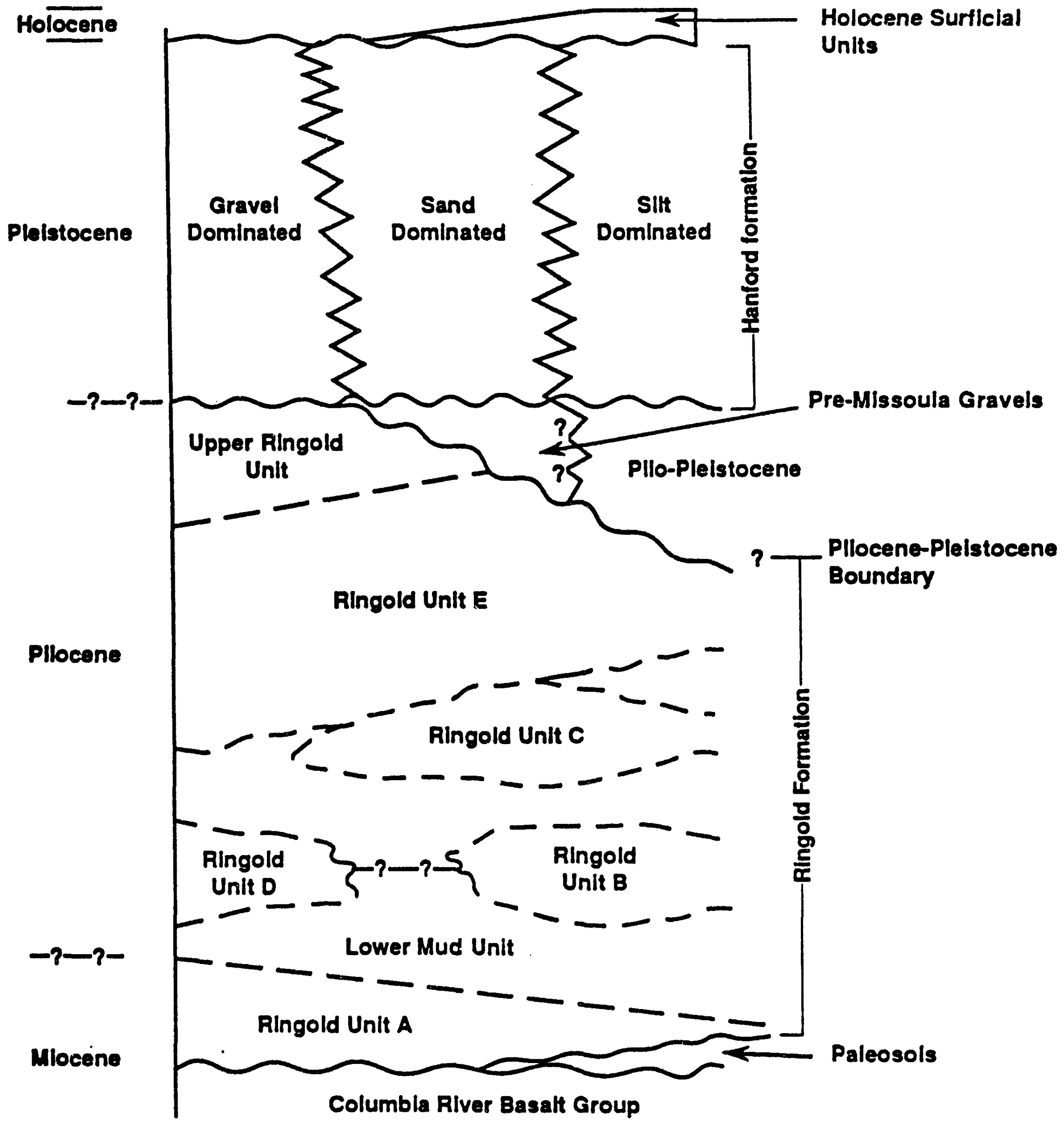

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Table B-1. Elevation of Geologic Contacts in the Vicinity of the ERA/VOC-Arid ID Site. (sheet 1 of 3)

Well Number	Plant Coordinates		Ground Elevation	Drill Depth	Holocene		Hanford					Plio-Pleis	Ringold Formation				SM Basalt
	North	West			Backfill	Sand	Upper Fine	Upper Coarse	Fine	Lower Coarse	Lower Fine		Upper Unit	Unit E	Lower Mud	Unit A	E. M. Basalt
299-W14-5	41269'	75441'	664	240	664	NP	NP	652	638	NP	NP	587	NP	547	ETD	-	-
299-W14-6	41469'	75441'	665	240	NP	665	NP	648	612	NP	NP	566	NP	543	ETD	-	-
299-W14-7	40003'	40003'	677	531	NP	677	NP	672	587	NP	NP	558	NP	547	253	214	159
299-W15-1	40962'	76576'	670	300	NP	670	NP	665	640	597	565	550	538	495	ETD	-	-
299-W15-4	41200'	75700'	660	217	NP	NP	NP	660	620	NP	NP	540	NP	537	ETD	-	-
299-W15-5	39537'	75984'	668	599	NP	668	NP	651	609	NP	NP	548	NP	531	241	187	141
299-W15-6	40005'	75765'	659	410	NP	659	NP	650	620	NP	NP	551	530	510	ETD	-	-
299-W15-7	40880'	76180'	661	350	661	NP	NP	656	606	NP	NP	556	NP	NP	537	ETD	-
299-W15-9	39930'	75890'	660	195	NP	660	NP	640	618	NP	NP	553	NP	535	ETD	-	-
299-W15-10	41080'	76920'	673	300	NP	NP	NP	673	648	573	NP	543	NP	523	ETD	-	-
299-W15-11	41041'	77771'	674	300	NP	NP	NP	674	649	599	NP	547	NP	527	ETD	-	-
299-W15-14	39990'	78089'	695	581	NP	695	NP	693	593	NP	NP	540	528	517	240	219	194
299-W15-16	40269'	77387'	682	243.5	682	NP	NP	672	647	607	NP	542	517	507	ETD	-	-
299-W15-17	40221'	77387'	683	450	NP	NP	NP	683	650	602	NP	547	512	507	247	ETD	-
299-W15-18	39705'	77383'	684	242	NP	NP	684	664	648	582	NP	553	535	513	ETD	-	-
299-W15-20	41028'	78120'	695	245	NP	695	NP	685	618	575	565	558	NP	519	ETD	-	-
299-W15-23	40680'	78119'	696	240	NP	696	NP	680	599	NP	NP	545	525	510	ETD	-	-
299-W15-216	39698'	75793'	661	210	661	660	NP	647	615	NP	NP	552	NP	541	ETD	-	-
299-W15-217	39811'	75998'	669	123.4	NP	669	NP	651	616	NP	NP	555	ETD	-	-	-	-
299-W15-218	40027'	75866'	665	206.1	665	659	NP	651	610	NP	NP	558	NP	545	ETD	-	-

NP = Not Present E. M. = Elephant Mountain ETD = Exceeds Total Depth Elevation in Feet Above Mean Sea Level

Table B-1. Elevation of Geologic Contacts in the Vicinity of the ERA/VOC-Arid ID Site. (sheet 2 of 3)

Well Number	Plant Coordinates		Ground Eleva-tion	Drill Depth	Holocene		Hanford					Plio-Pleis	Ringold Formation				SM Basalt
	North	West			Backfill	Sand	Upper Fine	Upper Coarse	Fine	Lower Coarse	Lower Fine		Upper Unit	Unit E	Lower Mud	Unit A	E. M. Basalt
299-W15-219	40004'	76004'	668	212	668	662	NP	655	623	NP	NP	554	NP	547	ETD	-	-
299-W15-220	39886'	75657'	657	201	657	651	NP	647	613	NP	NP	554	NP	543	ETD	-	-
299-W15-223	40081'	75917'	666	119	666	665	NP	646	614	NP	NP	556	NP	ETD	-	-	-
299-W18-1	39388'	77013'	677	427	NP	NP	677	647	637	577	NP	558	531	511	ETD	-	-
299-W18-6	39212'	76706'	676	300	NP	NP	676	661	611	586	NP	555	NP	534	ETD	-	-
299-W18-7	39204'	76491'	677	300	NP	NP	677	666	622	590	NP	555	NP	539	ETD	-	-
299-W18-9	38852'	76846'	680	220	NP	NP	680	649	623	574	NP	549	NP	523	ETD	-	-
299-W18-10	38847'	76803'	680	220	NP	NP	680	646	621	581	NP	546	NP	521	ETD	-	-
299-W18-11	38735'	76955'	680	220	NP	NP	680	646	626	571	NP	546	NP	521	ETD	-	-
299-W18-15	36990'	77152'	660	248	NP	NP	660	650	625	550	NP	541	NP	498	ETD	-	-
299-W18-18	38903'	76270'	668	265	NP	NP	NP	668	596	NP	NP	538	NP	523	ETD	-	-
299-W18-19	38503'	76403'	670	250	NP	670	NP	663	629	578	NP	568	NP	529	ETD	-	-
299-W18-20	38103'	76477'	667	250	NP	667	NP	662	635	596	575	559	NP	536	ETD	-	-
299-W18-22	37831'	78109'	666	455	NP	NP	666	646	591	NP	NP	536	NP	521	281	ETD	-
299-W18-23	38987'	78120'	695	255	NP	NP	695	645	590	NP	NP	550	NP	515	ETD	-	-
299-W18-24	38998'	77180'	682	240	NP	NP	682	647	602	571	NP	552	527	517	ETD	-	-
299-W18-26	39477'	78097'	696	249.9	NP	NP	696	680	590	NP	NP	548	520	510	ETD	-	-
299-W18-27	38607'	78103'	687	238.5	NP	NP	687	624	586	NP	NP	546	NP	531	ETD	-	-
299-W18-28	38214'	78096'	677	229.7	NP	NP	677	628	605	NP	NP	540	NP	522	ETD	-	-
299-W18-29	37952'	76560'	671	150	NP	671	NP	663	570	NP	NP	543	NP	523	ETD	-	-

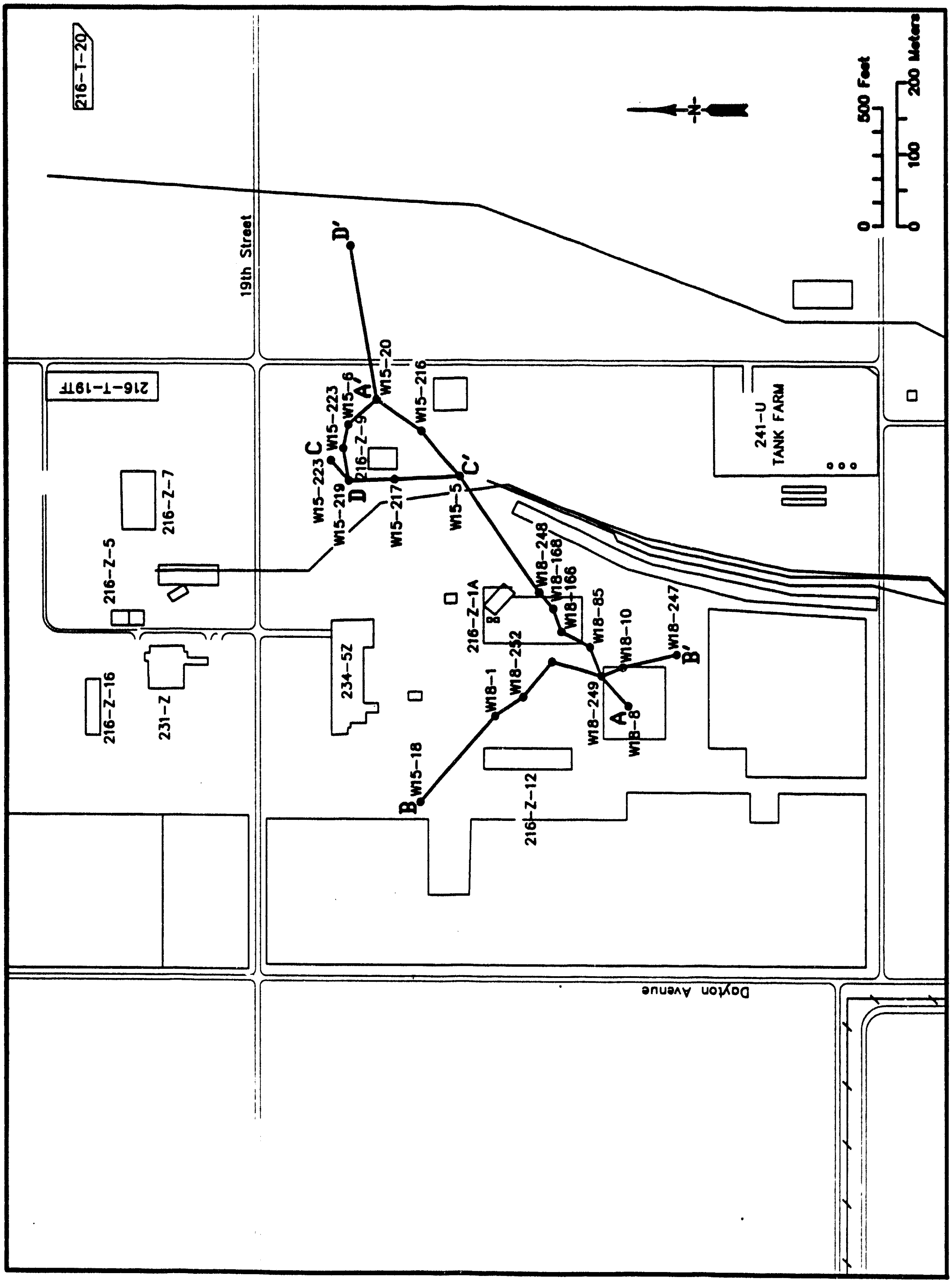
NP = Not Present E. M. = Elephant Mountain ETD = Exceeds Total Depth Elevation in Feet Above Mean Sea Level

Table B-1. Elevation of Geologic Contacts in the Vicinity of the ERA/VOC-Arid ID Site. (sheet 3 of 3)

Well Number	Plant Coordinates		Ground Eleva-tion	Drill Depth	Holocene		Hanford					Plio-Pleis	Ringold Formation				SM Basalt
	North	West			Backfill	Sand	Upper Fine	Upper Coarse	Fine	Lower Coarse	Lower Fine		Upper Unit	Unit E	Lower Mud	Unit A	E. M. Basalt
299-W18-30	38493'	75541'	669	235.3	NP	NP	NP	669	609	NP	NP	546	NP	529	ETD	-	-
299-W18-31	38105'	76032'	661	227.6	NP	NP	NP	661	636	NP	NP	543	NP	521	ETD	-	-
299-W18-32	37780'	76709'	674	225	NP	NP	NP	674	632	577	567	556	NP	523	ETD	-	-
299-W18-33	37238'	76029'	666	231.5	NP	666	NP	659	609	NP	NP	541	NP	514	ETD	-	-
299-W18-85	38989'	76717'	677	150	NP	677	673	655	625	576	NP	528	ETD	-	-	-	-
299-W18-86	39106'	76742'	680	150	NP	680	NP	567	622	577	NP	542	ETD	-	-	-	-
299-W18-96	38825'	76970'	682	149.2	682	NP	NP	670	629	565	554	551	NP	ETD	-	-	-
299-W18-166	39108'	76650'	668	137	668	NP	654	634	624	562	552	544	NP	ETD	-	-	-
299-W18-167	39214'	76552'	666	134	666	NP	NP	649	625	577	567	548	NP	ETD	-	-	-
299-W18-168	39043'	76552'	666	131	666	NP	657	633	624	567	566	547	NP	ETD	-	-	-
299-W18-174	39296'	76565'	670	131.5	670	NP	NP	656	623	585	557	550	NP	ETD	-	-	-
299-W18-175	39117'	76600'	670	130	670	NP	644	634	621	584	582	544	NP	ETD	-	-	-
299-W18-246	39149'	76779'	681	230	681	NP	NP	668	627	576	NP	547	NP	534	ETD	-	-
299-W18-247	38621'	76747'	678	227.2	678	NP	NP	675	624	563	555	547	NP	524	ETD	-	-
299-W18-248	39202'	76482'	676	141	676	667	NP	664	632	590	575	550	ETD	ETD	-	-	-
299-W18-249	38940'	76841'	680	146.7	NP	680	NP	674	622	576	553	549	ETD	ETD	-	-	-
299-W18-252	39269'	76931'	680	228	680	NP	NP	679	629	579	NP	555	NP	540	ETD	-	-
299-W19-12	38052'	75456'	672	300	NP	672	NP	668	597	NP	NP	532	NP	512	ETD	-	-

NP = Not Present E. M. = Elephant Mountain ETD = Exceeds Total Depth Elevation in Feet Above Mean Sea Level

Figure B-2. Location of Cross Sections Within the ERA/VOC-Arid ID Site.



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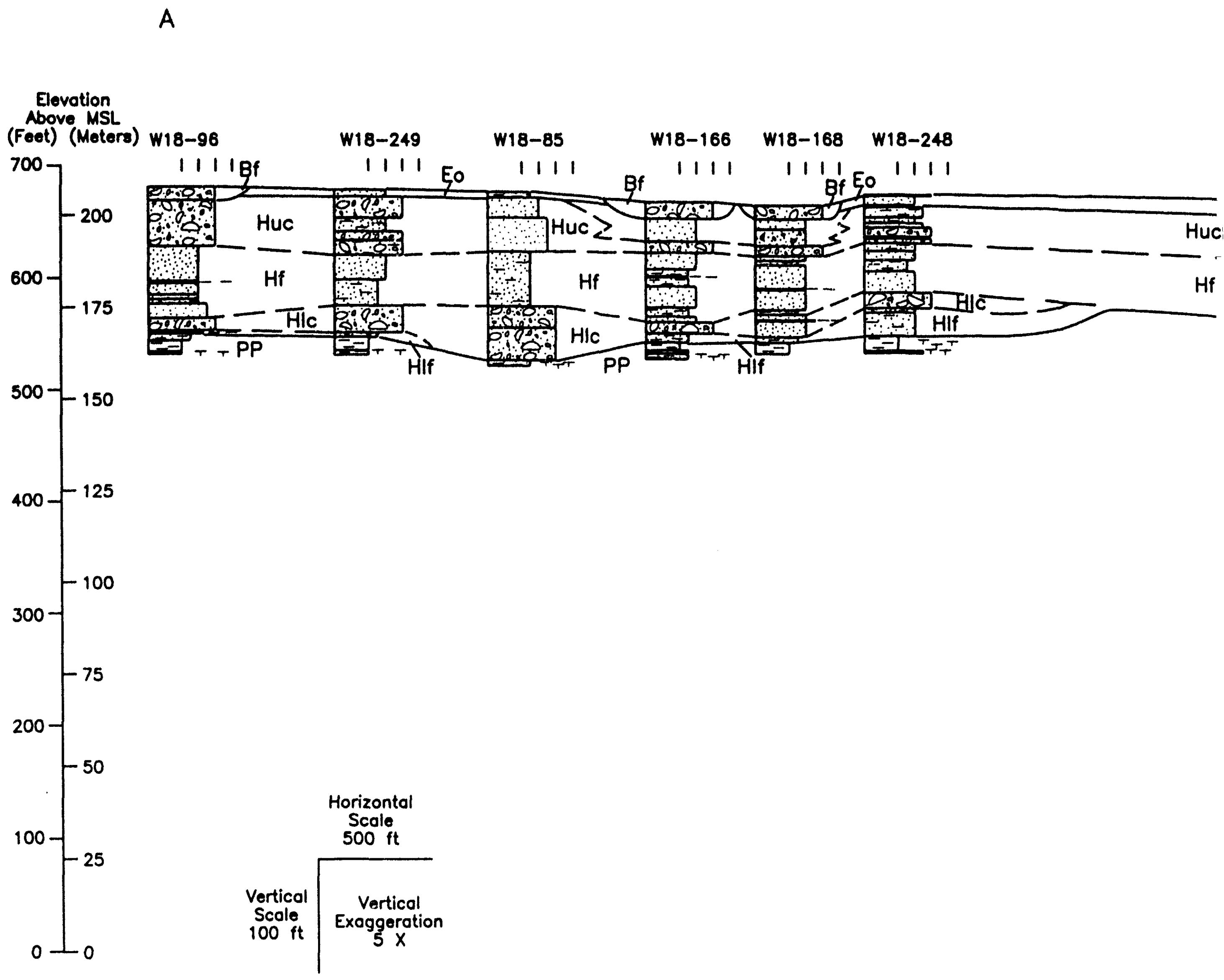


A
Elevation Above MSL
(Feet) (Meters)
700
600
500
400
300
200
100
0
200
175
150
125
100
75
50
25
0
W18-96
W18-249
W18-85
W18-166
W18-168
W18-248
Bf
Eo
Bf
Bf
Eo
Huc
Huc
Huc
Hf
Hf
Hf
Hlc
Hlc
Hlc
Hlf
Hlf
Hlf
PP
PP
Horizontal Scale 500 ft
Vertical Scale 100 ft
Vertical Exaggeration 5 X

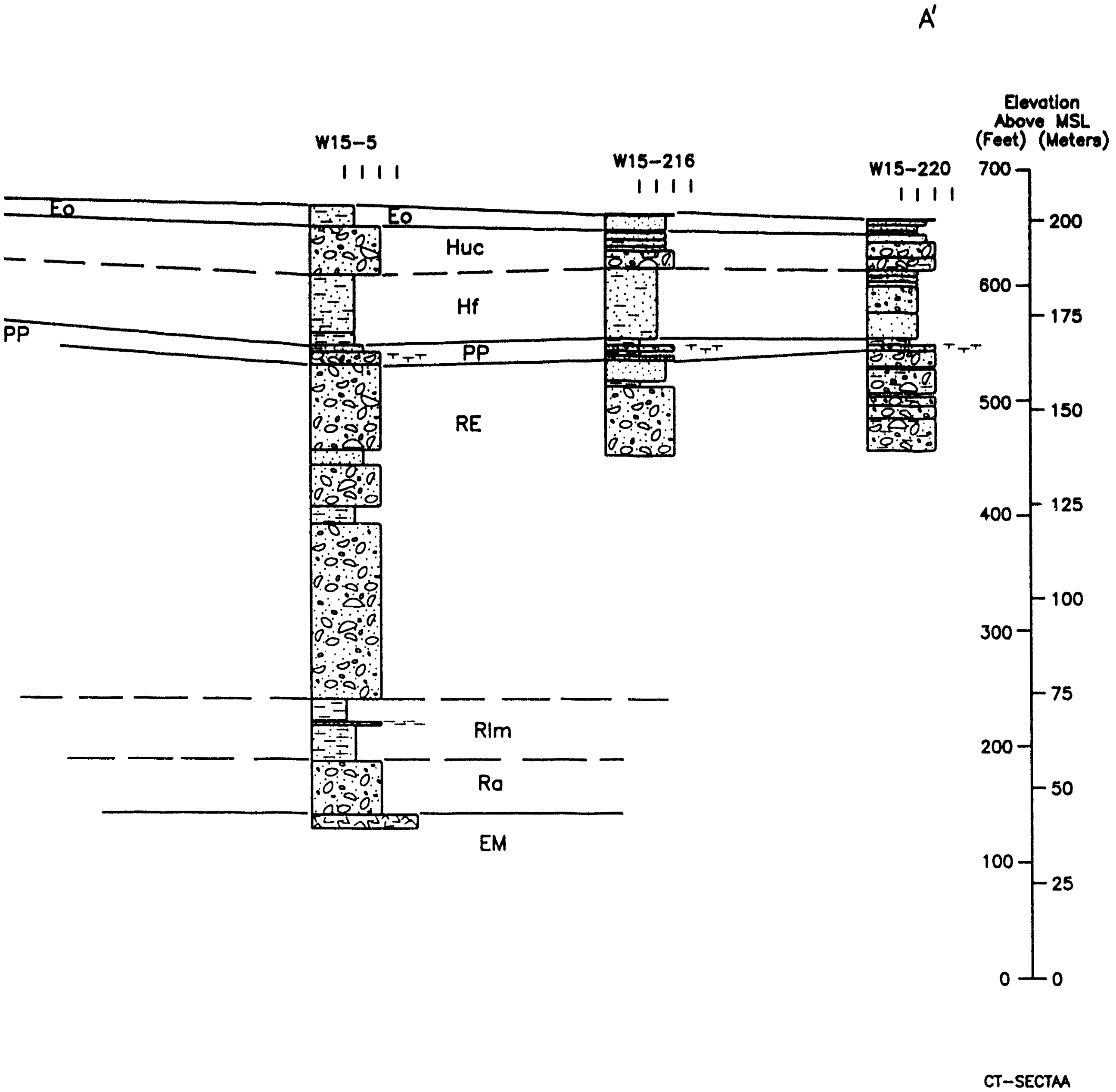
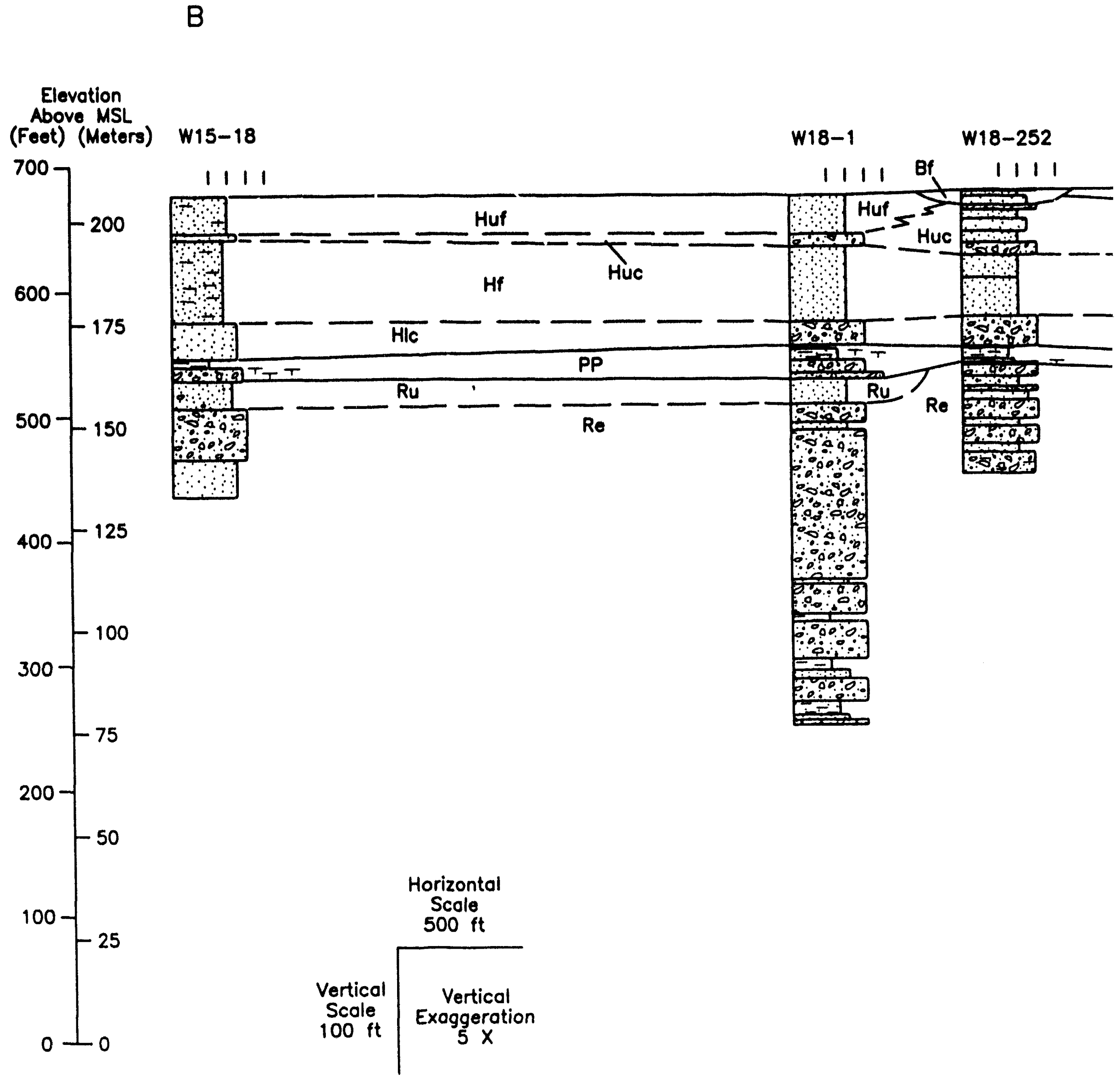


Figure B-3. Geologic Cross Section A-A'.


B
Elevation
Above MSL
(Feet) (Meters)
W15-18
W18-1
W18-252
700
200
600
175
500
150
400
125
100
300
75
200
50
100
25
0
0
Bf
Huf
Huc
Hf
Hlc
PP
Ru
Re
Horizontal
Scale
500 ft
Vertical
Scale
100 ft
Vertical
Exaggeration
5 X

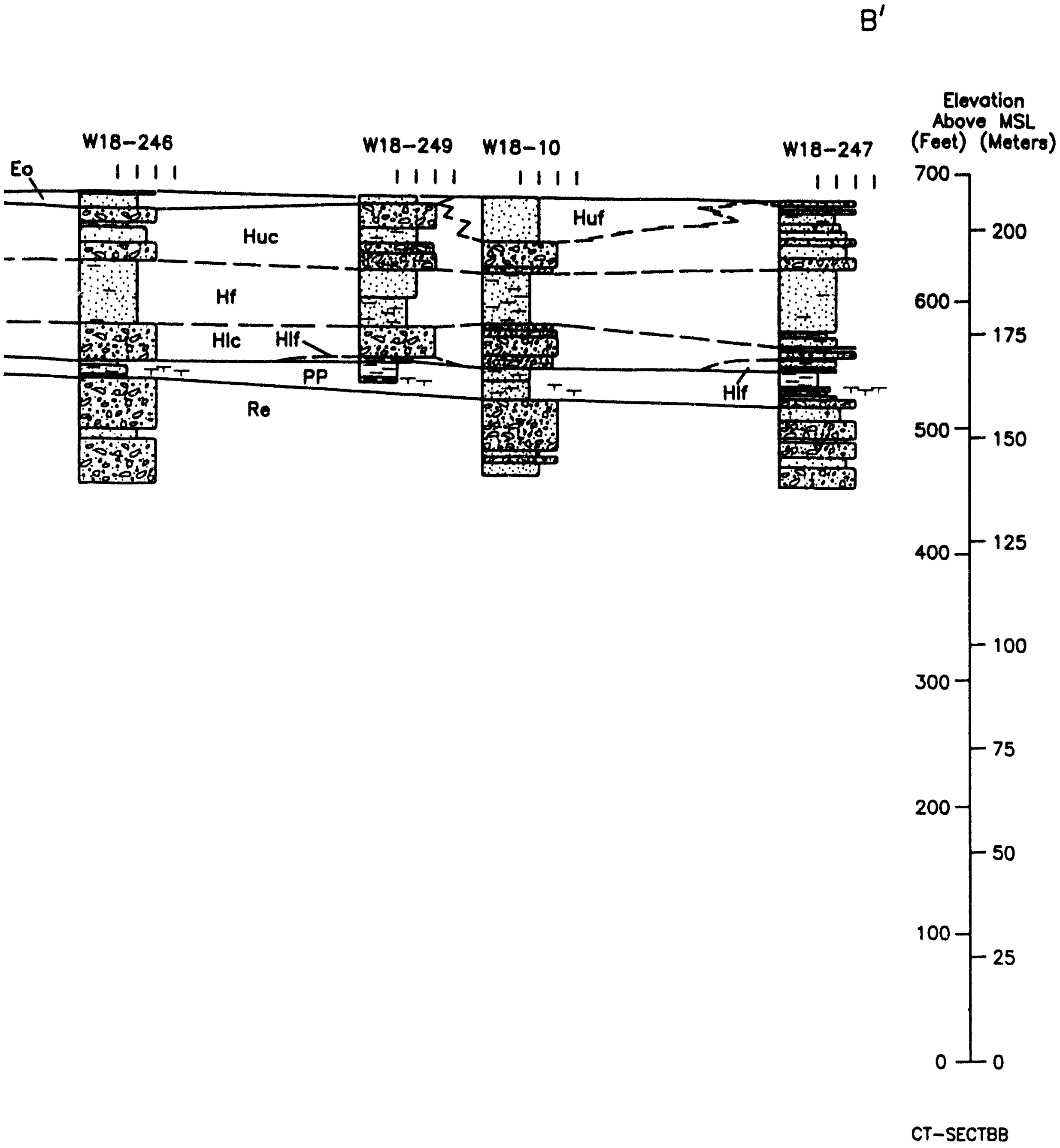


Figure B-4. Geologic Cross Section B-B'.

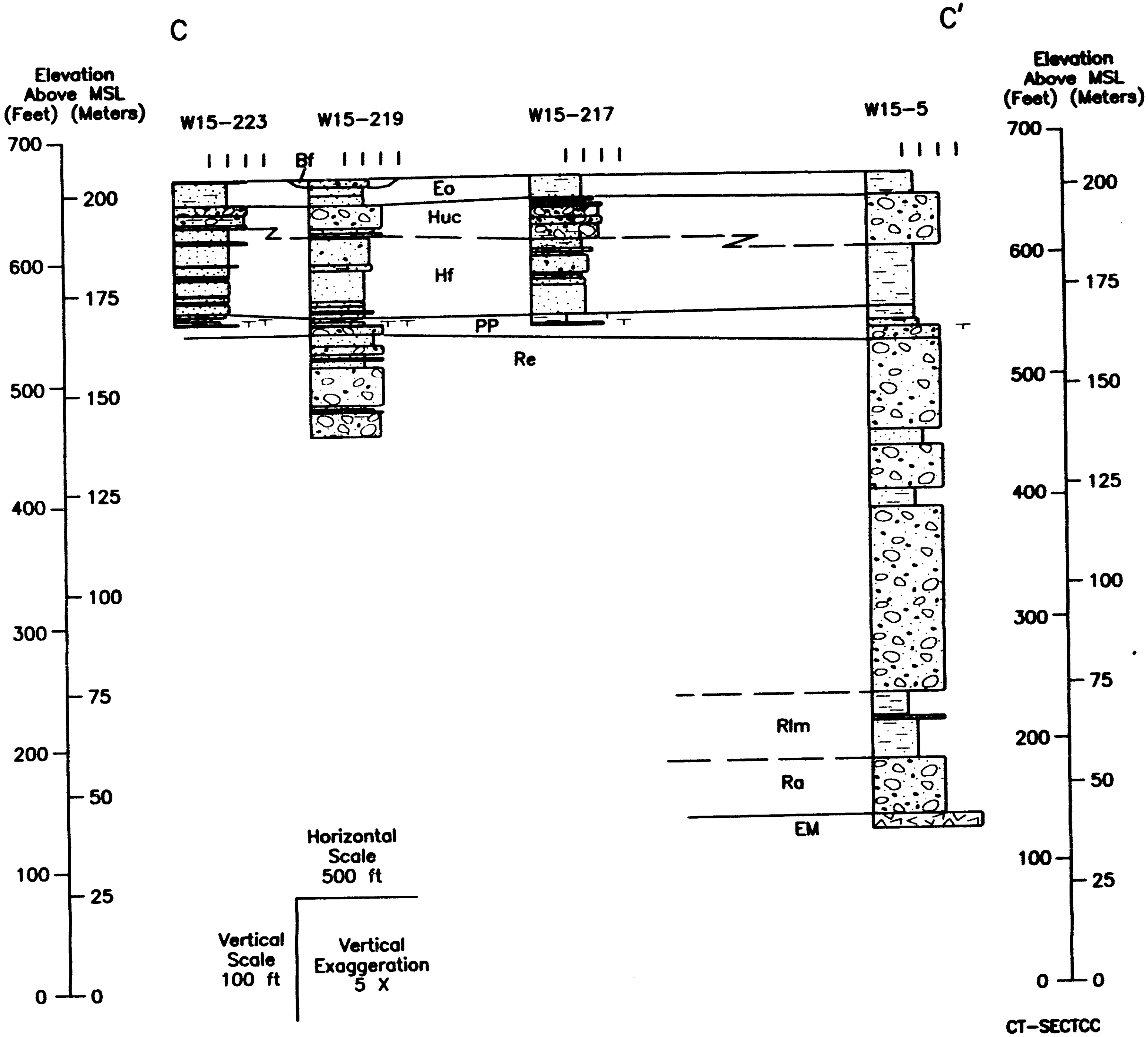
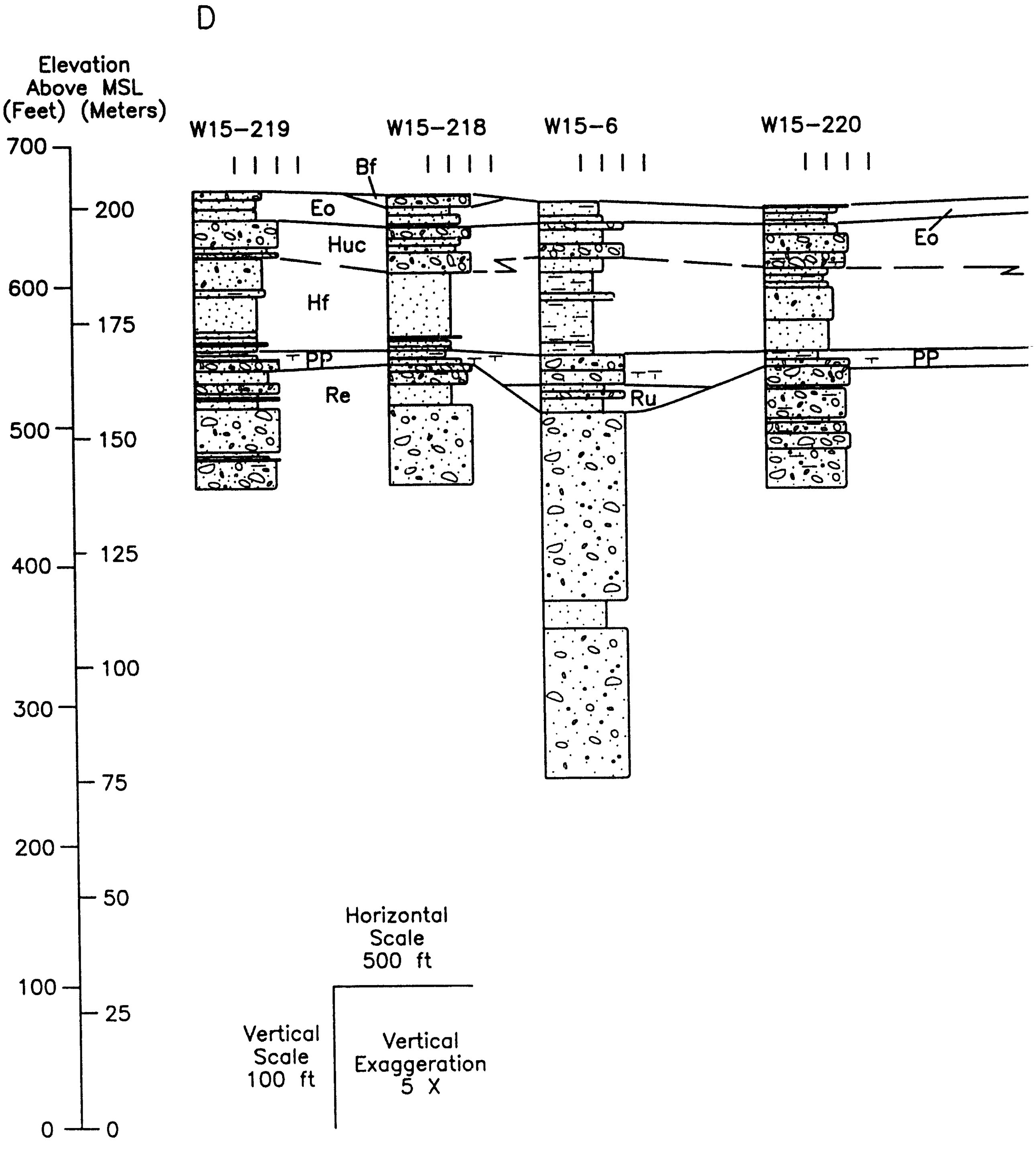


Figure B-5. Geologic Cross Section C-C'.


D
Elevation
Above MSL
(Feet) (Meters)
700
600
500
400
300
200
100
0
200
175
150
125
100
75
50
25
0
W15-219
W15-218
W15-6
W15-220
Bf
Eo
Huc
Hf
PP
Re
Ru
Eo
PP
Horizontal
Scale
500 ft
Vertical
Scale
100 ft
Vertical
Exaggeration
5 X

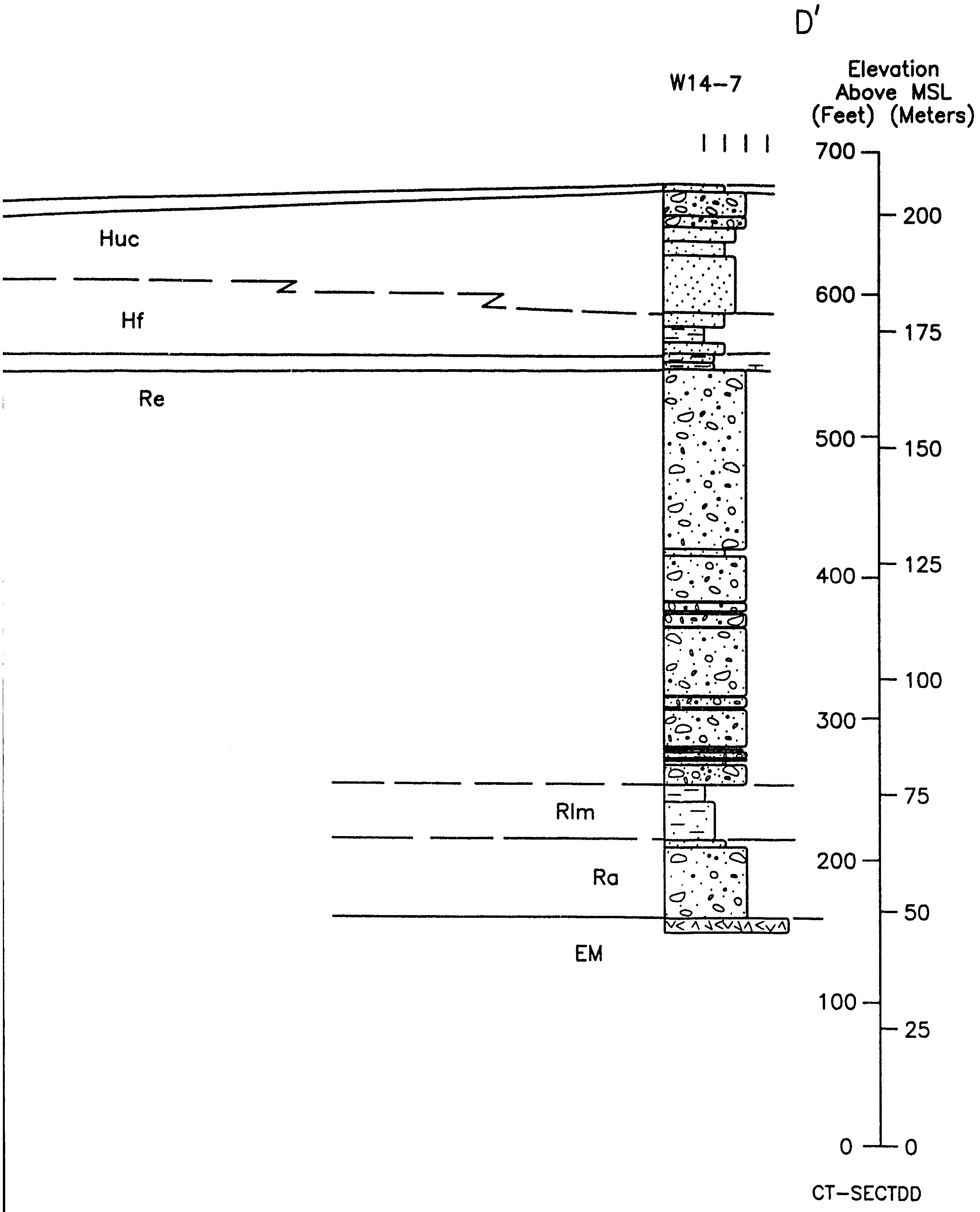
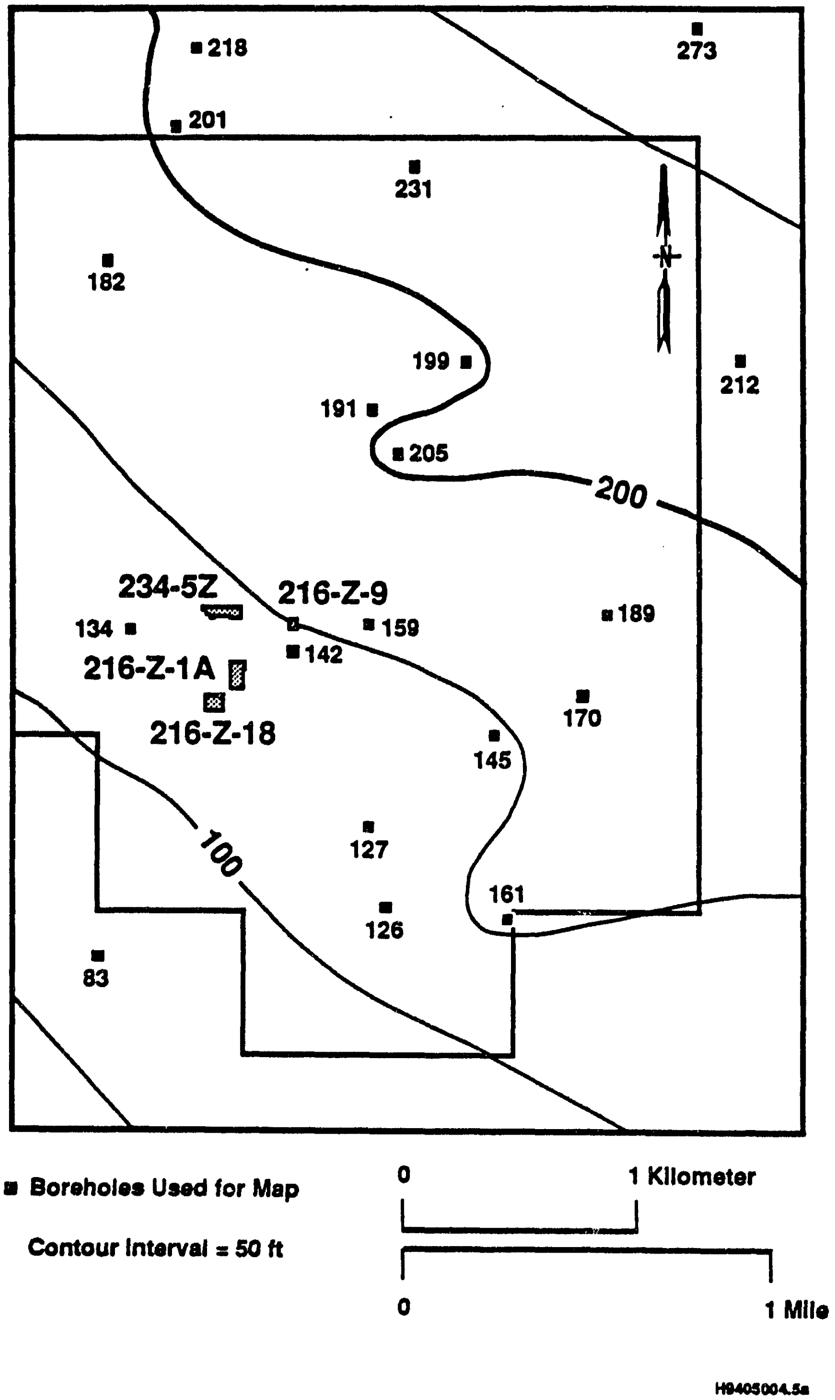


Figure B-6. Geologic Cross Section D-D'.

Figure B-7. Structure-Contour Map of the Elephant Mountain Member Beneath the ERA/VOC-Arid ID Site (contours extrapolated from data outside study area).



RINGOLD FORMATION

The Ringold Formation consists of semi-indurated clay, silt, fine to coarse sand, and pebble to cobble gravel. Ringold deposits are grouped into five facies (fluvial gravel, fluvial sand, overbank-paleosol, lacustrine, basaltic alluvium) that are defined based on lithology, petrology, stratification, and pedogenic alteration. The facies are summarized as follows:

(1) Fluvial gravel -- Consists of clast- and lesser matrix-supported pebble to cobble gravel with a fine- to medium-grained sand matrix. Grain size distributions tend to be bimodal with granules and coarse-grained sand being rare. Crude to well-defined stratification and low angle, lenticular bedding geometries generally dominate.

(2) Fluvial sand -- Fine- to coarse-grained quartzo-feldspathic sands displaying well-defined stratification dominate. Fining upward sequences from less than one to several meters thick are common.

(3) Overbank-Paleosol -- Laminated to massive silty sand, silt, and clay displaying evidence of pedogenic alteration dominate.

(4) Lacustrine -- Characterized by well-stratified clay with interbedded silt and silty sand.

(5) Basaltic alluvium -- Massive to crudely stratified, weathered to unweathered, basaltic, pebble to cobble gravel, commonly with a mud-rich matrix dominates.

The distribution of facies within the Ringold Formation forms the basis for stratigraphic subdivision (Lindsey 1991). The lower half of the Ringold Formation, which underlies the Hanford Site, is characterized by fluvial gravel- and fluvial sand-dominated intervals, designated units A, B, C, D, and E, that interfinger with fine-grained deposits typical of the overbank-paleosol and lacustrine facies (Figure B-1). The lowest of these fine-grained intervals is designated the lower mud unit. Interstratified deposits of the fluvial sand and overbank-paleosol facies and strata dominated by the lacustrine facies form the upper half of the Ringold Formation (commonly referred to as the upper unit), which are primarily exposed throughout the White Bluffs along the Colmbia River. The 200 Areas are underlain by a combination of unit A (Figures B-8 and B-9), the lower mud (Figures B-10 and B-11), unit E (Figure B-12), and the upper unit (Figures B-13 and B-14). The upper unit pinches out beneath the ERA/VOC-Arid ID site (Figures B-8 and B-9).

Figure B-8. Structure-Contour Map of the Ringold Formation Unit A Beneath the ERA/VOC-Arid ID Site (contours extrapolated from data outside study area).

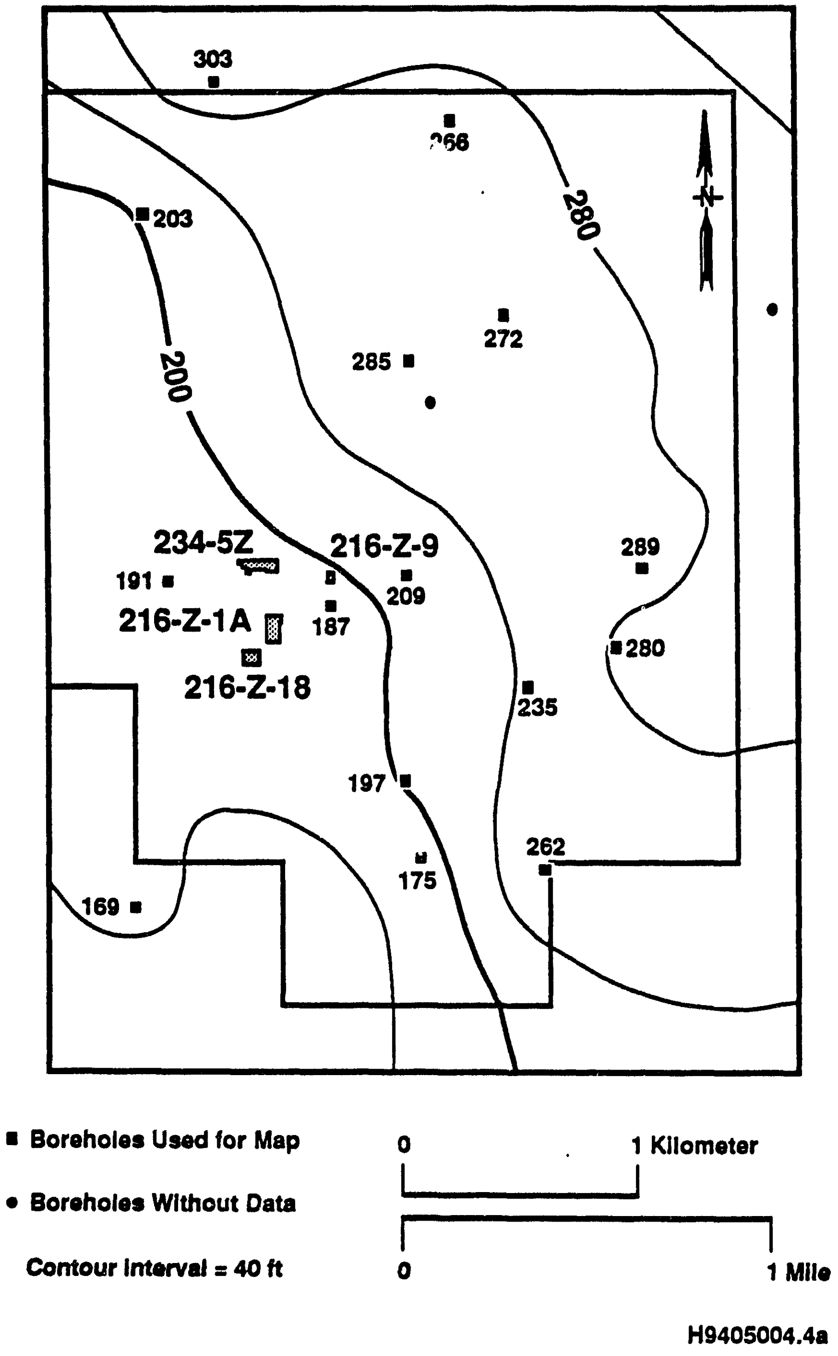


Figure B-9. Isopach Map of the Ringold Formation Unit A Beneath the ERA/VOC-Arid ID Site (contours extrapolated from data outside study area).

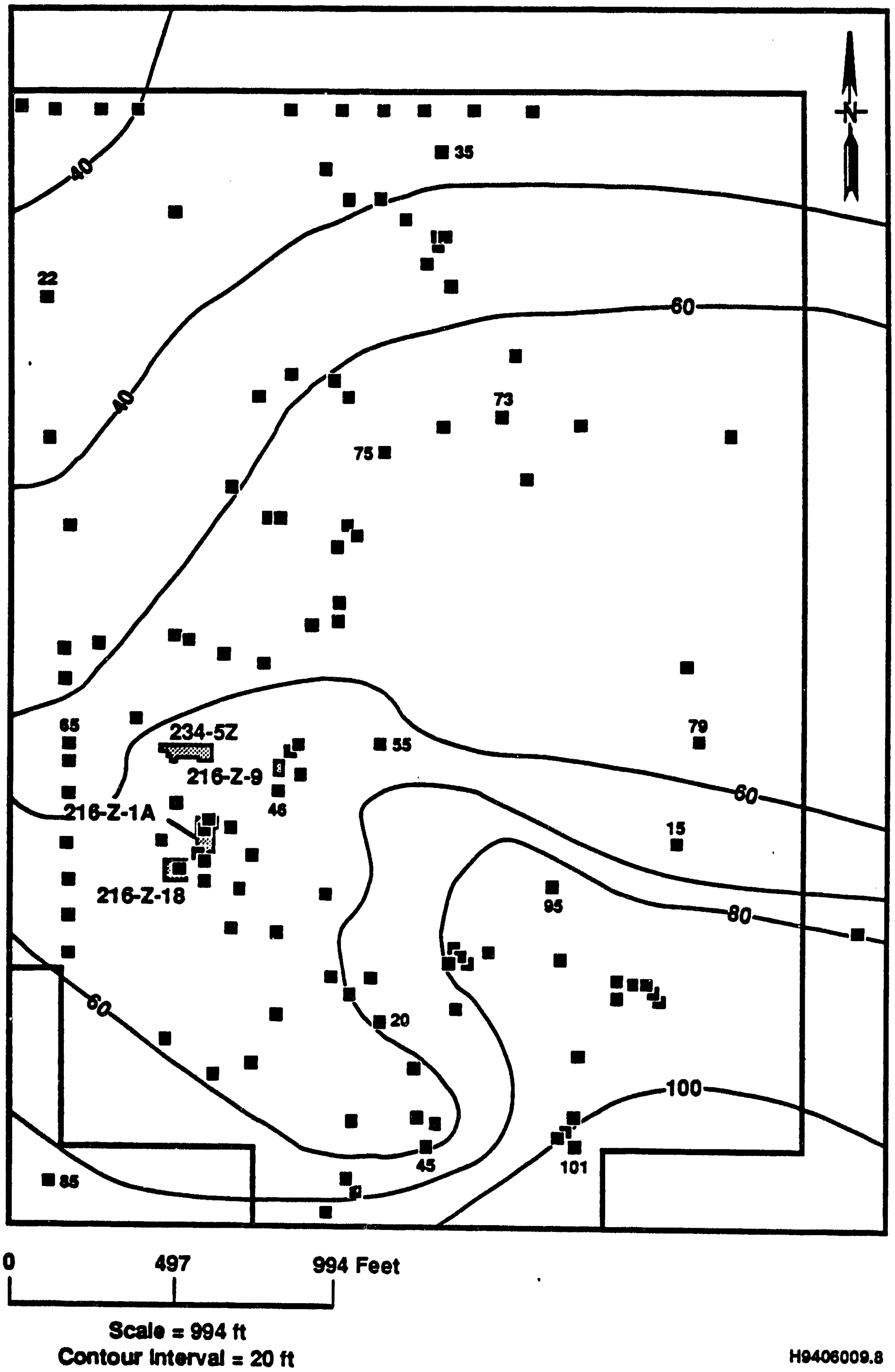


Figure B-10. Structure-Contour Map of the Ringold Formation Lower Mud Unit Beneath the ERA/VOC-Arid ID Site (contours extrapolated from data outside study area).

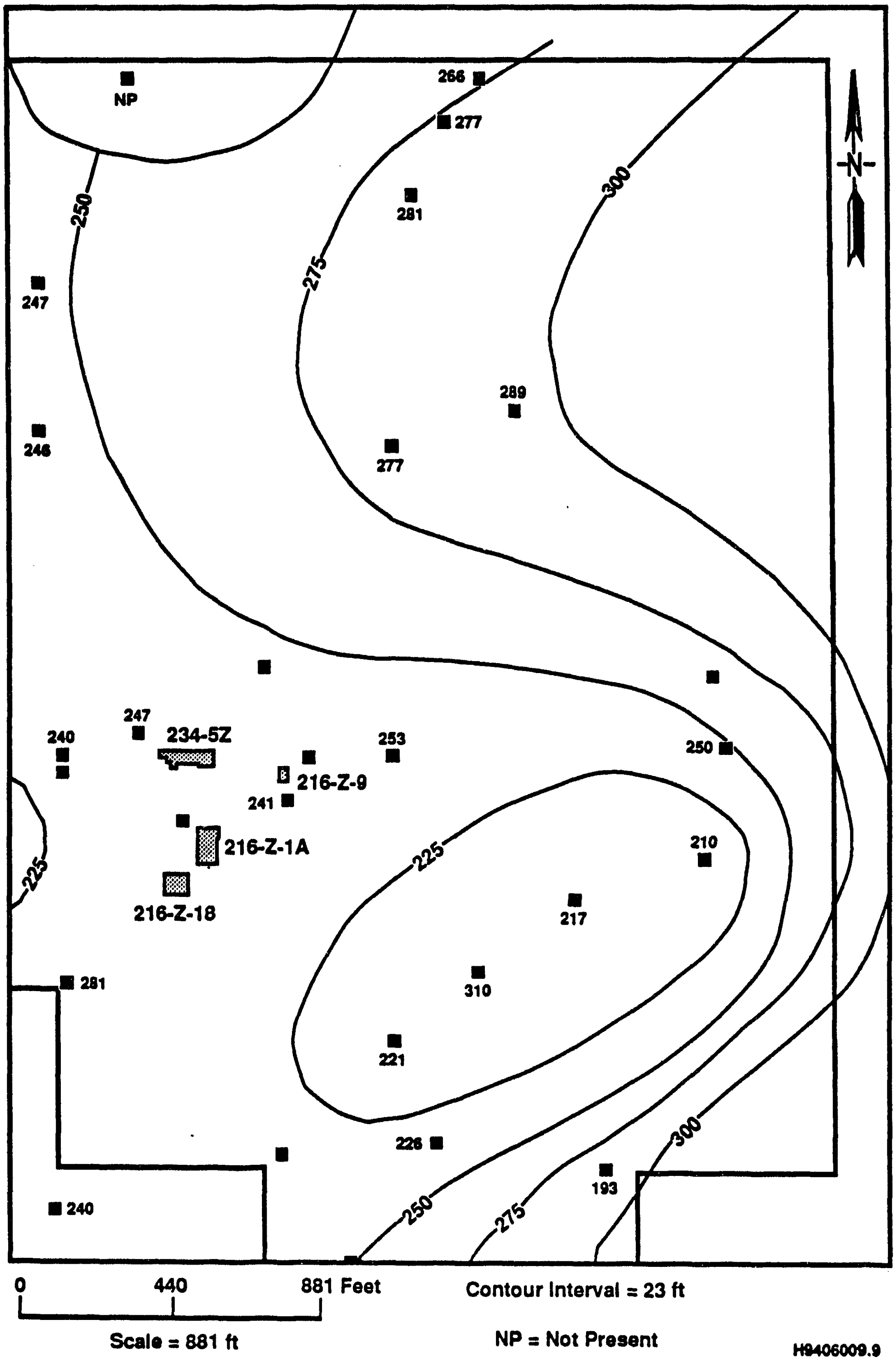


Figure B-11. Isopach Map of the Ringold Formation Lower Mud Unit Beneath the ERA/VOC-Arid ID Site (contours extrapolated from data outside study area).

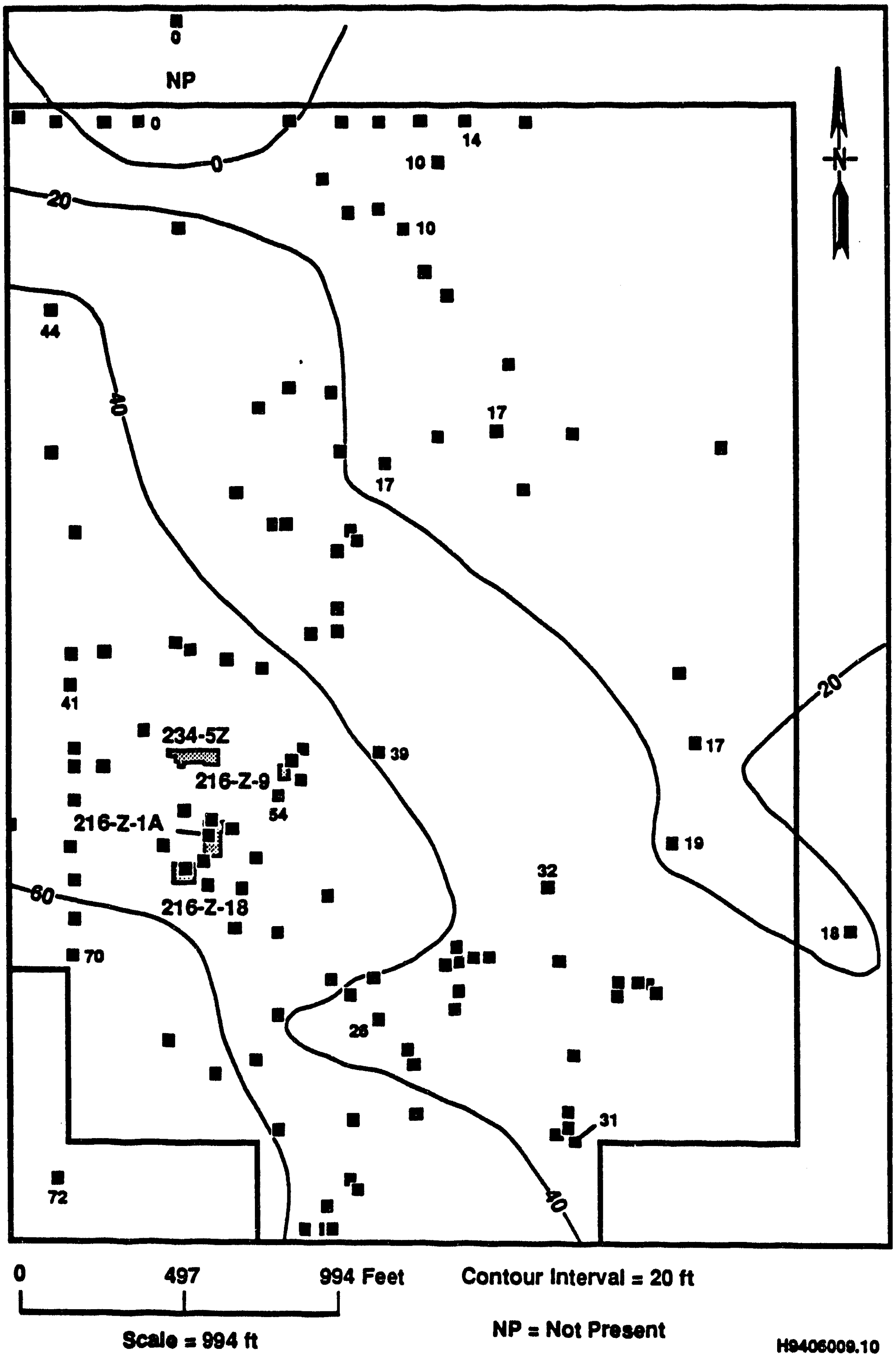


Figure B-12. Structure-Contour Map of the Ringold Formation Unit E Beneath the ERA/VOC-Arid ID Site (contours extrapolated from data outside study area).

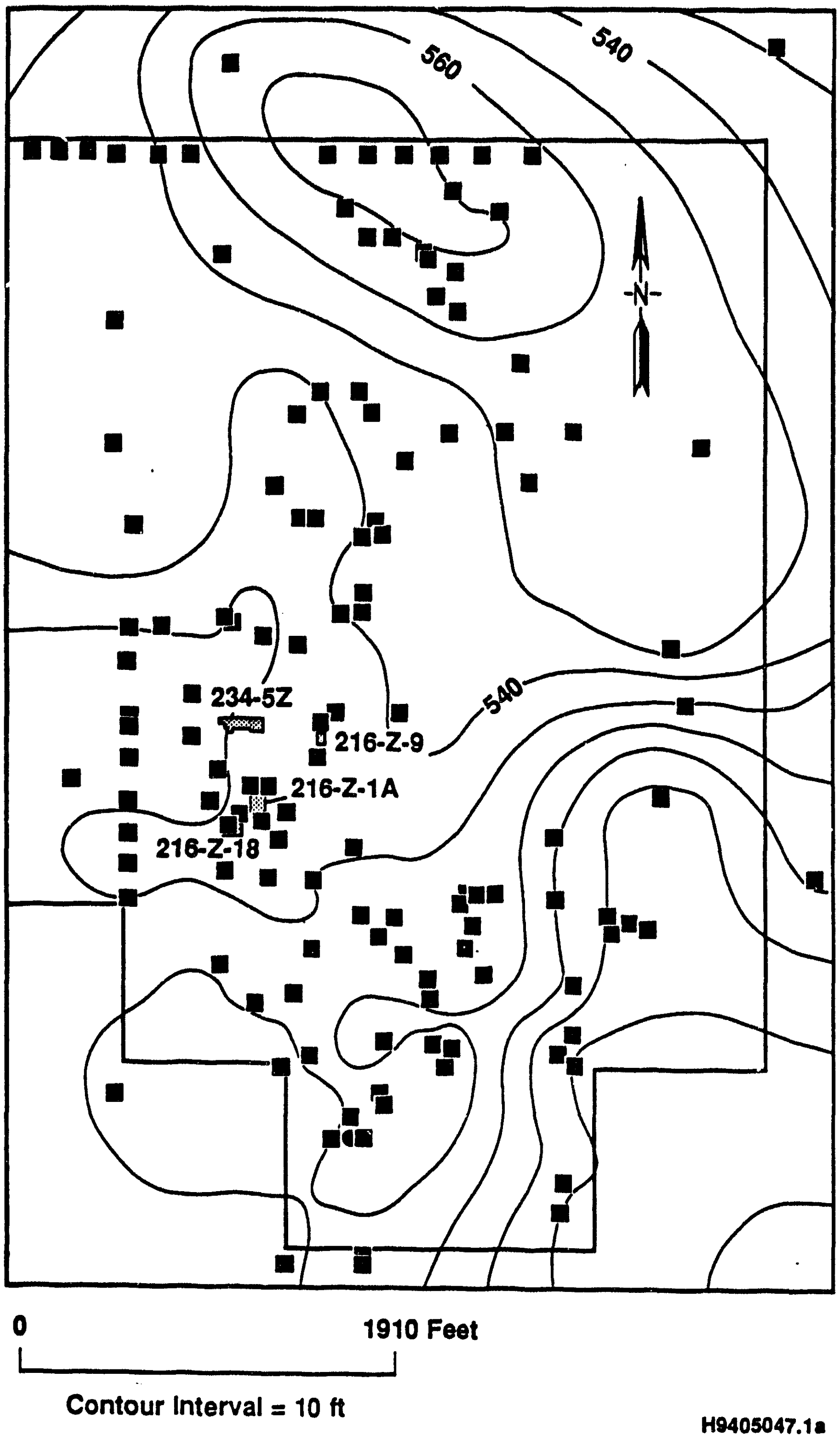


Figure B-13. Structure-Contour Map of the Upper Ringold Formation Beneath the ERA/VOC-Arid ID Site (contours extrapolated from data outside study area).

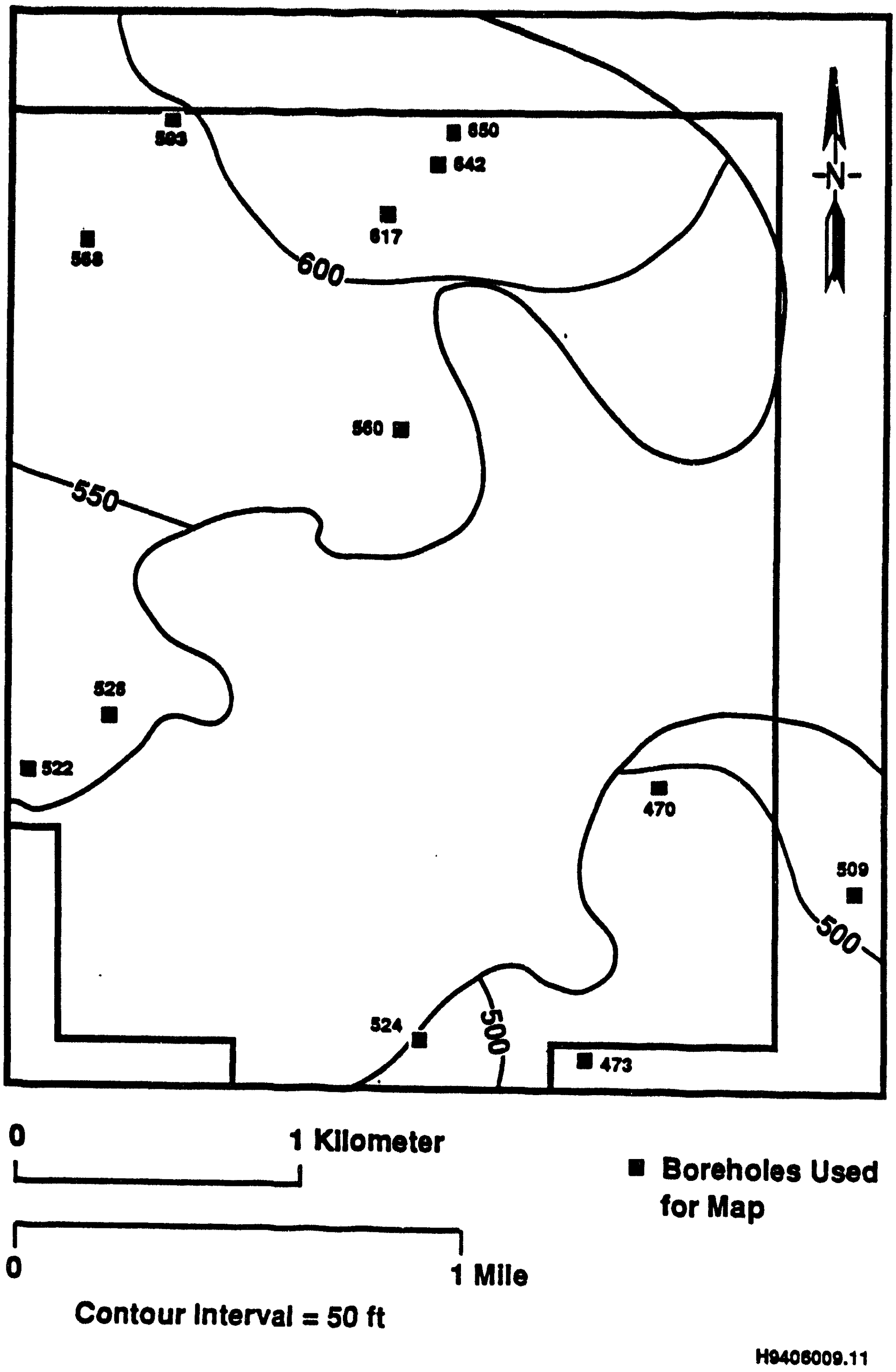
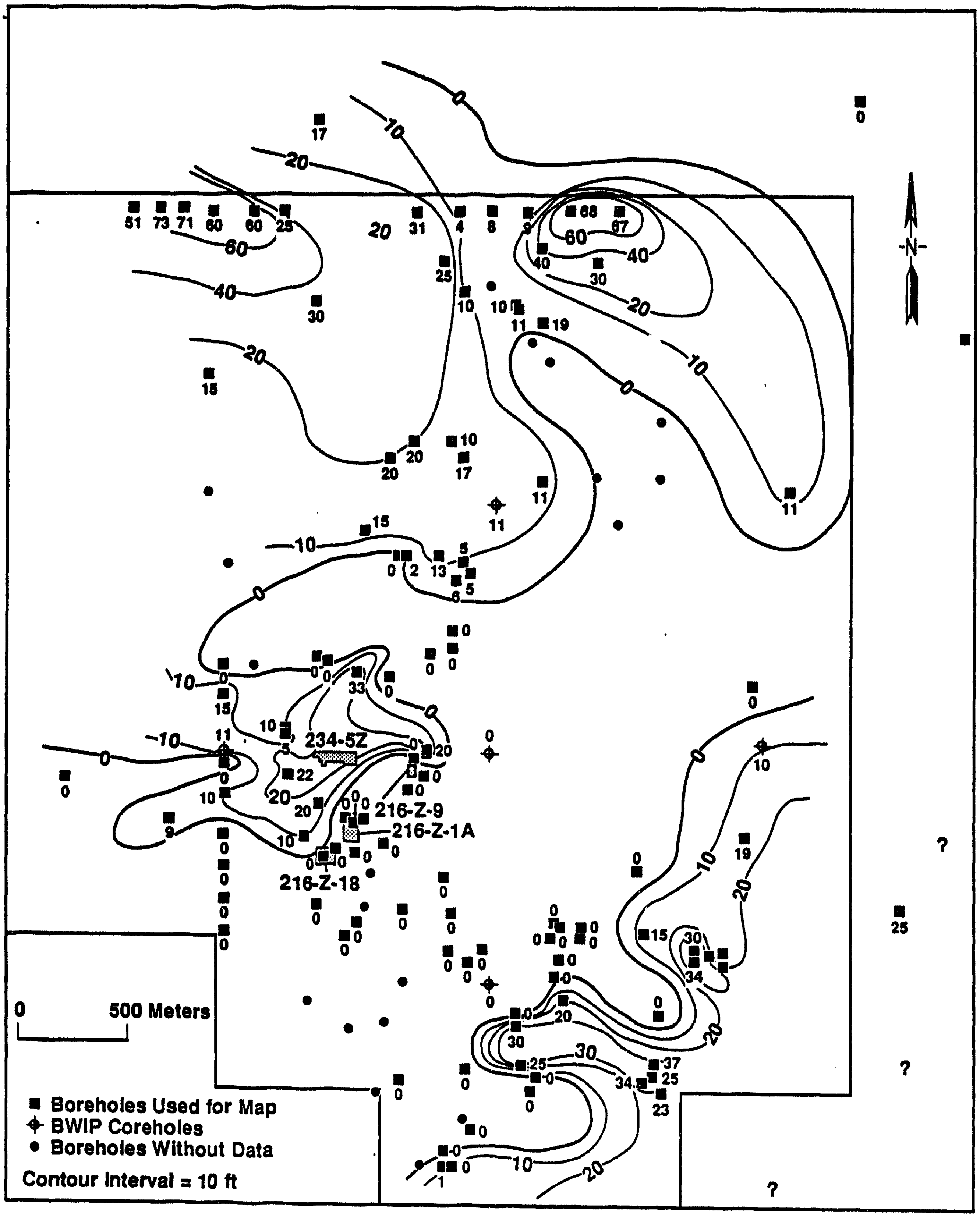


Figure B-14. Isopach Map of the Upper Ringold Formation Beneath the ERA/VOC-Arid ID Site (contours extrapolated from data outside study area).



PLIO-PLEISTOCENE UNIT

The Plio-Pleistocene unit includes all material overlying the Ringold Formation and underlying the Hanford formation. This interval formerly was divided into three units: (1) the Plio-Pleistocene unit; (2) early "Palouse" soil; and (3) pre-Missoula gravels (Myers at al. 1979, Tallman et al. 1981, Bjornstad 1984, DOE 1988, Last et al. 1989, Lindsey et al. 1991, Reidel et al. 1992). Recent core logging, borehole sampling, and outcrop studies indicate a unified Plio-Pleistocene unit consisting of two subunits (locally derived and distantly derived) better represents this interval because of uncertainties in the stratigraphic relationships among the three units, and a paucity of evidence to define a later, separate eolian unit (the early "Palouse" soil).

Major rivers (ancestral Columbia, Yakima, and Snake), local sidestreams and wind-deposited Plio-Pleistocene alluvium in the Pasco basin. The two subunits of the Plio-Pleistocene unit are based on these different sources. The major ancestral rivers transported clastic detritus from the northern Rocky Mountains, Idaho batholith, Okanogan Highlands, Cascade Range, and Wallowa Terrane consisting of quartzite and other metasediments, gneiss, basalt, andesite, rhyolite, greenstones, and silicic metavolcanics (Fecht et al. 1987). Local sources contributed basalt and material reworked from previously deposited sediments. The distally derived subunit is not present in the subsurface of the ERA/VOC-Arid ID carbon tetrachloride site.

The locally derived subunit, which is present in the subsurface of the ERA/VOC-Arid ID carbon tetrachloride site, ranges from basalt-dominated gravel to sand and silt, with carbonate irregularly dispersed throughout (Figures B-15 and B-16). At the ERA/VOC-Arid ID site, these sediments are divided into two distinct sequences, fine sandy silt and carbonate cemented sandy gravel.

The gravels are interbedded with sand and silt that vary from bedded or laminated to massive. The gravels mark the course of channels whereas the fine-grained material represents overbank deposition or eolian reworking.

Several forms of carbonate are developed in sediments of the locally derived subunit, including disseminated (which lightens the matrix and reacts slightly with dilute hydrochloric acid but is otherwise indistinct), filamentous, nodular, massive (which impregnates the matrix imparting a white color and reacts strongly to violently with dilute hydrochloric acid), and partial to complete carbonate coating on clasts. Carbonate developed subaerially during hiatuses in deposition; morphologic development generally reflects the length of time the surfaces were exposed. But the absence of associated soil horizons, no apparent decrease in carbonate content with depth in some of the carbonate layers (as would be expected in pedogenic carbonates), and some carbonates with textures that are not common to pedogenic carbonates indicates that groundwater (or capillary fringe) processes may have influenced the morphology of some of these horizons.

Thickness (up to 20 m) and facies distribution are related to depositional environment as well as to the erosional surface on top of the Ringold Formation and post-depositional erosion by the catastrophic Missoula floods. Cold Creek or unnamed drainages of Umtanum Ridge deposited this subunit along a northwest-trending channel or fan complex.

Figure B-15. Structure-Contour Map of the Plio-Pleistocene Unit Beneath the ERA/VOC-Arid ID Site (contours extrapolated from data outside the study area).

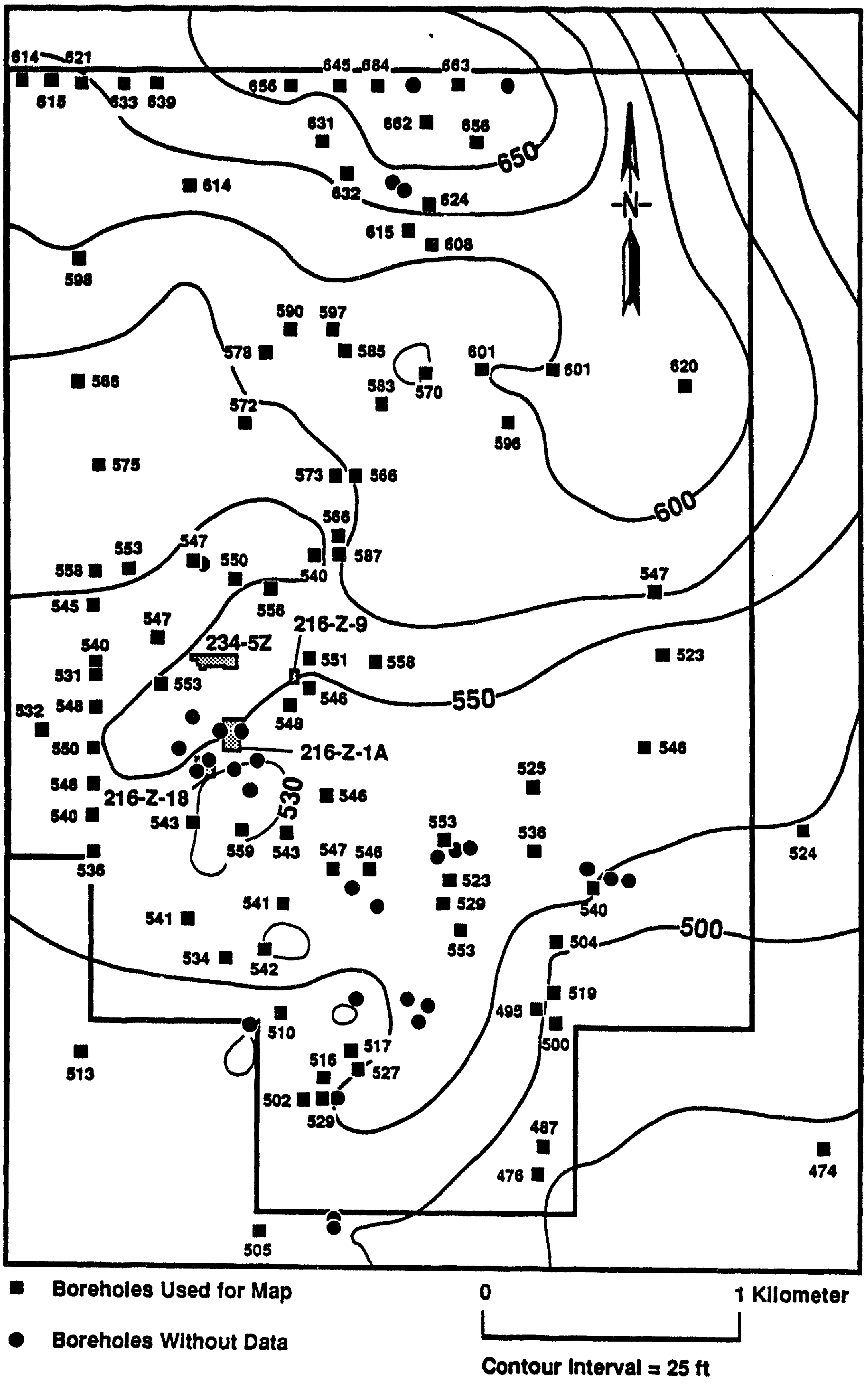
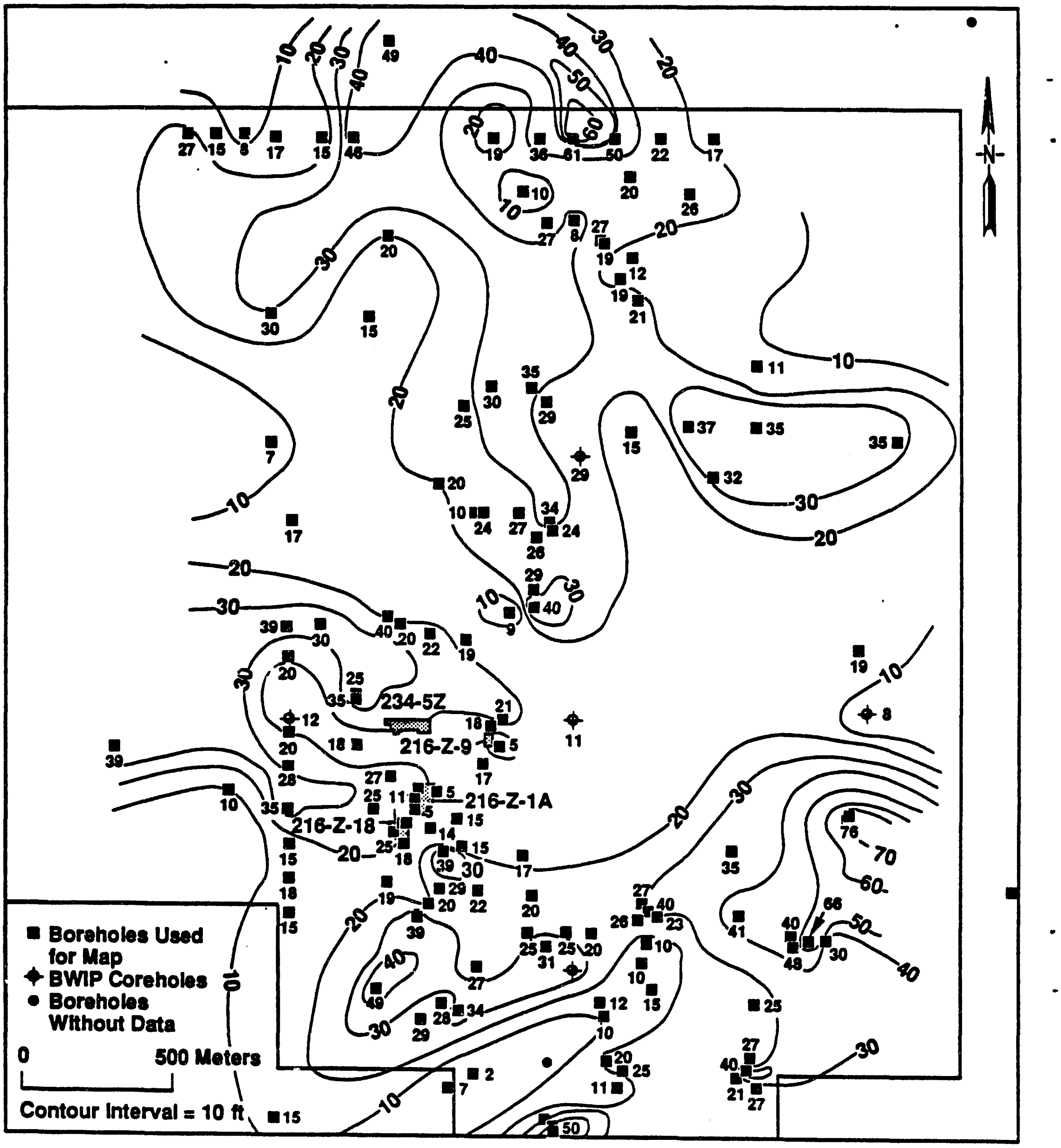


Figure B-16. Isopach Map of the Plio-Pleistocene Unit Beneath the ERA/VOC-Arid ID Site (contours extrapolated from data outside study area).



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HANFORD FORMATION

The Hanford formation consists of uncemented gravel, sand, and silt deposited by Pleistocene cataclysmic Lake Missoula floods (Fecht et al. 1987, DOE 1988, Baker et al. 1991). The Hanford formation is divided into three facies, all of which are found beneath the 200 West Area. These facies are gradational with each other and are summarized as follows:

(1) Silt-dominated facies -- This facies consists of interbedded silt and fine- to coarse-grained sand forming well-stratified, normally graded rhythmites. This facies is also referred to as slackwater deposits, Touchet Beds, and graded rhythmites. The silt-dominated facies is differentiated from the laminated silts of the Plio-Pleistocene unit by the presence of interbedded sand. The silt-dominated facies was deposited in backflooded areas during high-stands of the Lake Missoula floods.

(2) Sand-dominated or transitional facies -- Well-stratified, fine- to coarse-grained sand and granule gravel dominate this facies. Silt content is variable and an open framework texture is common where the silt content is low. Small pebbles and rip-up clasts may be present in addition to lenticular, pebble-gravel interbeds and silty interbeds. These sediments were deposited in areas adjacent to high-energy main flood channels and during periods of waning flood flow.

(3) Gravel-dominated facies -- This facies generally consists of cross-stratified, coarse-grained sand and granule to boulder gravel that contain minor intercalated silt-rich horizons. The gravels are generally uncemented and matrix poor, displaying an open framework texture. These sediments were deposited during high-energy flood events in main flood channels.

At the ERA/VOC-Arid ID site, the Hanford formation is divided into five informal units that are defined on the basis of the facies that comprise them. These units are summarized as follows:

(1) Lower fine unit -- This unit consists of interbedded silt and fine sand (with occasional basaltic gravel lags) of the silt-dominated facies. This unit is present in the vicinity of the 216-Z-1A Tile Field and 216-Z-18 Crib, overlying the Plio-Pleistocene unit (Figures B-17 and B-18).

(2) Lower coarse unit -- Deposits of the gravel-dominated facies dominate this unit, which is present in the vicinity of the 216-Z-1A Tile Field and 216-Z-12 and 216-Z-18 Cribs. The lower coarse unit overlies the Plio-Pleistocene unit and Hanford formation lower fine unit, where present (Figures B-19 and B-20).

(3) Fine unit -- The fine unit consists of sand and minor gravel of the sand-dominated or transitional facies. This unit is present throughout the ERA/VOC-Arid ID site. Clastic dikes were identified from samples recovered during the drilling of borehole 299-W15-218 approximately 45 m north of the 216-Z-9 Trench (Figures B-21 and B-22).

Figure B-17. Structure-Contour Map of the Hanford Formation Lower Fine Unit Beneath the ERA/VOC-Arid ID Site (contours extrapolated from data outside study area).

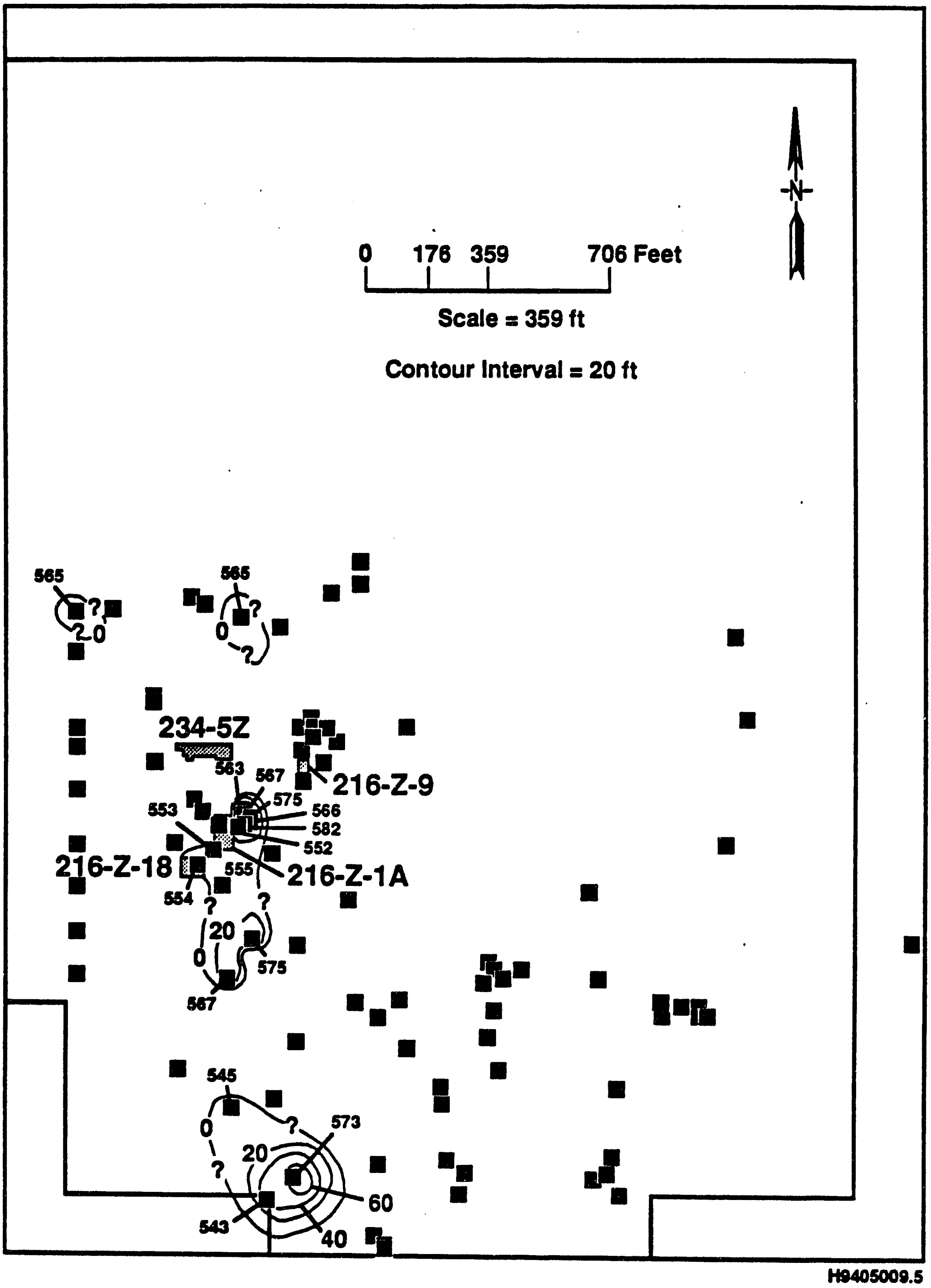

Figure B-18. Isopach Map of the Hanford Formation Lower Fine Unit Beneath the ERA/VOC-Arid ID Site (contours extrapolated from data outside study area).

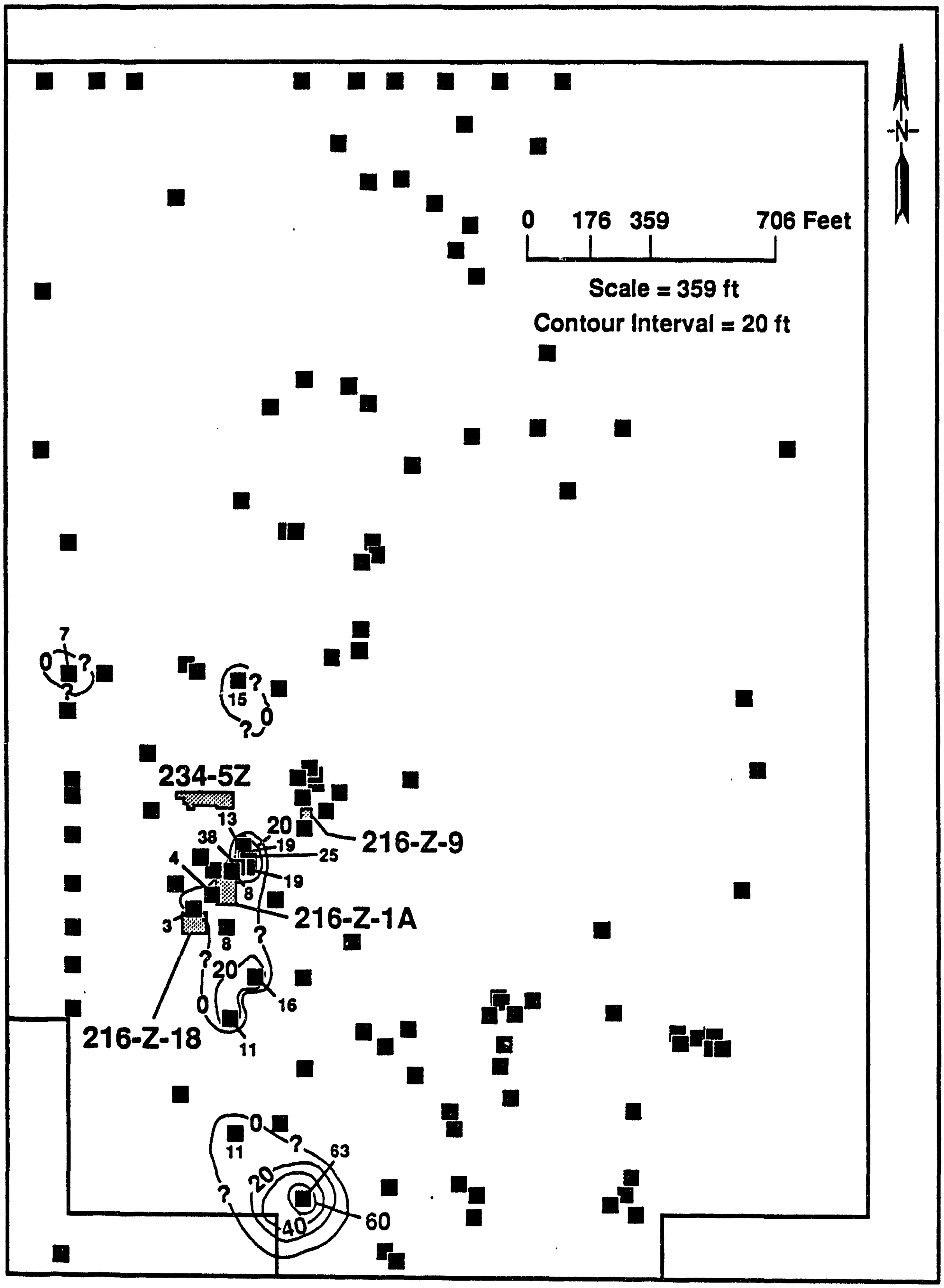

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Figure B-19. Structure-Contour Map of the Hanford Formation Lower Coarse Unit Beneath the ERA/VOC-Arid ID Site (contours extrapolated from data outside study area).

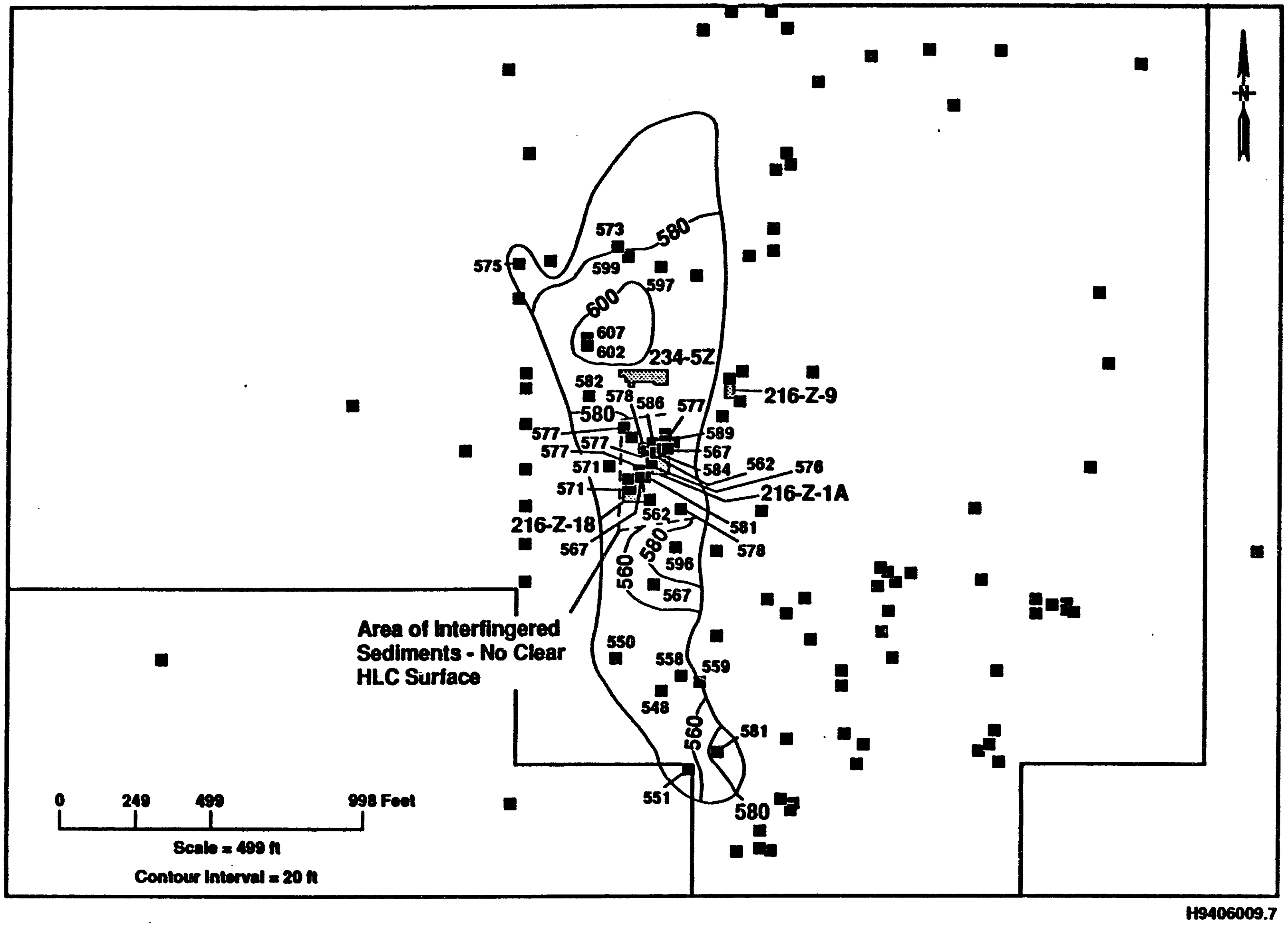


Figure B-20. Isopach Map of the Hanford Formation Lower Coarse Unit Beneath the ERA/VOC-Arid ID Site (contours extrapolated from data outside study area).

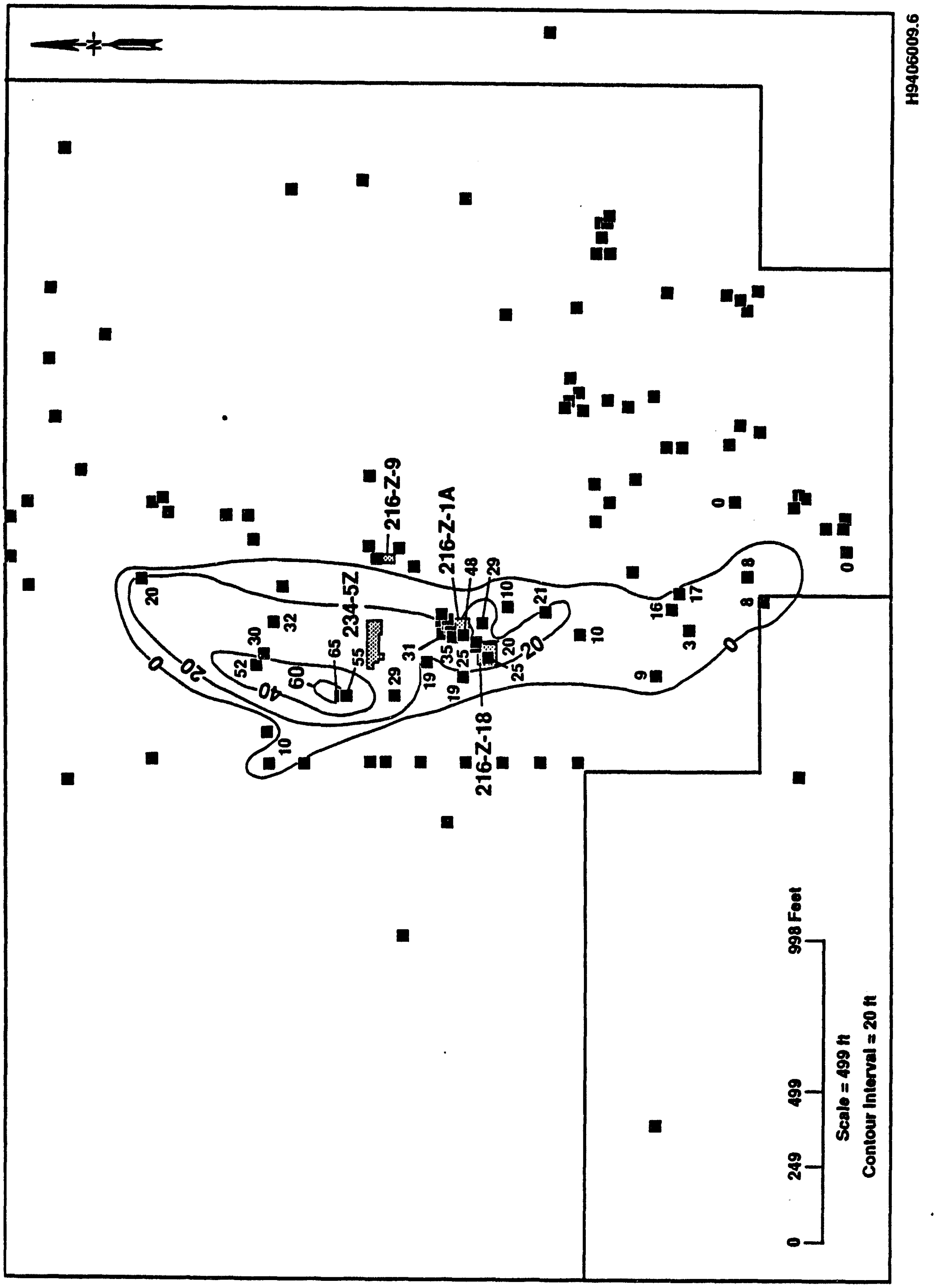
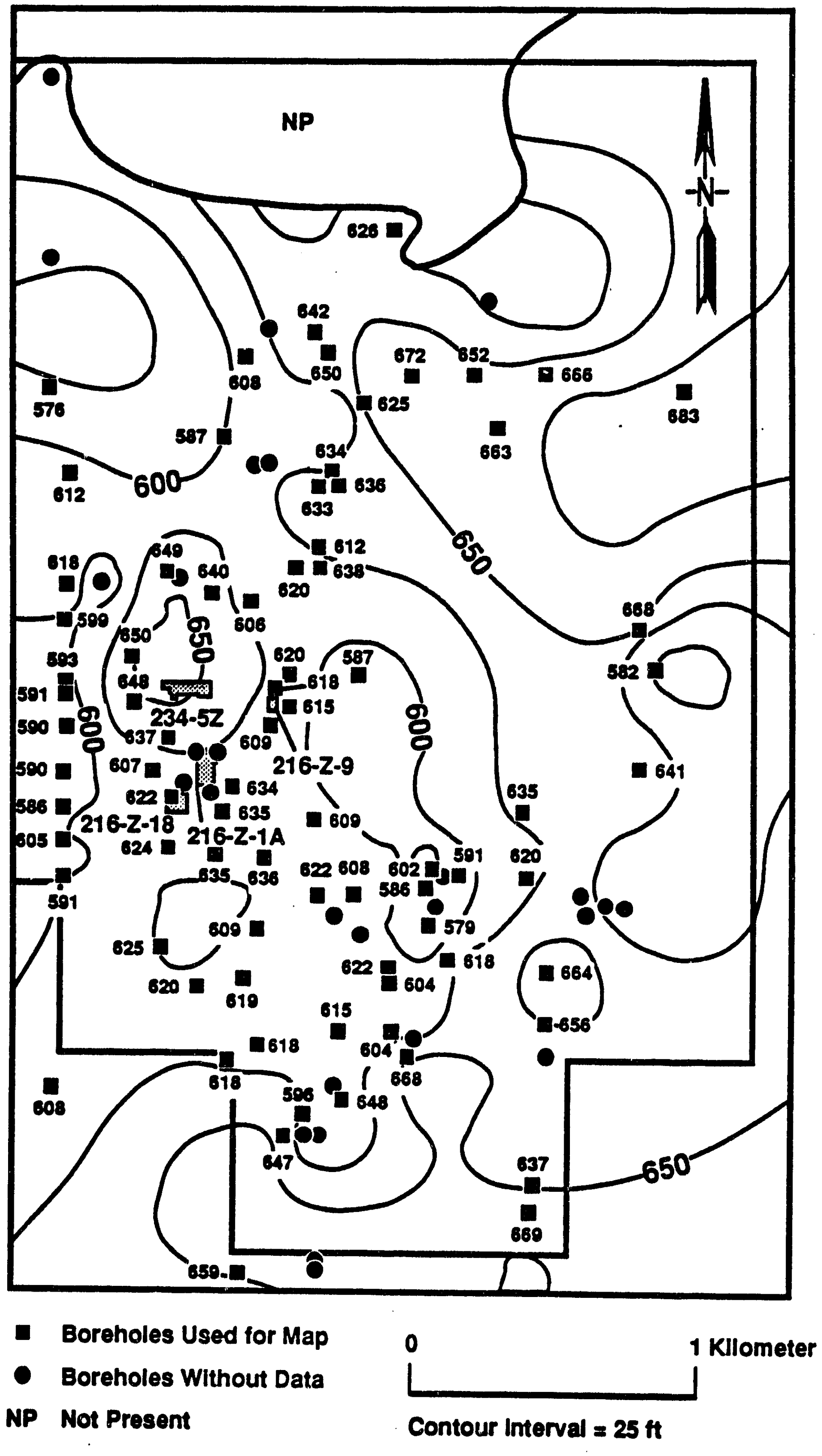


Figure B-21. Structure-Contour Map of the Hanford Formation Fine Unit Beneath the ERA/VOC-Arid ID Site (contours extrapolated from data outside study area).



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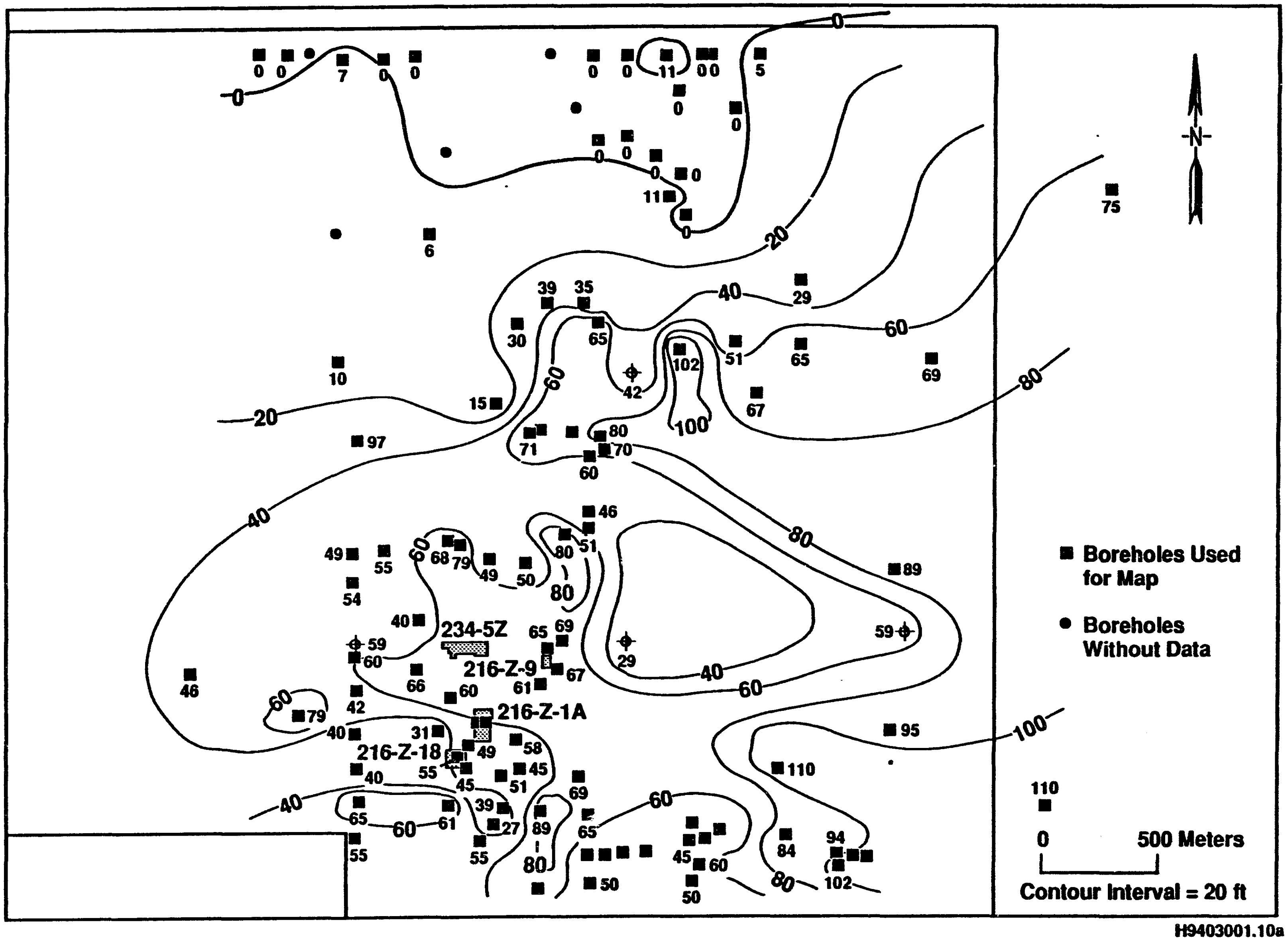

Figure B-22. Isopach Map of the Hanford Formation Fine Unit Beneath the ERA/VOC-Arid ID Site (contours extrapolated from data outside study area).

(4) Upper coarse unit -- Open framework gravels and minor interbedded sands typical of the gravel-dominated facies form this unit. It is present throughout the ERA/VOC-Arid ID site (Figure B-23).

(5) Upper fine unit -- The upper coarse unit fines upward to gravelly sand and sand of the upper fine unit. Borehole logs of the 200 West Area suggest this unit is not widespread.

HOLOCENE SURFICIAL DEPOSITS

Holocene-age eolian sand deposits locally blanket the surface of the Hanford formation. Much of these deposits, consisting of medium to very fine-grained and occasionally silty sands, have been removed or redistributed by construction activities.

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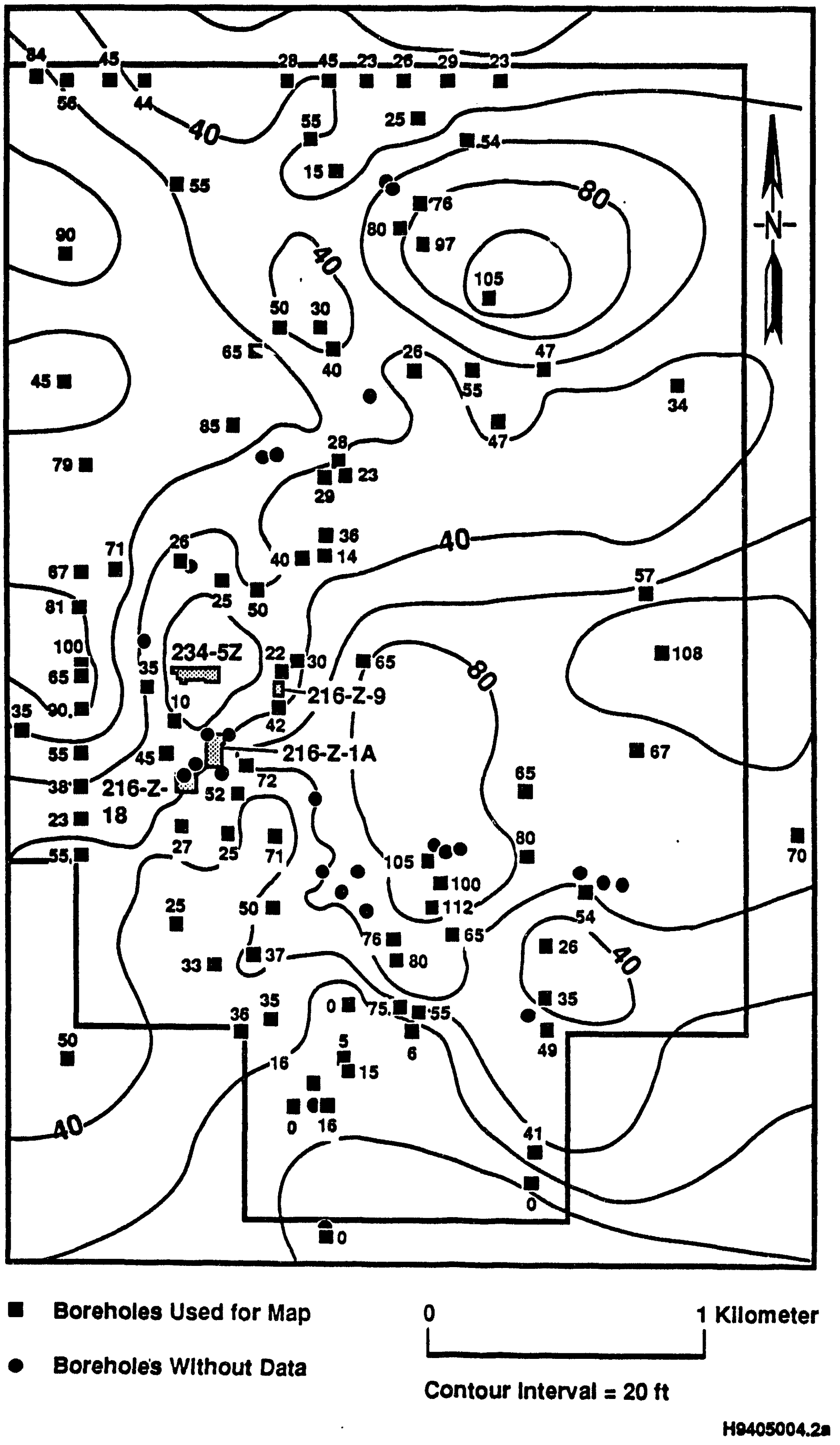
Figure B-23. Isopach Map of the Hanford Formation Upper Coarse Unit Beneath the ERA/VOC-Arid ID Site (contours extrapolated from data outside study area). NOTE: The Hanford formation upper coarse unit top is essentially the ground surface topography.



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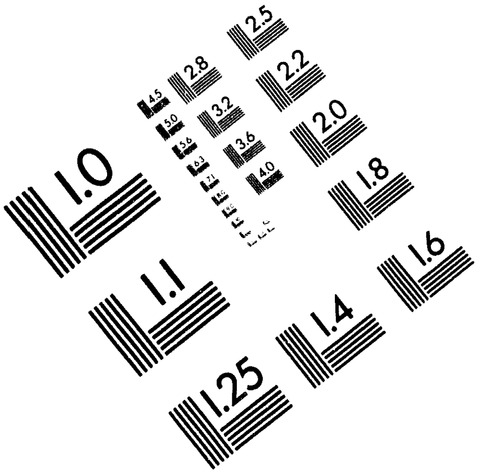
APPENDIX C

GROUNDWATER ELEVATIONS BENEATH THE ERA/VOC-ARID ID SITE



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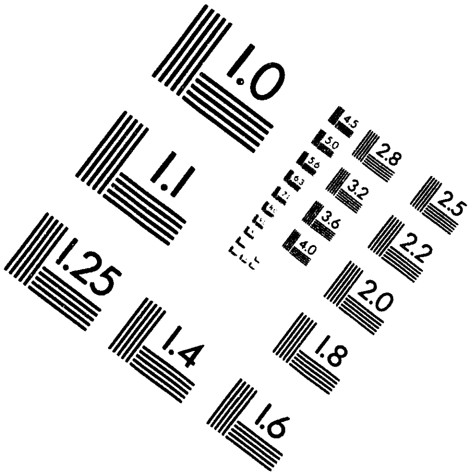

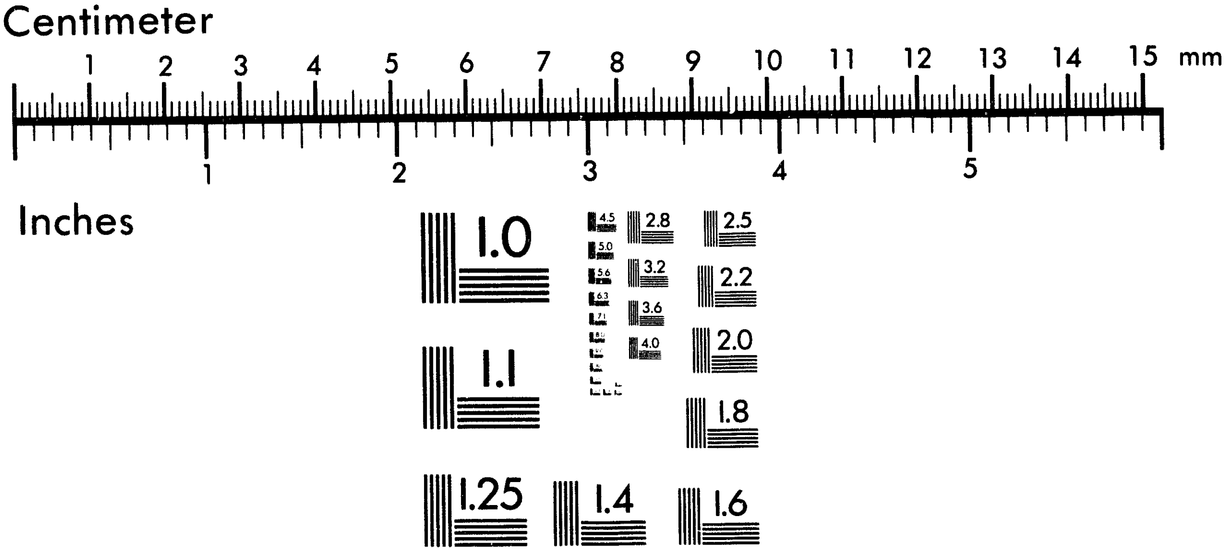

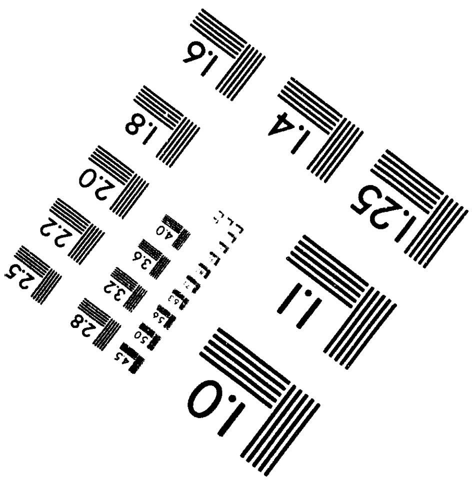

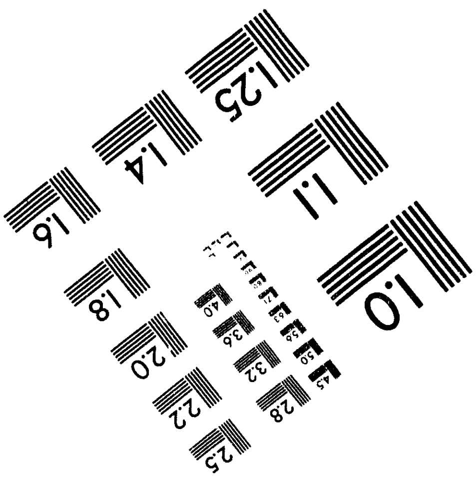

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3 of 3

Table C-1. Groundwater Elevations Beneath the ERA/VOC-Arid ID Site. (sheet 1 of 2)

Water Level Elevations for Summer 1992

WELL[a]	EW[b]	NS[b]	DATE	HEAD[c]
14-9	75002	40003	6/9/92	455.8
15-5	75984	39537	6/9/92	467.5
15-6	75765	40005	3/11/92	467.4
15-7	76180	40880	1/10/92	464.4
15-8	75910	39740	3/3/92	467.7
15-10	76920	41080	6/9/92	464.3
15-15	78103	40330	6/11/92	465.3
15-16	77387	40269	6/11/92	465.9
15-18	77383	39705	6/11/92	466.2
15-19	77772	41041	6/11/92	464.8
15-20	78120	41028	6/11/92	464.9
15-23	78118	40680	6/11/92	465.1
15-24	78096	39851	6/11/92	465.5
15-216	75793	39698	6/22/92	467.5
18-9	76846	38852	5/7/92	467.3
18-17	76091	39256	10/2/92	468.7
18-21	78080	37794	6/11/92	466.6
18-23	78120	38987	6/11/92	465.6
18-24	77180	38998	6/11/92	466.4
18-25	76034	37786	6/17/92	467.5
18-26	78097	39477	6/11/92	465.5
18-27	78103	38607	6/11/92	465.5
18-28	78096	38214	6/11/92	465.7
18-30	75541	38493	6/17/92	466.6
18-31	76032	38105	6/19/92	467.2
18-246	76779	39149	5/7/92	467.3
18-247	76747	38621	3/31/92	466.4
19-1	75491	37613	6/11/92	467.5
19-12	75456	38052	6/19/92	466.9
19-27	75072	37629	6/11/92	466.9
19-31	75457	38275	6/19/92	466.6
19-32	75459	37887	6/19/92	466.9

Water Level Elevations for Summer 1993

WELL[a]	EW[b]	NS[b]	DATE	HEAD[c]
15-5	75984	39537	6/17/93	465.6
15-10	76920	41080	6/16/93	462.8
15-15	78103	40330	6/24/93	463.4
15-16	77387	40269	6/24/93	464.0
15-18	77383	39705	6/24/93	464.1
15-19	77772	41041	6/24/93	463.3
15-20	78120	41028	6/24/93	463.1
15-23	78118	40680	6/24/93	463.3
15-24	78096	39851	6/24/93	463.5
15-218	75866	40027	2/19/93	465.9
15-219	76004	40004	5/25/93	465.9
15-220	75657	39886	7/22/93	465.6
18-17	76091	39256	3/1/93	468.1
18-20	76477	38103	3/1/93	467.2
18-21	78080	37794	6/24/93	463.5
18-23	78120	38987	6/24/93	463.5
18-24	77180	38998	6/24/93	464.3
18-25	76034	37786	6/24/93	464.9
18-26	78097	39477	6/24/93	463.5
18-27	78103	38607	6/24/93	463.6
18-28	78096	38214	6/24/93	463.8
18-30	75541	38493	6/22/93	465.1
18-31	76032	38105	6/24/93	464.9
18-32	76709	37780	5/18/93	464.7
18-252	76931	39269	7/20/93	464.4
19-1	75491	37613	6/17/93	466.5
19-12	75456	38052	6/24/93	465.1
19-27	75072	37629	6/16/93	465.6
19-31	75457	38275	6/24/93	465.1
19-32	75459	37887	6/24/93	465.3

Table C-1. Groundwater Elevations Beneath the ERA/VOC-Arid ID Site. (sheet 2 of 2)

Water Level Elevations for Winter 1993/1994

WELL[a]	EW[b]	NS[b]	DATE	HEAD[c]
14-9	75002	40003	12/2/93	452.7
15-5	75984	39537	12/2/93	465.0
15-8	75910	39740	12/3/93	464.9
15-10	76920	41060	12/2/93	462.4
15-15	78103	40330	12/10/93	463.3
15-16	77387	40269	12/14/93	463.8
15-18	77383	39705	12/10/93	464.0
15-19	77772	41041	12/10/93	463.2
15-20	78120	41028	12/10/93	463.1
15-23	78118	40680	12/10/93	463.3
15-24	78096	39851	12/10/93	463.4
18-21	78060	37794	12/10/93	463.3
18-23	78120	38987	12/10/93	463.4
18-24	77180	38998	12/10/93	464.1
18-25	76034	37786	12/15/93	464.2
18-26	78097	39477	12/10/93	463.4
18-27	78103	38607	12/10/93	463.5
18-28	78096	38214	12/10/93	463.6
18-30	75541	38493	12/15/93	464.4
18-31	76032	38105	12/15/93	464.3
18-32	76709	37760	12/10/93	464.7
19-1	75491	37613	12/2/93	465.4
19-12	75456	38052	12/15/93	464.4
19-27	75072	37629	12/15/93	464.5
19-31	75457	38275	12/15/93	464.4
19-32	75459	37887	12/15/93	464.6

(a) Well numbers preceded by 299-.
(b) EW/NS are Hanford Coordinates.
(c) To convert feet to meters, multiply by 0.3048.

APPENDIX D

BASELINE MONTORING STATISTICS--DECEMBER 1991 THROUGH DECEMBER 1993

BASELINE MONITORING STATISTICS - DECEMBER 1991 THROUGH DECEMBER 1993
(OVM Readings - ppmv)

SAMPLE POINT	MAXIMUM (all points)	MINIMUM (all points)	AVERAGE (all points)	AVERAGE (all positive points)	# SAMPLES (all points)	# SAMPLES (all positive points)
CPT 15-6	10400.0	0.0	1534.41	1613.10	205	195
CPT 15-84	259.0	0.0	17.72	28.65	131	81
CPT PNL-5	12.4	0.0	0.74	4.75	58	9
CPT-4B 5'	1093.4	0.0	39.23	78.45	38	19
CPT-4B 25'	137.8	0.0	17.02	20.86	38	31
CPT-4B 50'	216.8	0.0	19.20	26.75	39	28
CPT-4B 75'	73.6	0.0	12.54	14.89	38	32
CPT-4B 90'	485.6	0.0	41.72	54.67	38	29
CPT-4C 10'	1058.6	0.0	33.28	54.98	38	23
CPT-4C 25'	81.2	0.0	10.47	13.26	38	30
CPT-4C 50'	144.6	0.0	23.85	29.23	38	31
CPT-4C 75'	1251.6	0.0	72.13	94.52	38	29
CPT-4C 107'	479.2	0.0	46.56	68.05	38	26
CPT-4D 10'	28.6	0.0	5.42	10.06	13	7
CPT-4D 25'	28.6	0.0	6.70	7.92	13	11
CPT-4D 40'	28.6	0.0	8.46	11.00	13	10
CPT-4D 75'	61.0	0.0	14.97	19.46	13	10
CPT-4D 99'	49.0	0.0	14.68	21.20	13	9
CPT-4E 10'	448.0	0.0	14.85	33.19	38	17
CPT-4E 25'	60.4	0.0	6.96	10.17	38	26
CPT-4E 75'	515.8	0.0	28.49	38.66	38	28
CPT-4E 103'	135.6	0.0	17.26	24.30	38	27
CPT-4F 10'	333.4	0.0	14.47	28.13	35	18
CPT-4F 25'	365.0	0.0	20.96	31.89	35	23
CPT-4F 50'	224.0	0.0	24.54	33.03	35	26
CPT-4F 75'	125.6	0.0	17.11	24.95	35	24
CPT-4F 109'	45.6	0.0	11.19	17.80	35	22
CPT-4G 100'	186.8	0.0	37.21	44.19	38	32
CPT-4H 75'	396.2	0.0	51.37	59.15	38	33

BASELINE MONITORING STATISTICS - DECEMBER 1991 THROUGH DECEMBER 1993
(OVM Readings - ppmv)

SAMPLE POINT	MAXIMUM (all points)	MINIMUM (all points)	AVERAGE (all points)	AVERAGE (all positive points)	# SAMPLES (all points)	# SAMPLES (all positive points)
CPT-4J 25'	25.6	0.0	5.08	7.43	38	26
CPT-4L 50'	156.8	0.0	20.36	24.96	38	31
SG 86-4	62.9	0.0	7.03	12.34	86	49
SG 86-5	67.9	0.0	3.44	8.00	86	37
SG 86-6	307.0	0.0	4.63	24.59	85	16
SG 94-2	132.0	0.0	19.53	24.06	85	69
SG 94-4	71.2	0.0	10.10	11.45	85	75
SG 94-5	19.0	0.0	1.35	8.08	84	14
SG 94-7	22.2	0.0	1.18	6.28	85	16
SG C-1	20.6	0.0	2.10	4.58	198	91
SG E-2	407.0	0.0	12.78	27.95	199	91
SG E-3	17.5	0.0	1.22	3.90	195	61
SG N-1	4.8	0.3	2.55	2.55	2	2
SG N-2	112.8	0.0	2.52	5.74	196	86
SG N-3	95.0	0.0	2.80	5.11	188	103
SG N-5	204.8	0.0	2.50	6.58	200	76
SG N-3	1249.6	0.0	7.44	24.89	194	58
SG N-7	134.6	0.0	4.15	7.21	200	115
SG N-8	10.0	10.0	10.00	10.00	1	1
SG N-9	517.2	0.0	7.37	12.12	199	121
SG S-1	0.6	0.6	0.60	0.60	1	1
SG W-1	291.2	0.0	2.92	7.27	197	79
SG W-3	2.4	2.4	2.40	2.40	1	1
SG W-5	50.2	0.0	2.93	4.66	194	122
W 10-15	0.1	0.0	0.00	0.10	84	1
W 10-16	0.0	0.0	0.00	0.00	84	0
W 10-17	0.2	0.0	0.00	0.20	84	1
W 10-18	0.2	0.0	0.00	0.20	83	1
W 10-71	0.0	0.0	0.00	0.00	78	0

BASELINE MONITORING STATISTICS - DECEMBER 1991 THROUGH DECEMBER 1993
(OVM Readings - ppmv)

SAMPLE POINT	MAXIMUM (all points)	MINIMUM (all points)	AVERAGE (all points)	AVERAGE (all positive points)	# SAMPLES (all points)	# SAMPLES (all positive points)
W 10-81	0.0	0.0	0.00	0.00	78	0
W 10-9	3.9	0.0	0.08	2.10	84	3
W 11-1	2.3	0.0	0.04	1.23	84	3
W 11-27	0.1	0.0	0.00	0.10	84	1
W 11-28	0.1	0.0	0.00	0.10	83	1
W 14-12	3.8	0.0	0.06	2.57	84	2
W 14-51	0.1	0.0	0.00	0.10	83	1
W 15-12	4.3	0.0	0.08	2.26	84	3
W 15-13	0.2	0.0	0.00	0.20	83	1
W 15-216	1271.0	0.0	40.18	123.06	49	16
W 15-216 Lower Interval	588.0	0.0	39.68	105.23	61	23
W 15-216 Upper Interval	621.0	0.0	42.09	142.62	61	18
W 15-217	3997.0	0.0	127.83	349.86	104	38
W 15-218	479.6	0.0	68.56	137.12	28	14
W 15-218 Lower Interval	212.6	0.0	22.79	72.92	16	5
W 15-218 Upper Interval	170.6	0.0	20.52	46.91	16	7
W 15-219 Lower Interval	31.8	0.0	3.48	26.10	15	2
W 15-219 Upper Interval	204.5	0.0	29.55	88.66	15	5
W 15-22	9.6	0.0	0.18	3.79	85	4
W 15-220 Lower Interval	114.8	0.0	16.99	63.70	15	4
W 15-220 Upper Interval	124.0	0.0	15.95	59.83	15	4
W 15-4	49.8	0.0	1.76	8.30	80	17
W 15-5	401.0	0.0	14.33	39.08	150	55
W 15-6	1367.0	0.0	34.86	77.51	189	85
W 1[illegible]-64	0.1	0.0	0.00	0.10	83	1
W 15-66	0.6	0.0	0.01	0.35	83	2
W 15-76	2.3	0.0	0.04	1.00	83	3
W 15-8	14.0	0.0	0.16	2.57	143	9
W 15-82	10000.0	0.0	383.96	651.07	195	115

BASELINE MONITORING STATISTICS - DECEMBER 1991 THROUGH DECEMBER 1993
(OVM Readings - ppmv)

SAMPLE POINT	MAXIMUM (all points)	MINIMUM (all points)	AVERAGE (all points)	AVERAGE (all positive points)	# SAMPLES (all points)	# SAMPLES (all positive points)
W 15-84	1295.0	0.0	26.95	91.92	191	56
W 15-85	5737.0	0.0	142.12	349.84	160	65
W 15-86	21.8	0.0	0.23	2.56	144	13
W 15-9	199.6	0.0	11.81	38.07	158	49
W 15-95	10704.0	0.0	206.52	440.41	177	83
W 18-1	1018.0	0.0	16.58	42.23	191	75
W 18-10	442.0	0.0	33.28	57.06	36	21
W 18-11	188.4	0.0	4.32	13.53	194	62
W 18-12	199.0	0.0	5.60	18.45	191	58
W 18-152	119.6	0.0	7.36	19.04	88	34
W 18-153	1671.5	0.0	28.07	82.47	191	65
W 18-155	0.0	0.0	0.00	0.00	64	0
W 18-157	696.5	0.0	8.24	30.84	191	51
W 18-17	135.0	0.0	4.47	16.35	183	50
W 18-171	140.5	0.0	3.82	12.69	209	63
W 18-18	28.2	0.0	0.70	4.06	180	31
W 18-19	22.8	0.0	0.48	4.15	180	21
W 18-2	806.0	0.0	22.24	47.72	191	89
W 18-24	336.0	0.0	6.79	18.90	192	69
W 18-246	498.0	0.0	60.06	110.63	35	19
W 18-246 Lower Interval	450.0	0.0	21.20	43.71	101	49
W 18-246 Upper Interval	382.0	0.0	10.45	29.77	94	33
W 18-247	180.0	0.0	8.78	23.04	63	24
W 18-247 Lower Interval	114.0	0.0	10.14	38.01	60	16
W 18-247 Upper Interval	47.0	0.0	4.64	12.31	61	23
W 18-248	1532.0	0.0	23.76	107.70	136	30
W 18-249	120.0	0.0	9.34	19.41	133	64
W 18-29	11.4	0.0	0.19	5.49	87	3
W 18-30	1.7	0.0	0.85	1.70	2	1

BASELINE MONITORING STATISTICS - DECEMBER 1991 THROUGH DECEMBER 1993
(OVM Readings - ppmv)

SAMPLE POINT	MAXIMUM (all points)	MINIMUM (all points)	AVERAGE (all points)	AVERAGE (all positive points)	# SAMPLES (all points)	# SAMPLES (all positive points)
W 18-5	0.0	0.0	0.00	0.00	2	0
W 18-6	1073.0	0.0	23.97	52.52	184	84
W 18-7	474.0	0.0	11.97	30.52	181	71
W 18-82	12.0	0.0	0.35	2.19	196	31
W 18-85	238.5	0.0	11.60	26.23	199	88
W 18-86	170.0	0.0	7.90	22.98	195	67
W 18-87	70.0	0.0	2.93	8.74	209	70
W 18-88	5.3	0.0	0.13	1.07	194	23
W 18-89	212.0	0.0	3.30	13.98	195	46
W 18-9	259.0	0.0	6.75	20.14	194	65
W 18-93	114.0	0.0	1.38	9.93	194	27
W 18-94	117.7	0.0	2.04	12.93	196	31
W 18-95	169.4	0.0	4.34	21.15	195	40
W 18-96	246.5	0.0	8.62	34.11	186	47
W 18-97	17.5	0.0	3.56	6.18	33	19
W 18-98	39.0	0.0	1.22	4.90	184	46
W 18-99	56.0	0.0	0.63	3.37	171	32
VR-1 at Z-18	0.0	0.0	0.00	0.00	4	0
VR-2 at Z-18	1.8	0.0	0.45	1.80	4	1
VR-3 at Z-18	0.0	0.0	0.00	0.00	4	0
VR-4 at Z-18	0.0	0.0	0.00	0.00	4	0
VR-5 at Z-18	0.5	0.0	0.13	0.51	4	1
DAYTON & 16TH	0.0	0.0	0.00	0.00	1	0
FENCELINE S OF Z1A CRIB	0.3	0.3	0.30	0.30	1	1
NE FENCE CORNER	0.0	0.0	0.00	0.00	1	0
NE PERIMETER	0.0	0.0	0.00	0.00	1	0
NW FENCE CORNER	0.0	0.0	0.00	0.00	1	0
NW PERIMETER	0.0	0.0	0.00	0.00	1	0
S OF Z-9	0.0	0.0	0.00	0.00	1	0

BASELINE MONITORING STATISTICS - DECEMBER 1991 THROUGH DECEMBER 1993
(OVM Readings - ppmv)

SAMPLE POINT	MAXIMUM (all points)	MINIMUM (all points)	AVERAGE (all points)	AVERAGE (all positive points)	# SAMPLES (all points)	# SAMPLES (all positive points)
SE FENCE CORNER	0.4	0.4	0.37	0.37	1	1
SE PERIMETER	0.0	0.0	0.00	0.00	1	0
SW FENCE CORNER	0.0	0.0	0.00	0.00	1	0
SW PERIMETER	0.3	0.3	0.30	0.30	1	1
Z18 CRIB BETW V-R 1 & 2	0.0	0.0	0.00	0.00	1	0

APPENDIX E

FINAL REPORT ON THE FINDINGS OF THE PETREX SOIL-GAS SURVEY

FINAL REPORT
ON THE FINDINGS OF THE PETREX SOIL GAS SURVEY PERFORMED AT THE DEPARTMENT OF ENERGY HANFORD, WASHINGTON SITE

CONDUCTED FOR:
BATTELLE PACIFIC NORTHWEST LABORATORY

BY CONTRACT NUMBER:
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April 7, 1993

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<u>ATTACHMENTS</u>:
Books 1-5

1.0 INTRODUCTION

Northeast Research Institute, Inc. (NERI) conducted a demonstration of the Petrex passive soil gas method at the Department of Energy's Hanford, Washington site for Battelle Pacific Northwest Laboratory (Battelle). The purpose of this demonstration was to determine if the Petrex soil gas method was an appropriate method for locating and identifying volatile and semivolatile organic compounds (VOCs and SVOCs) at this site and if so, to determine the most appropriate field exposure time. Specific compounds of interest included carbon tetrachloride (CCL_4), methylene chloride, chloroform, trichloroethene (TCE), tributyl phosphate (TBP), dibutyl butyl phosphonate (DBBP), dibutyl phosphite (DBP), monobutyl phosphite (MBP), and triglycerides (lard oil).

2.0 OBJECTIVES

The objectives of this soil gas survey were to:

1. Determine if the Petrex passive soil gas method was appropriate for this site;
2. Determine the most appropriate sampler field exposure time at this site; and
3. Collect and report VOCs and SVOCs in the soil gas.

3.0 OVERVIEW OF THE PETREX TECHNIQUE AS DEMONSTRATED AT THE HANFORD SITE

Each Petrex soil gas sampler consisted of two soil gas collectors, each a ferromagnetic wire coated with an activated carbon adsorbent. These wires were packed under an inert atmosphere in a screw top glass culture tube.

3.1 Sampler Installation

Each soil gas sampler was installed by unsealing the sampler and placing it (open end down) in a hole 14-18 inches deep. The sampler was then backfilled with the original excavated soil. To complete installation, the sampler location was marked with a numbered pin flag.

3.2 Sampler Retrieval

Once a week for five weeks, a sampler was retrieved from each site, resealed, labelled, and submitted to the NERI laboratory for analysis.

3.3 Analysis Techniques

One collection wire was analyzed by Thermal Desorption-Mass Spectrometry (TD-MS) and the other was analyzed by Thermal Desorption-Gas Chromatography/Mass Spectrometry (TD-GC/MS). The TD-MS analysis was conducted with an Extrel quadrupole mass spectrometer interfaced with a proprietary pyrolysis system. Upon receipt of the samplers, the number on each tube was recorded, and any missing or duplicate numbers was noted. The entire group of each week's samplers was analyzed as one run without interruption. The results were reported as a mass spectrum, with intensity of the soil gas signal on the vertical axis, and atomic mass units (AMU) on the horizontal axis. The mass spectra are provided in Appendix A.

The TD-GC/MS analysis was conducted by using a cyrofocusing unit, a pyrolyzer, a gas chromatograph, and a mass spectrometer on a Hewlett-Packard system. The collection wires were analyzed and then a computerized library search was performed. The TD-GC/MS results were reported as chromatograms, mass spectra, and tables of computerized search results.

4.0 QUALITY ASSURANCE/QUALITY CONTROL FOR THE HANFORD PROJECT

Approximately ten percent of the Petrex survey samplers contain three collection wires. These third wires were used for quality control. One of the quality control wires was used to test the mass spectrometer's operating conditions prior to analyzing the samples. Some of the other quality control collectors were used to check the mass spectrometer sensitivity during survey analysis. In addition, quality control collectors were used to compare the reproducibility of the sample results. Quality assurance was maintained by tuning the instrument to manufacturer's specifications and analysis of blank wires.

4.1 Travel Blanks

For each of the five groups of samplers, two Petrex travel blank samplers, which remained sealed, traveled with the survey samplers from the lab, to the field, and back to the lab. These travel blank samplers were analyzed concurrently with the survey samplers under the same operating conditions on the mass spectrometer. The results of the analysis of the ten travel blanks indicated the only significant peaks present in the mass spectra were attributable to the atmospheric compounds normally seen on all Petrex samplers.

5.0 FIELD ACTIVITIES

A NERI geologist and a Battelle representative installed a total of 25 Petrex soil gas samplers at this site. Five samplers were placed approximately one foot apart at each of five sites within the DOE facility. All of the samplers were installed approximately 18 inches below the surface. The collectors were divided into the following five groups:

Site 1: Suspected Contaminated Area - Samples 1, 2, 3, 4, 5
Site 2: Suspected Contaminated Area - Samples 6, 7, 8, 9, 10
Site 3: Suspected Contaminated Area - Samples 11, 12, 13, 14, 15
Site 4: Suspected Contaminated Area - Samples 16, 17, 18, 19, 20
Site 5: Control Uncontaminated Area - Samples 21, 22, 23, 24, 25

A Battelle representative retrieved one sampler from each site each week for five weeks. The samplers were sealed upon removal and submitted to NERI's Lakewood, Colorado laboratory for TD-MS analysis. Further analysis by TD-GC/MS was performed on all of the samplers in NERI's Farmington, Connecticut laboratory.

6.0 THERMAL DESORPTION/MASS SPECTROMETRY (TD-MS) RESULTS

One collector wire from each survey sampler was analyzed by NERI's standard TD-MS method. The results of each analysis was provided in two types of output. One type of output was a numerical data file which listed one column of atomic mass units (AMUs) or peaks and a second column of the corresponding ion counts for each AMU. The second type of output was a graphical representation of the numerical data file. These graphical representations are the mass spectra provided in Appendix A.

Interpretation of the survey mass spectra proceeded by visually comparing the mass assignment of each peak and the ratio of peak heights to reference spectra where the peak heights were directly proportional to the number of ion counts at a peak. Ion count values are used to illustrate the relative intensity of each peak and are the unit of measure generated by mass spectrometric analysis. Ion counts do not represent a concentration measurement but are very useful in showing relative differences in response over the five weeks of exposure. Upon completion of the interpretation, six compounds were selected to best represent the results of the survey.

In order to compare the relative level of response for each of the six compounds from one week to another week, one unique or indicator peak out of all the peaks associated with each compound was selected. Table 2 lists the reported compounds and their indicator peaks. Table 3, Appendix B, lists the ion counts of each compound indicator peak as a function of site location and length of exposure.

TABLE 2
Reported Compounds and Their Selected Indicator Peaks

Reported Compounds	Indicator Peak
Toluene	92
Benzene	78
Trichloroethene (TCE)	130
Carbon Tetrachloride (CCl4)	121
Chloroform	83
Tetrachloroethene (PCE,	164

Table 3, Appendix B, lists the results of each sample from the site for each of the six reported compounds. As can be seen, none of the phosphorus-related compounds was detected. However, it was not expected that these compounds would volatilize to a gas phase so that they could be detected. With the exception of methylene chloride, all of the other target compounds were detected, as well as toluene, benzene, and PCE. Later in this report, the TD-GC/MS analyses will show the presence of non-target compounds.

Addressing the second objective of determining an appropriate residence time for Petrex samplers at the Hanford site, review of Table 3 shows that for most compounds that the ion count values stabilized at the two week exposure interval. Ion count data are usually interpreted on an order of magnitude basis such that large difference in responses are considered to be significant.

7.0 THERMAL DESORPTION-GAS CHROMATOGRAPHY/MASS SPECTROMETRY (TD-MS) RESULTS

The TD-GC/MS chromatograms and mass spectra obtained during the analysis of the Petrex samplers which were retrieved from the Hanford site on a weekly basis may be found in Books 1-5. Each book contains the results obtained during the analysis of samplers which were removed from the five sites simultaneously, thus, providing information pertaining to the effects of the length of the exposure on the samplers' ability to adsorb various compounds from the soil gas. The compounds were identified by employing the computer search routine which compares the mass spectra obtained during the TD-GC/MS analysis of the Petrex collector wires with those in the National Institute of Science and Technology's Library of Mass Spectra. The project manager screened the search results obtained by the computer and where necessary verified the computer's suggested identifications. A standard mixture, containing the six compounds reported in the TD-MS results, was prepared to provide gas chromatographic retention times as well as mass spectral information. This mixture was run under the identical conditions used to analyze the unknowns.

Additional quality control and quality assurance procedures were employed for this study. A systems blank was obtained on a daily basis; this procedure provided information pertaining to the status of the TD-GC/MS system as a result of conducting a "no sample test" standard. In addition to this procedure, a "non-exposed Petrex wire" was run to identify the presence of any low-level chemical species produced as a consequence of sampling procedures or unknown contamination.

8.0 CONCLUSIONS

Based on the objectives of this survey, the following conclusions can be made. Overall, the Petrex passive soil gas method has worked well for this survey. Three of the compounds of interest, TCE, CCL_4, and chloroform were detected at this site. In addition, toluene, benzene, and PCE were also detected. Methylene chloride was not detected by the TD-MS analysis, and its absence was confirmed by TD-GC/MS analysis.

Some of the compounds of interest, TBP, DBBP, DBP, MBP, and triglycerides were not detected in this survey due to their absence from the soil gas. This possibility was noted prior to the start of the survey.

Based on the TD-MS analytical results, two weeks is the appropriate sampler field exposure time at this site. After two weeks, the samplers showed sufficient levels of the detected compounds and were within the range of response normally used by NERI for mapping and reporting compounds.

APPENDIX A

MASS SPECTRA

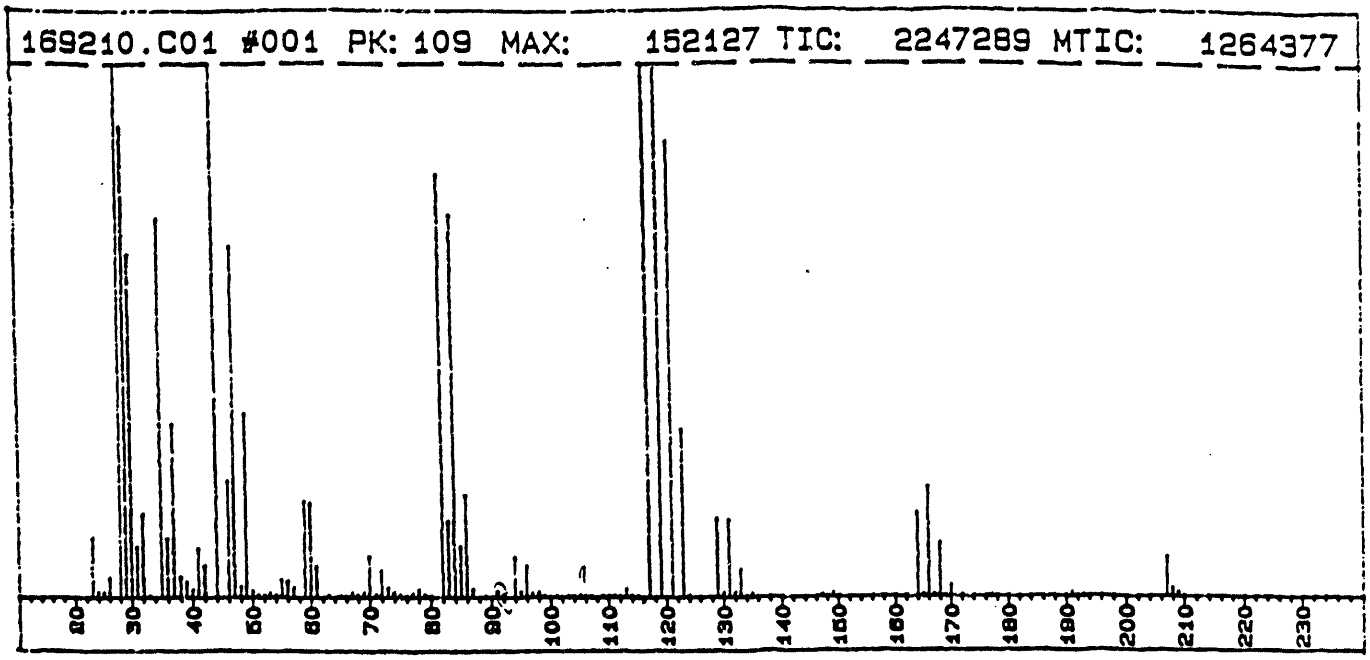


Figure B-1a. PY/MS Spectrum - Site # 1 - 1 Week Exposure

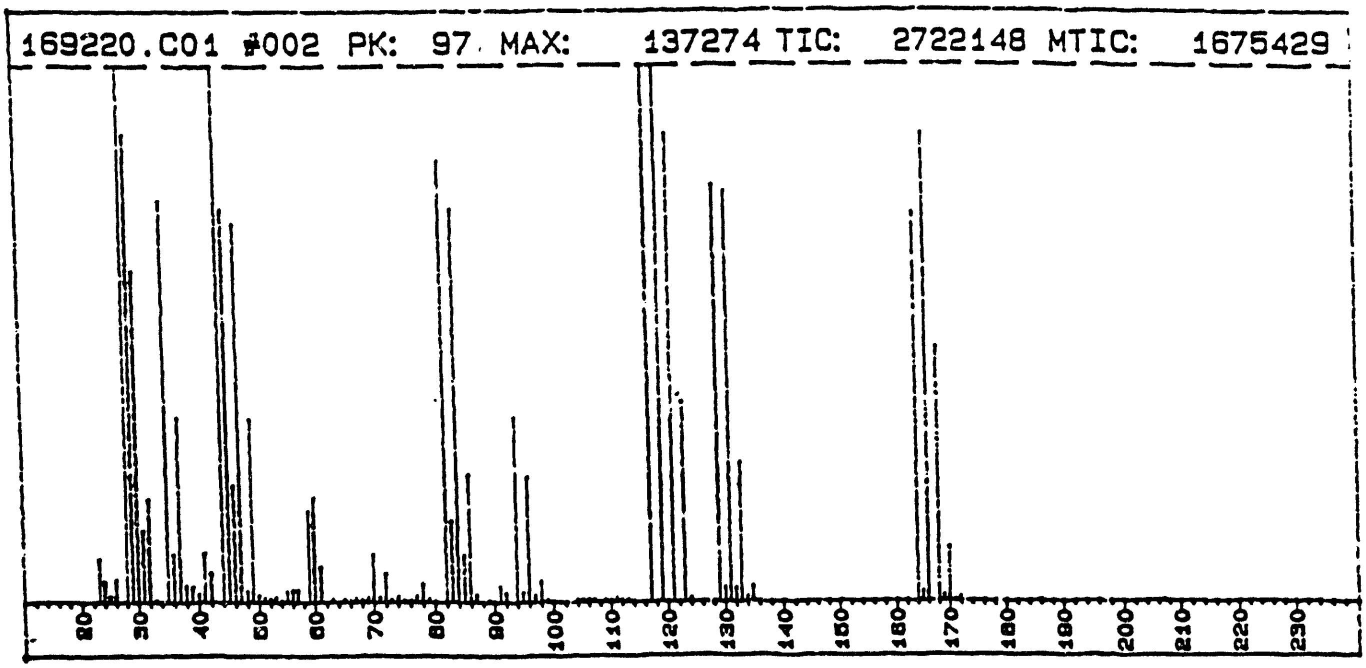


Figure B-1b. PY/MS spectrum - Site # 1 - 2 Weeks Exposure

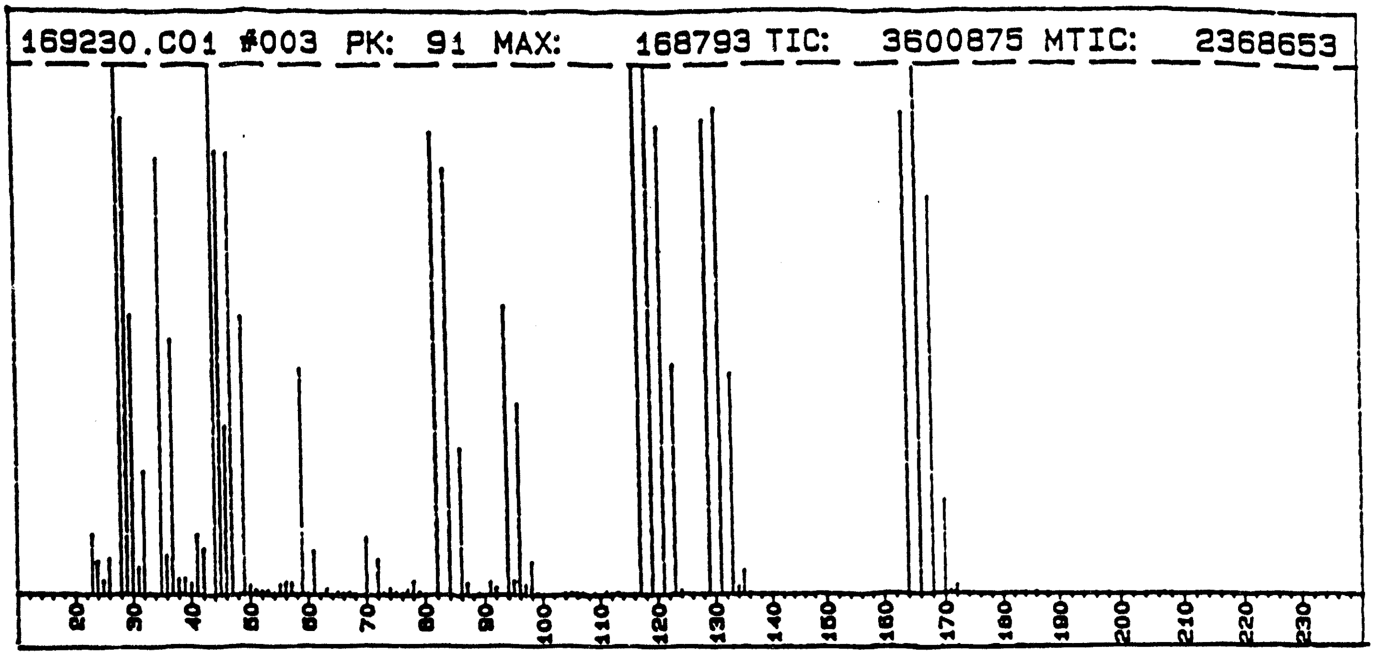


Figure B-1c. PY/MS Spectrum - Site # 1 - 3 Weeks Exposure

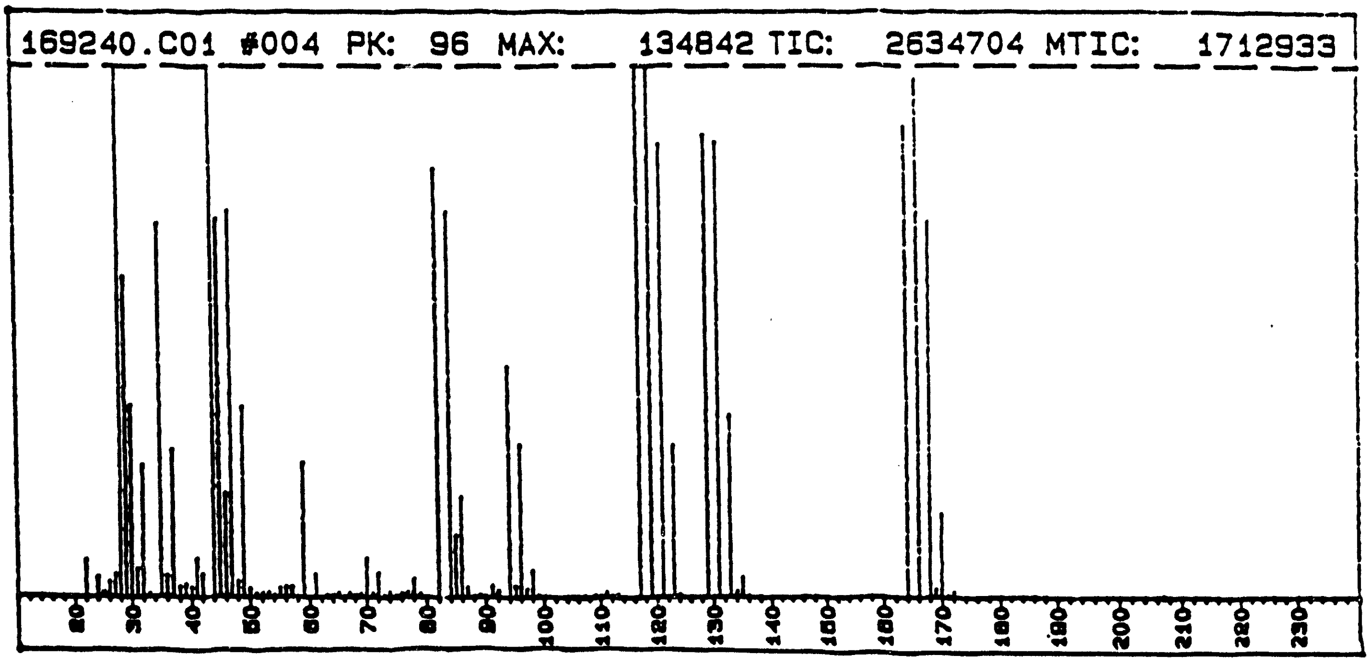


Figure B-1d. PY/MS spectrum - Site # 1 - 4 Weeks Exposure

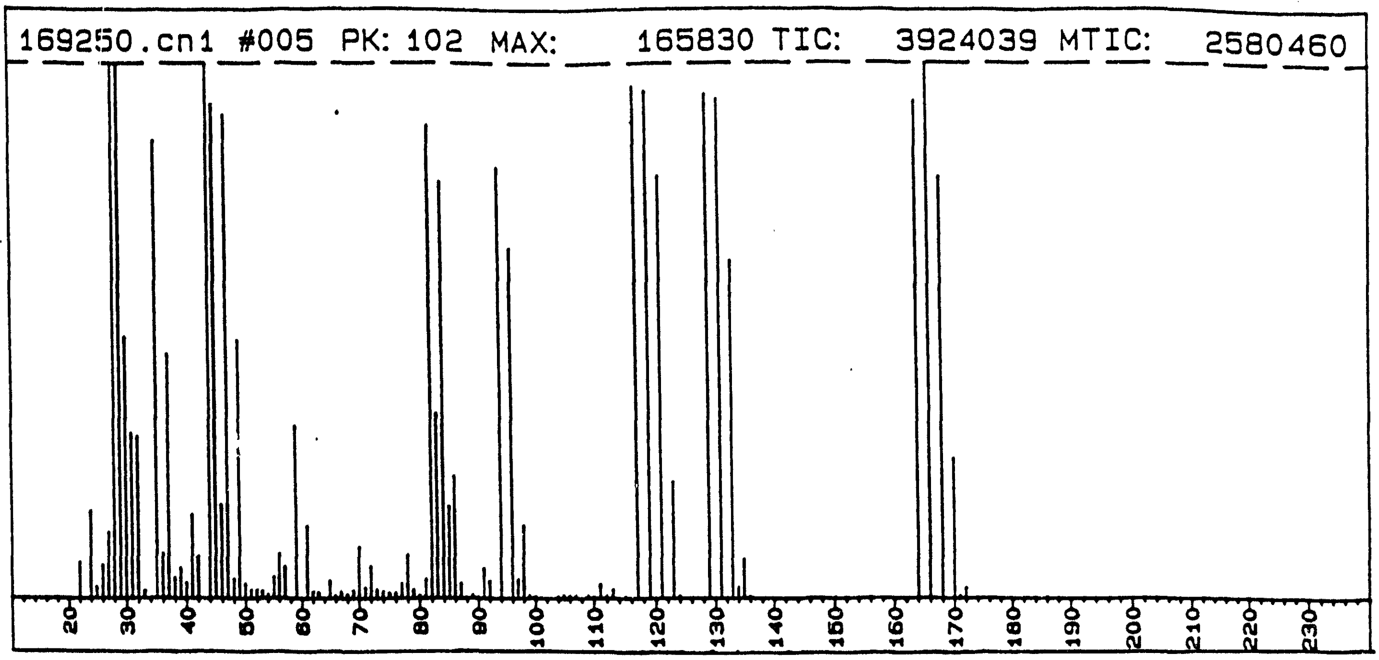


Figure B-1e. PY/MS Spectrum - Site # 1 - 5 Weeks Exposure

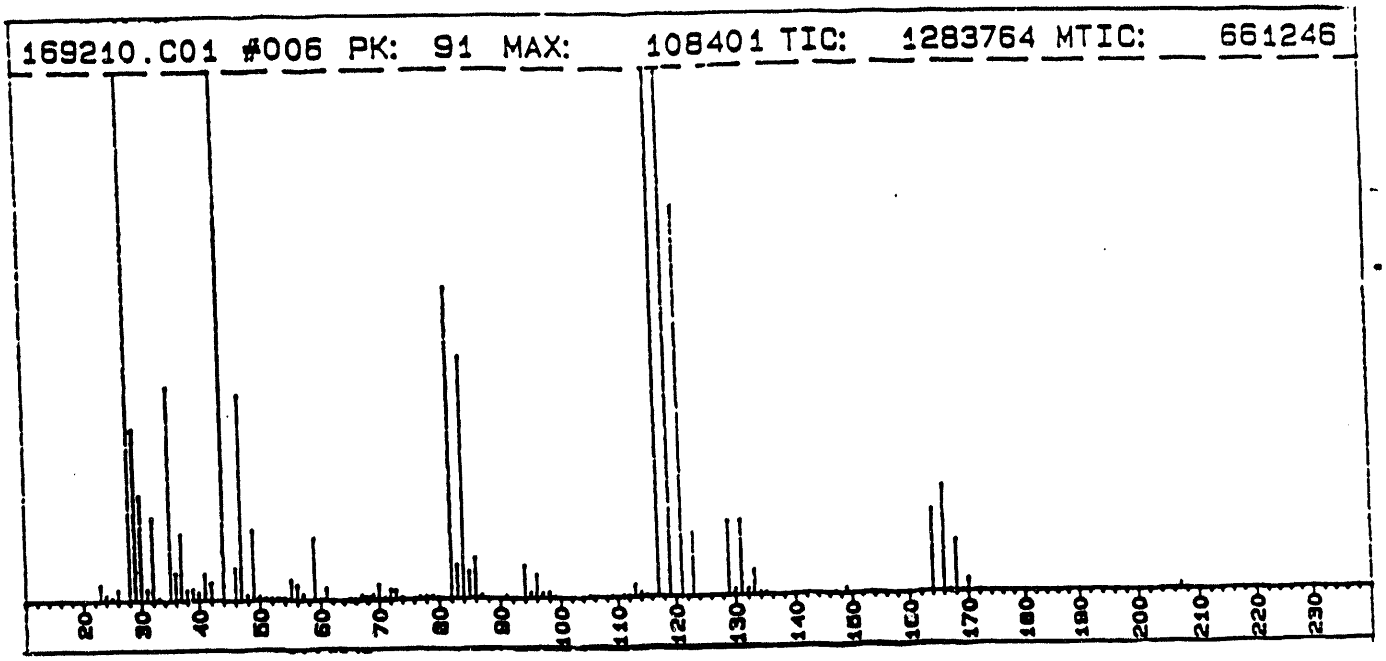


Figure B-2a. PY/MS Spectrum - Site # 2 - 1 Week Exposure

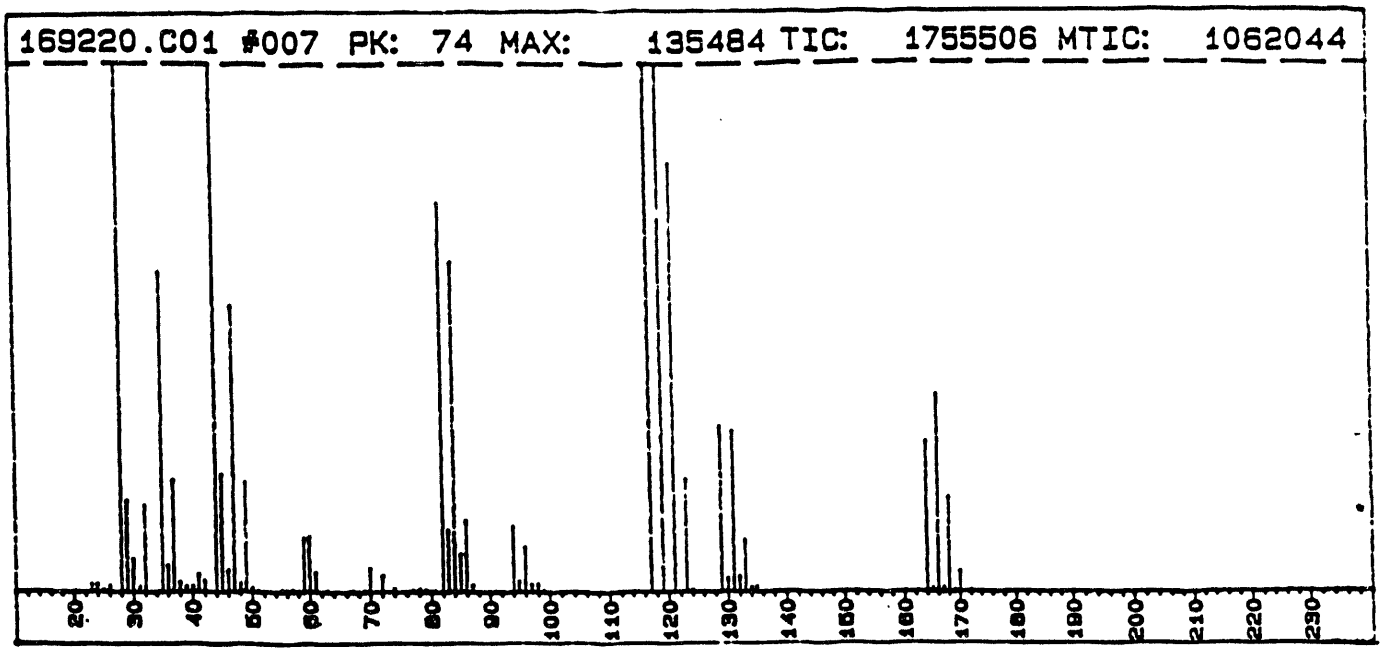


Figure B-2b. PY/MS spectrum - Site # 2 - 2 Weeks Exposure

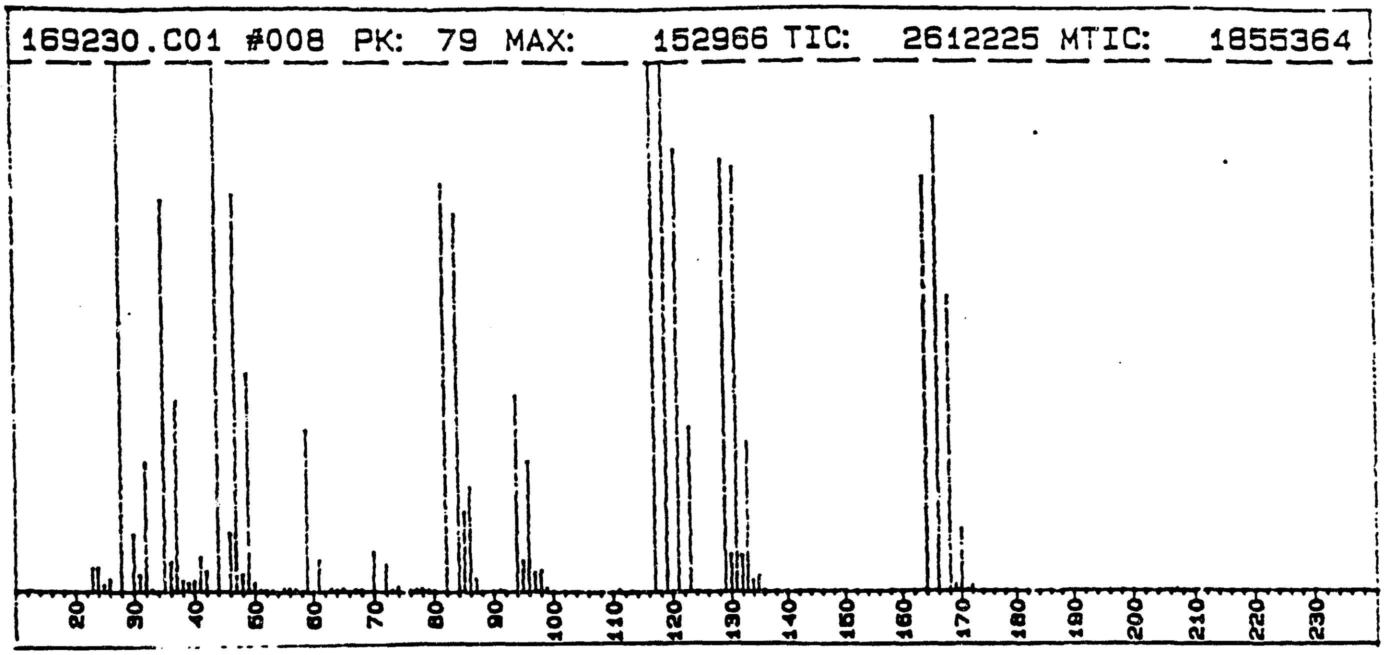


Figure B-2c. PY/MS Spectrum - Site # 2 - 3 Weeks Exposure

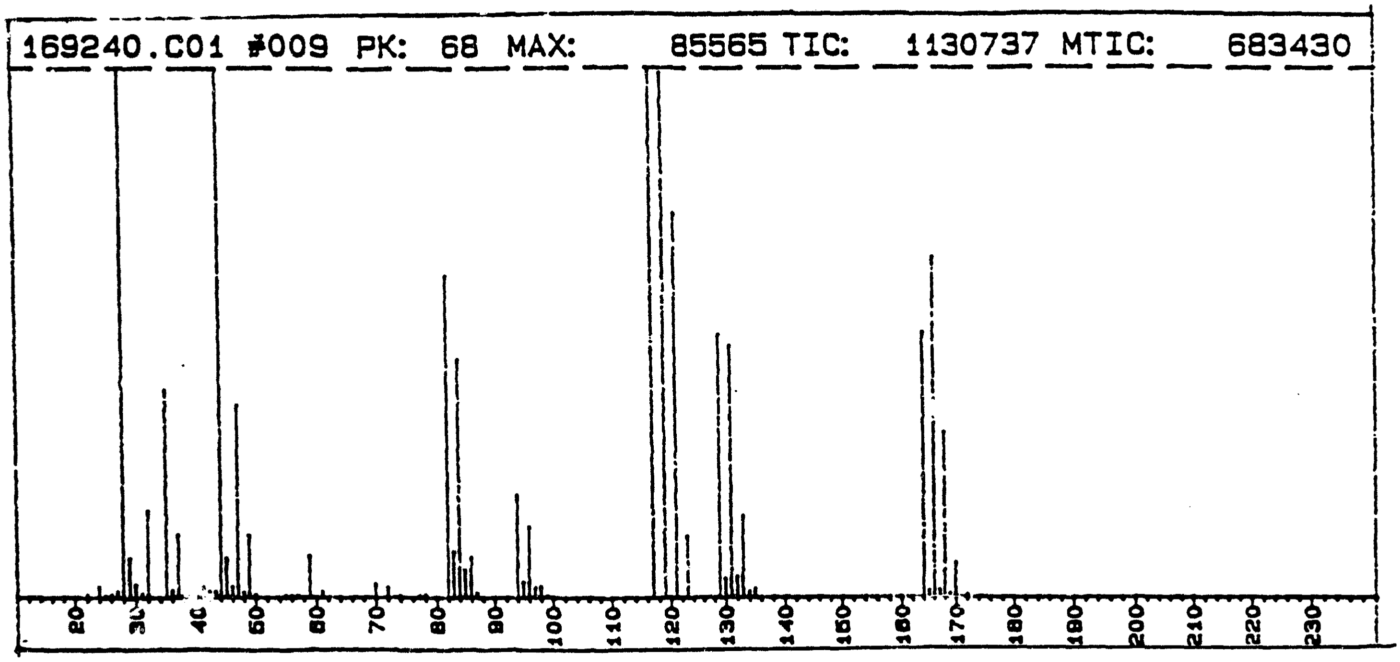


Figure B-2d. PY/MS spectrum - Site # 2 - 4 Weeks Exposure

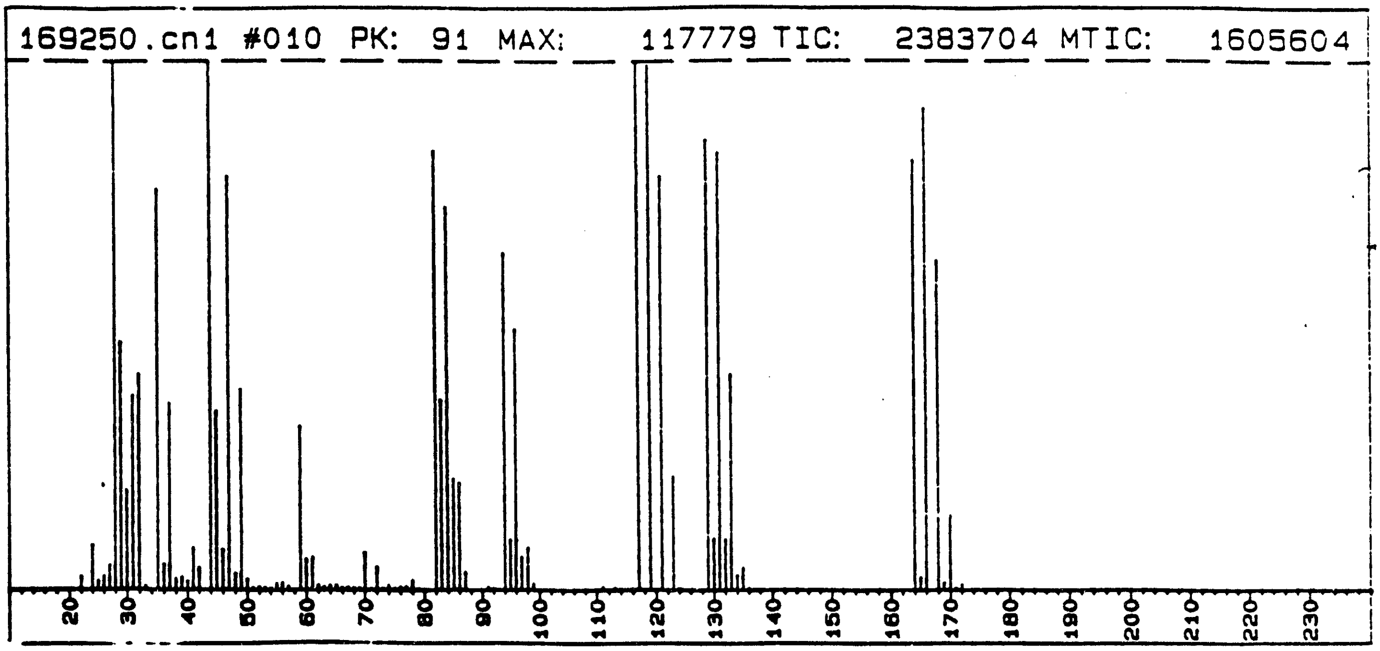


Figure B-2e. PY/MS Spectrum - Site # 2 - 5 Weeks Exposure

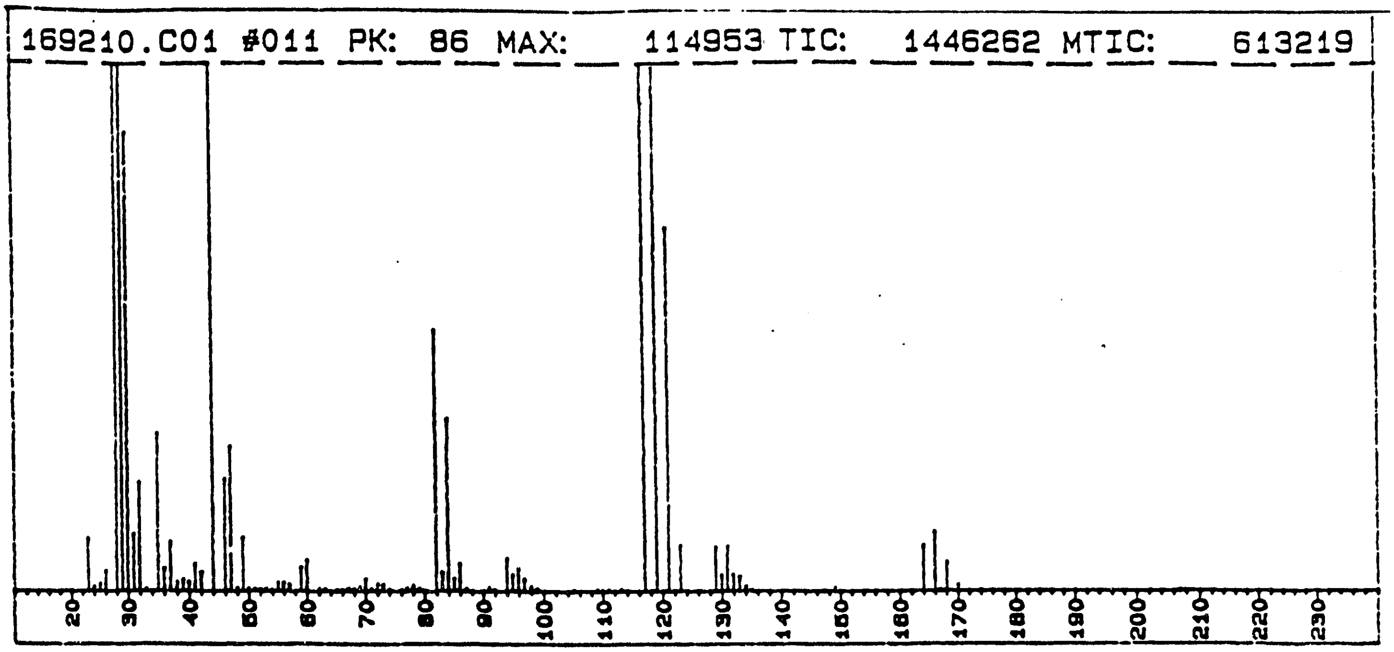


Figure B-3a. PY/MS Spectrum - Site # 3 - 1 Week Exposure

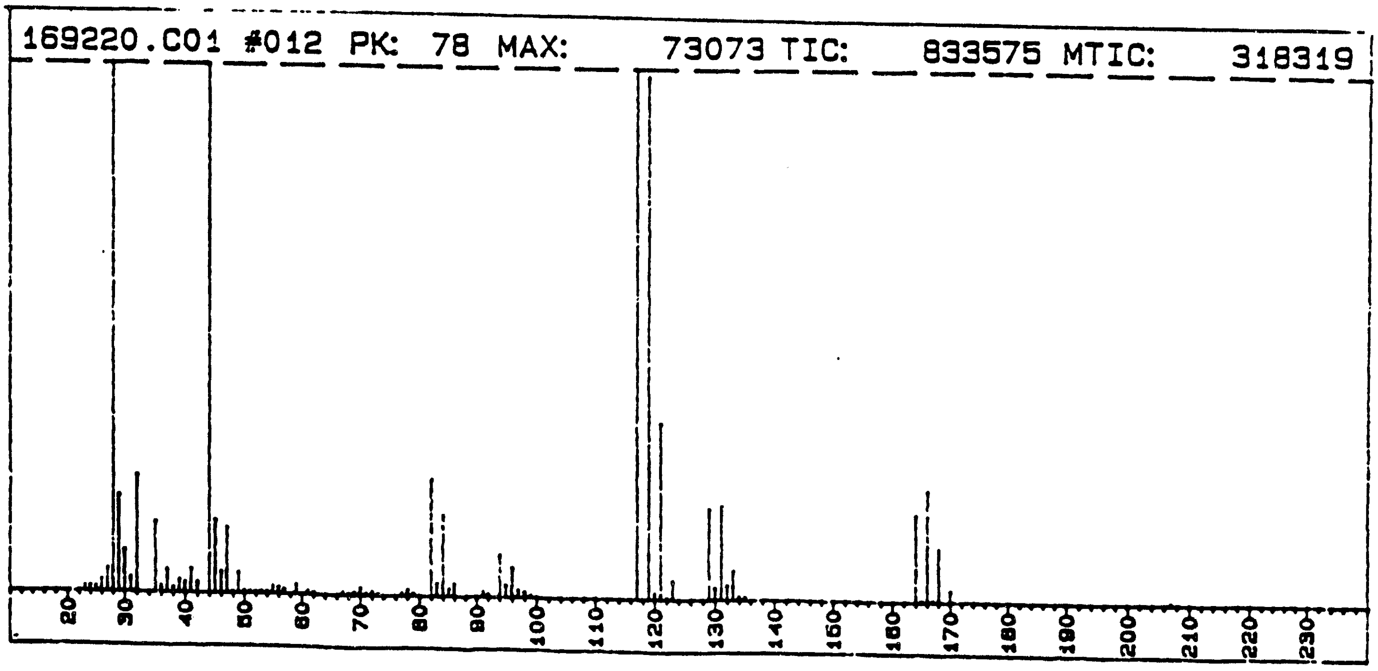


Figure B-3b. PY/MS spectrum - Site # 3 - 2 Weeks Exposure

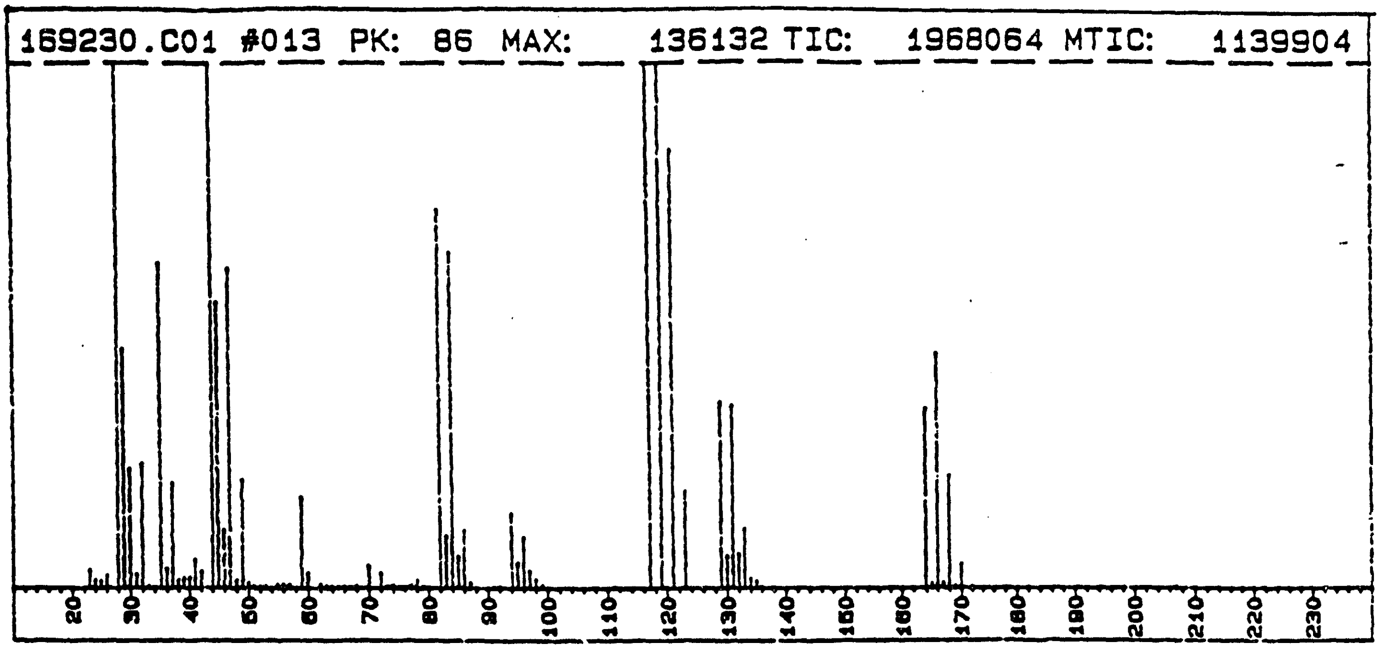


Figure B-3c. PY/MS Spectrum - Site # 3 - 3 Weeks Exposure

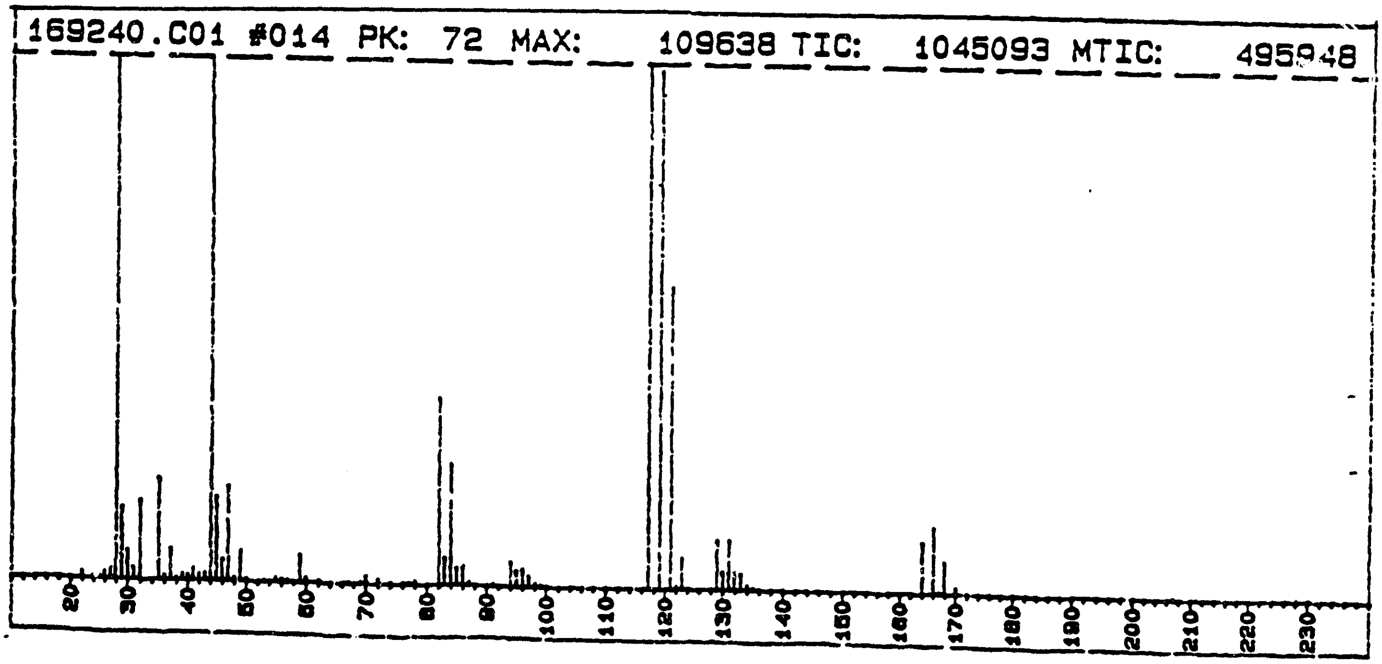


Figure B-3d. PY/MS spectrum - Site # 3 - 4 Weeks Exposure

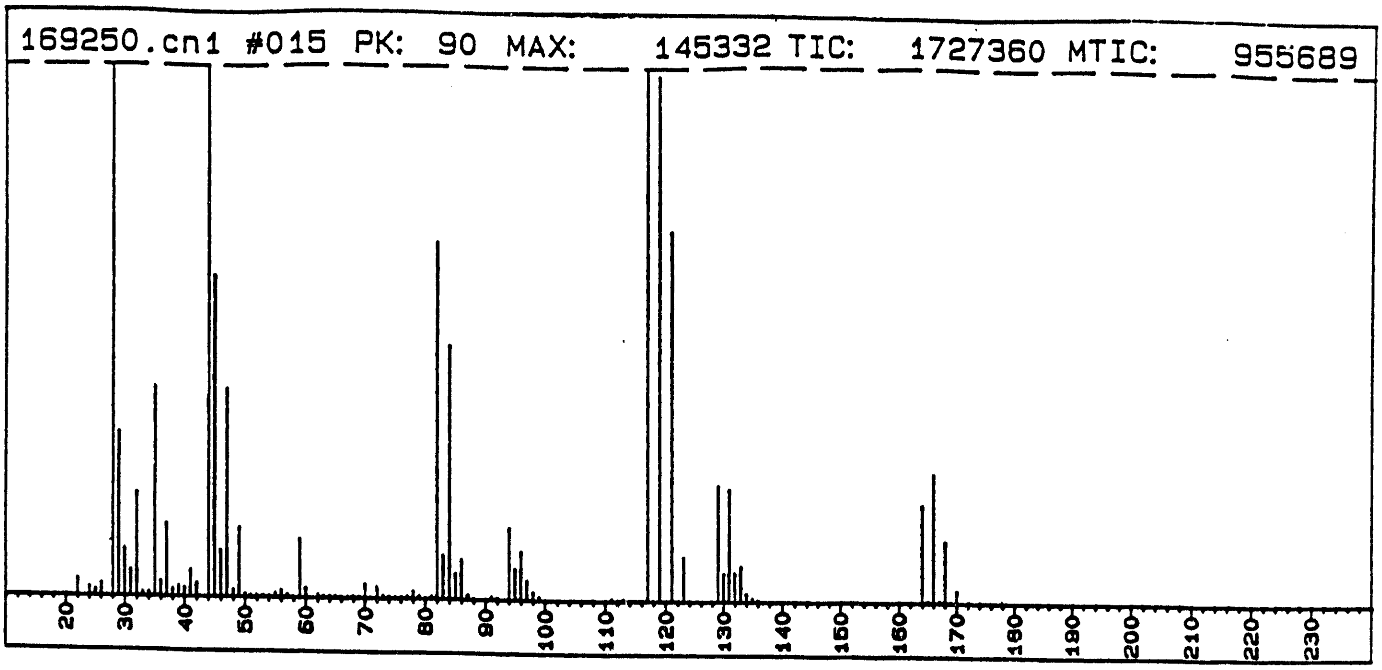
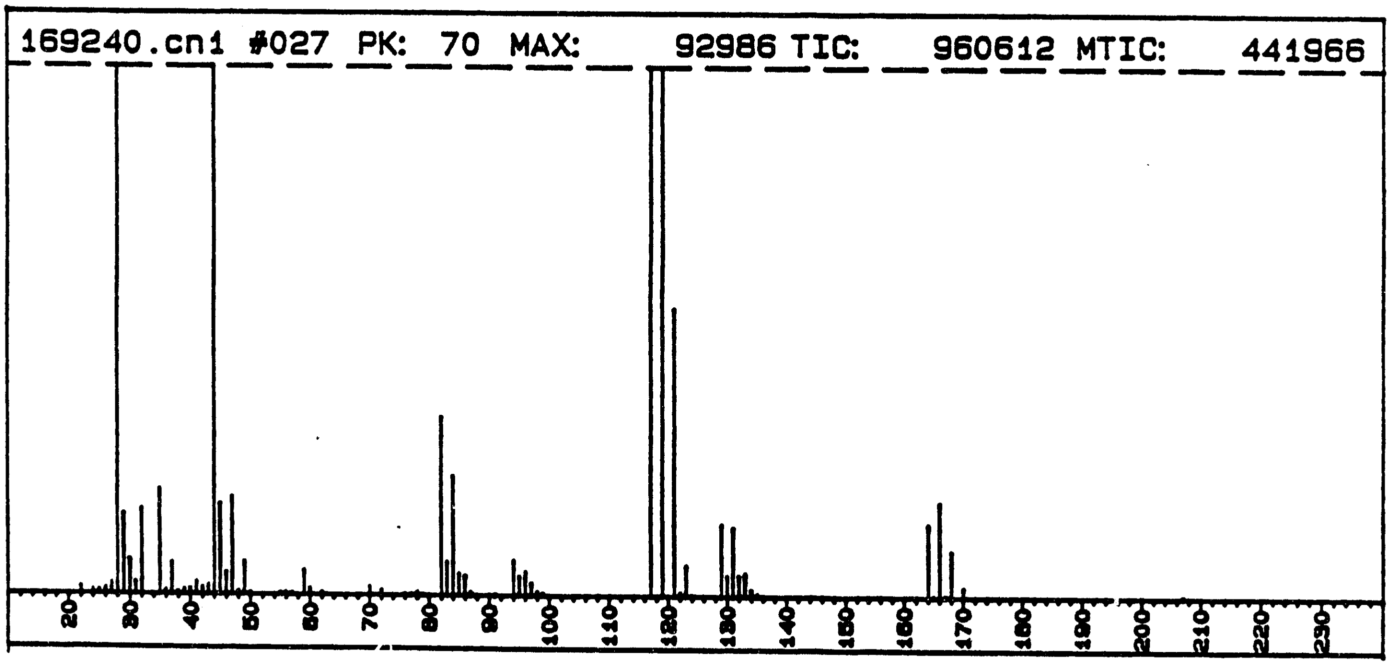


Figure B-3e. PY/MS Spectrum - Site # 3 - 5 Weeks Exposure



Duplicate of Sample #014

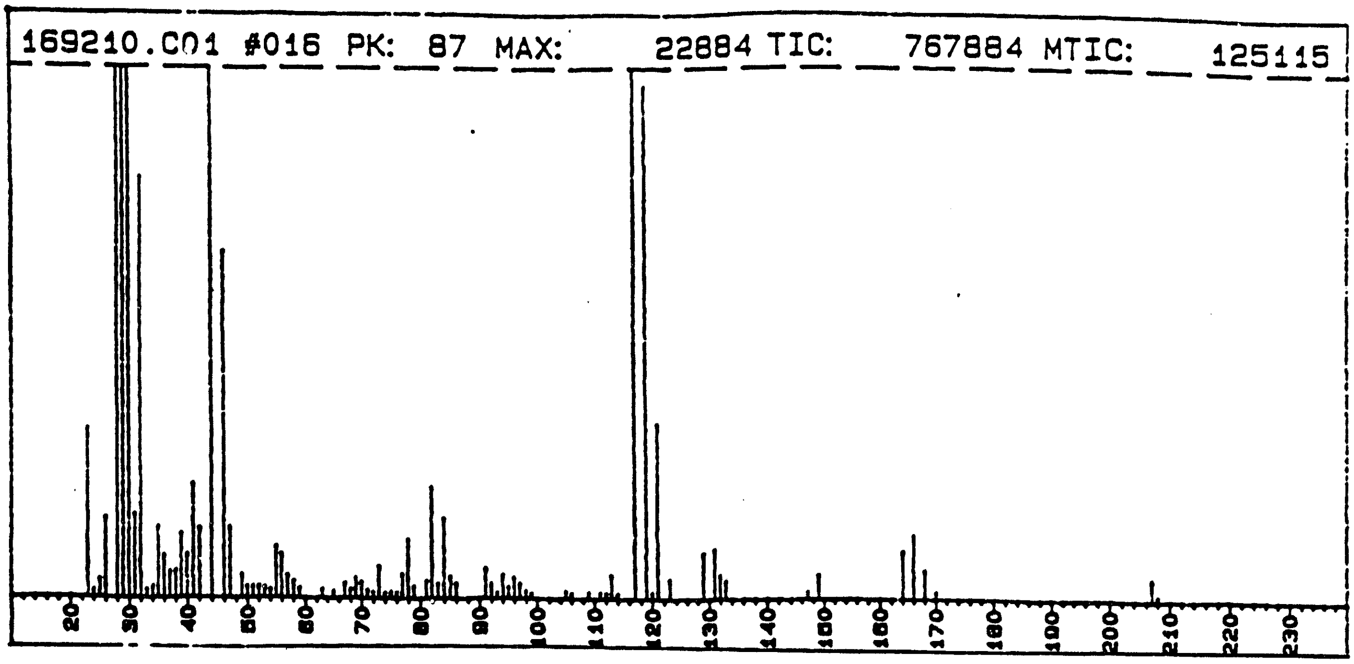


Figure B-4a. PY/MS Spectrum - Site # 4 - 1 Week Exposure

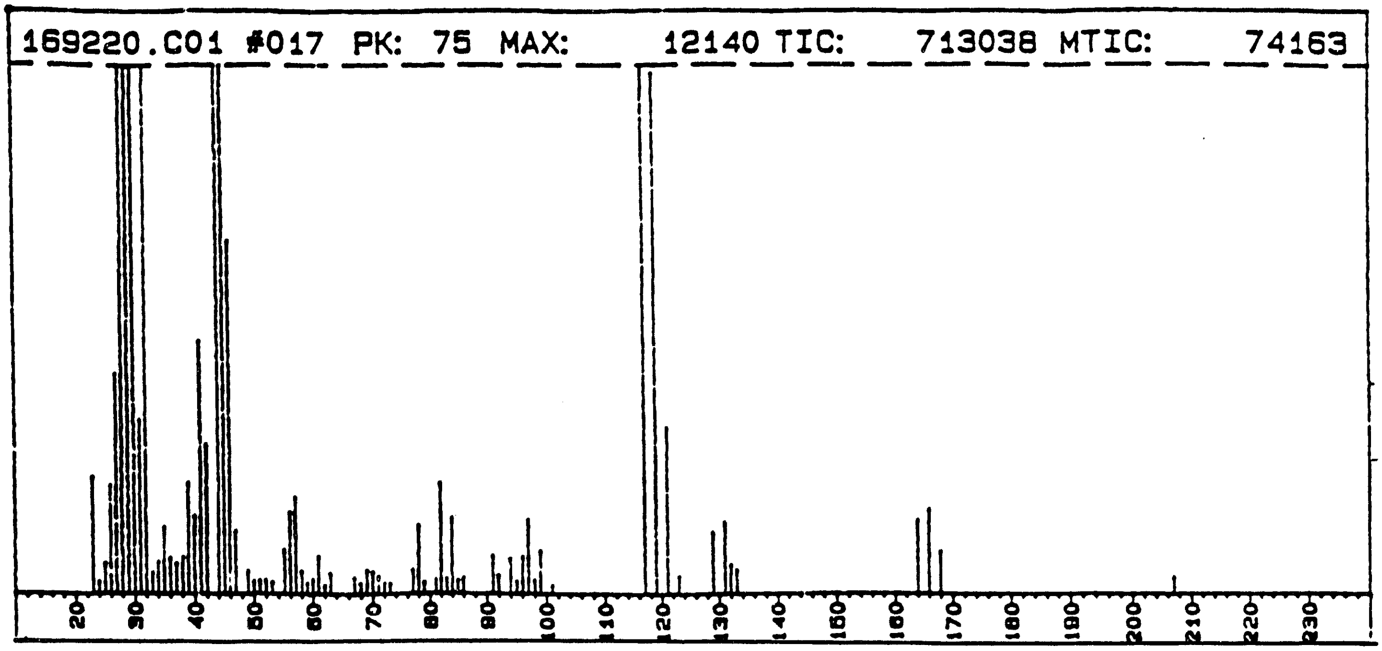


Figure B-4b. PY/MS spectrum - Site # 4 - 2 Weeks Exposure

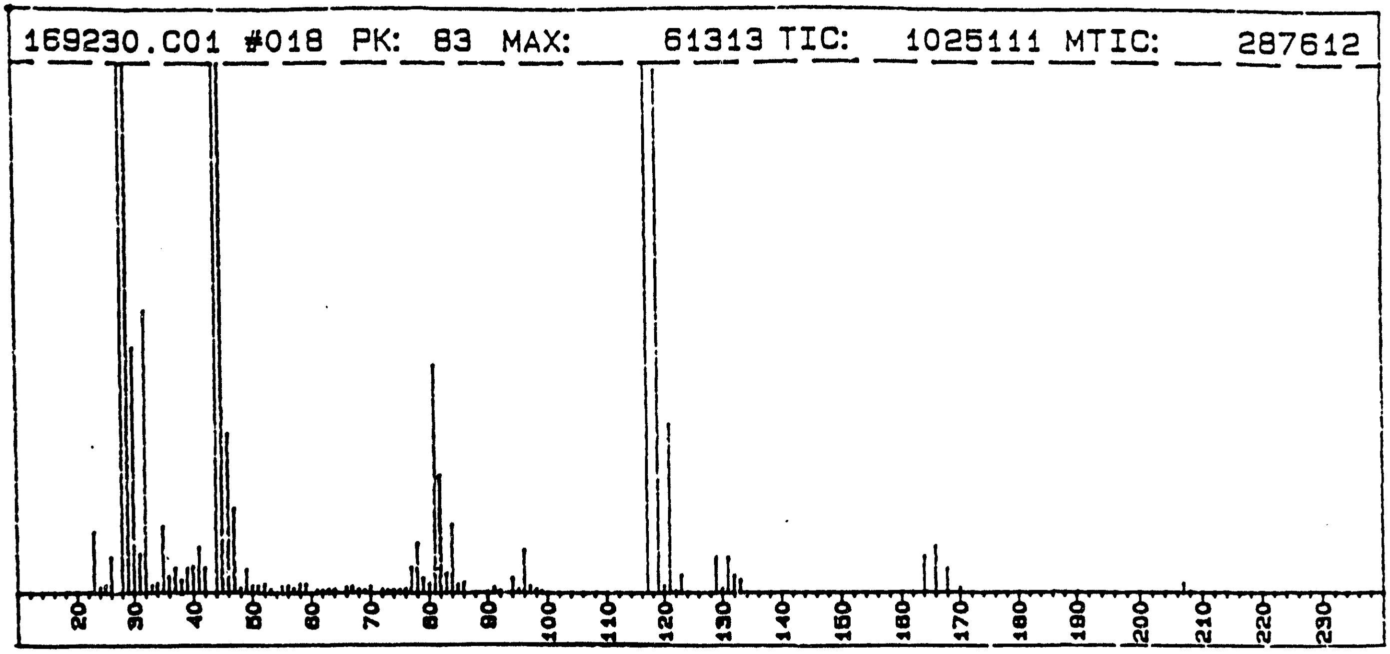


Figure B-4c. PY/MS Spectrum - Site # 4 - 3 Weeks Exposure

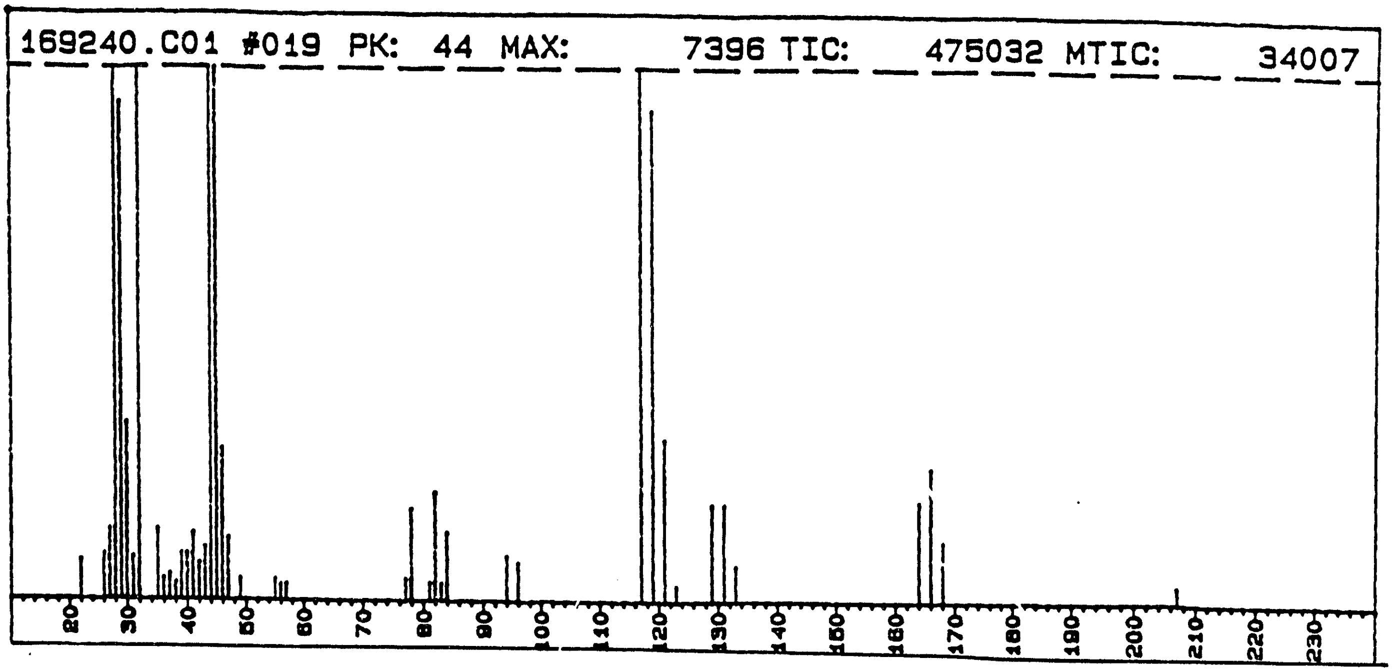


Figure B-4d. PY/MS spectrum - Site # 4 - 4 Weeks Exposure

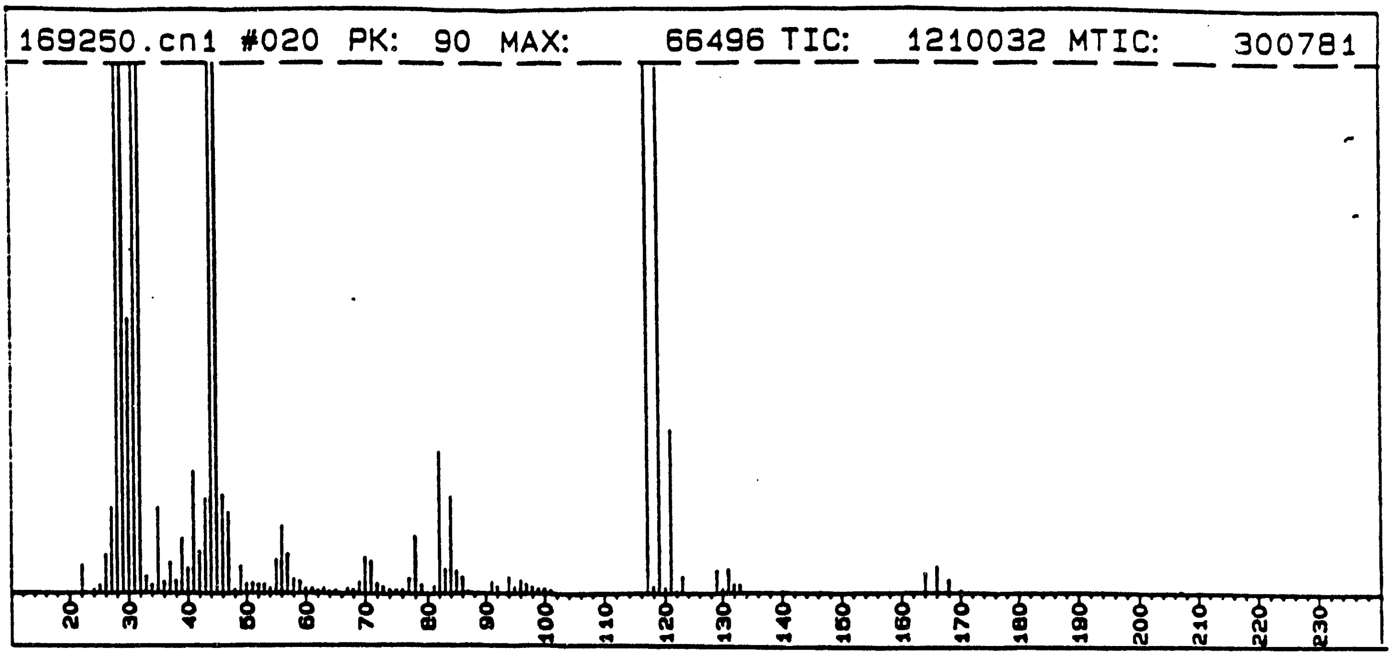
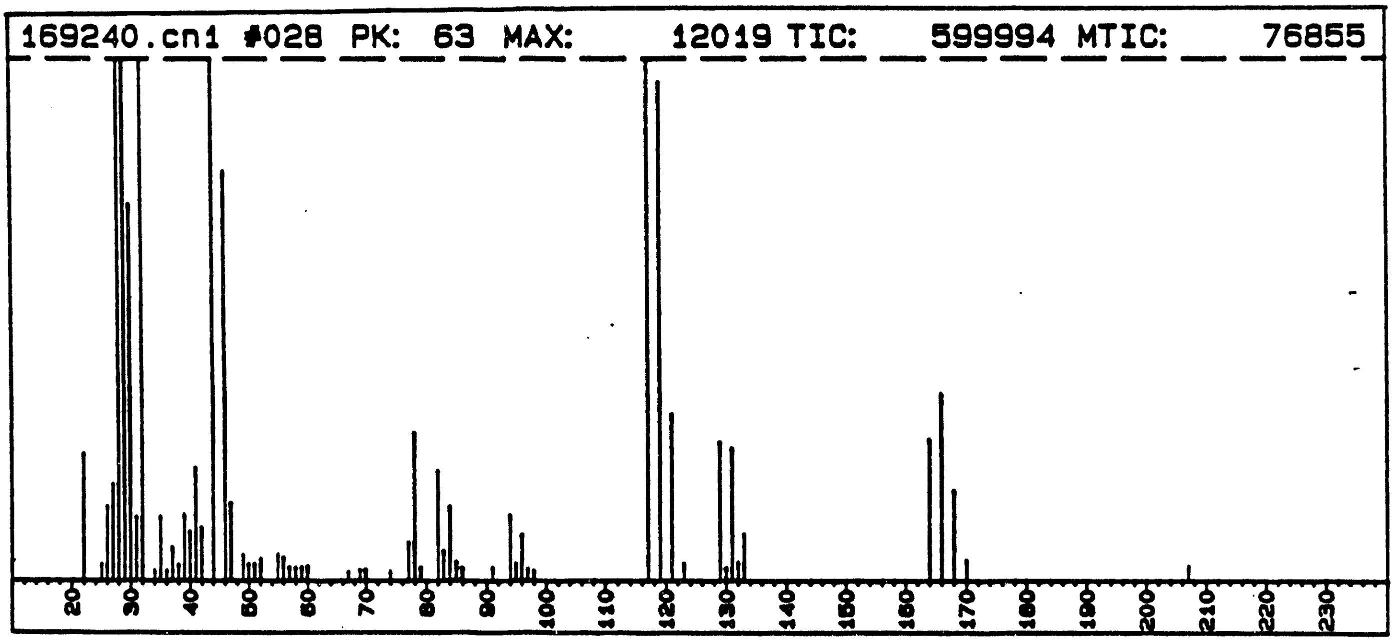


Figure B-4e. PY/MS Spectrum - Site # 4 - 5 Weeks Exposure



Duplicate of #019

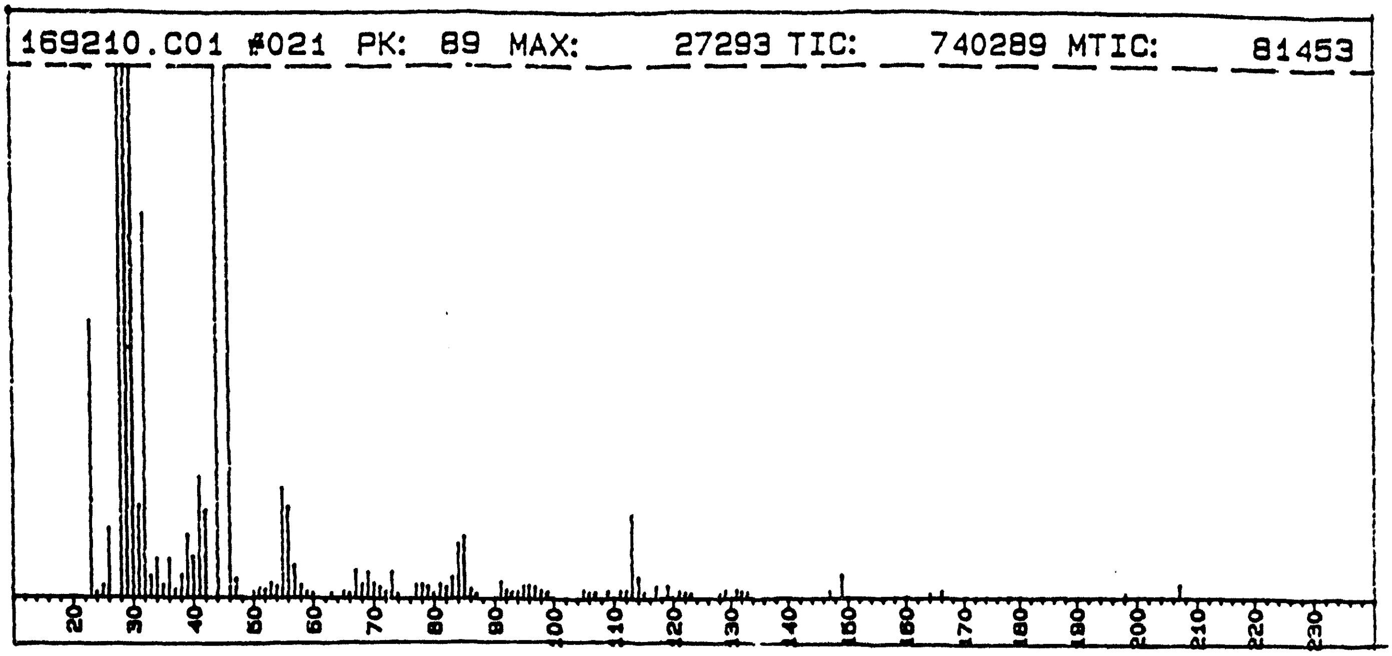


Figure B-5a. PY/MS Spectrum - Site # 5 - 1 Week Exposure

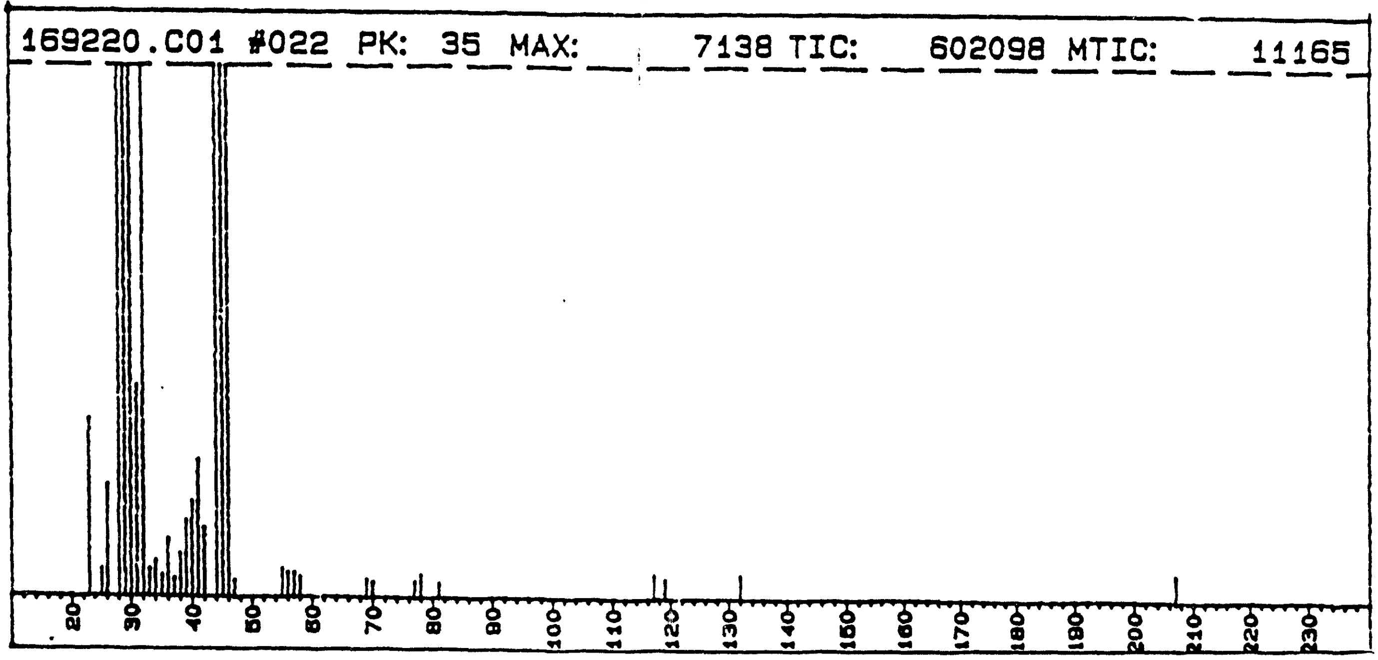


Figure B-5b. PY/MS spectrum - Site # 5 - 2 Weeks Exposure

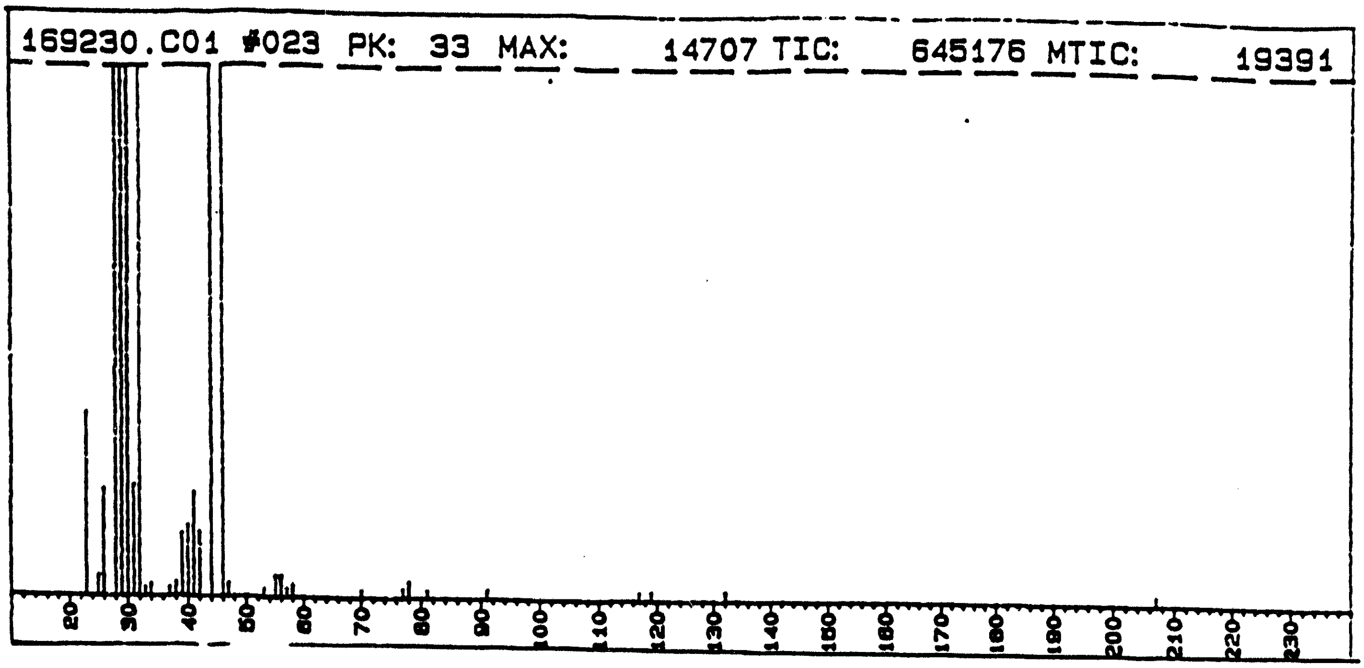


Figure B-5c. PY/MS Spectrum - Site # 5 - 3 Weeks Exposure

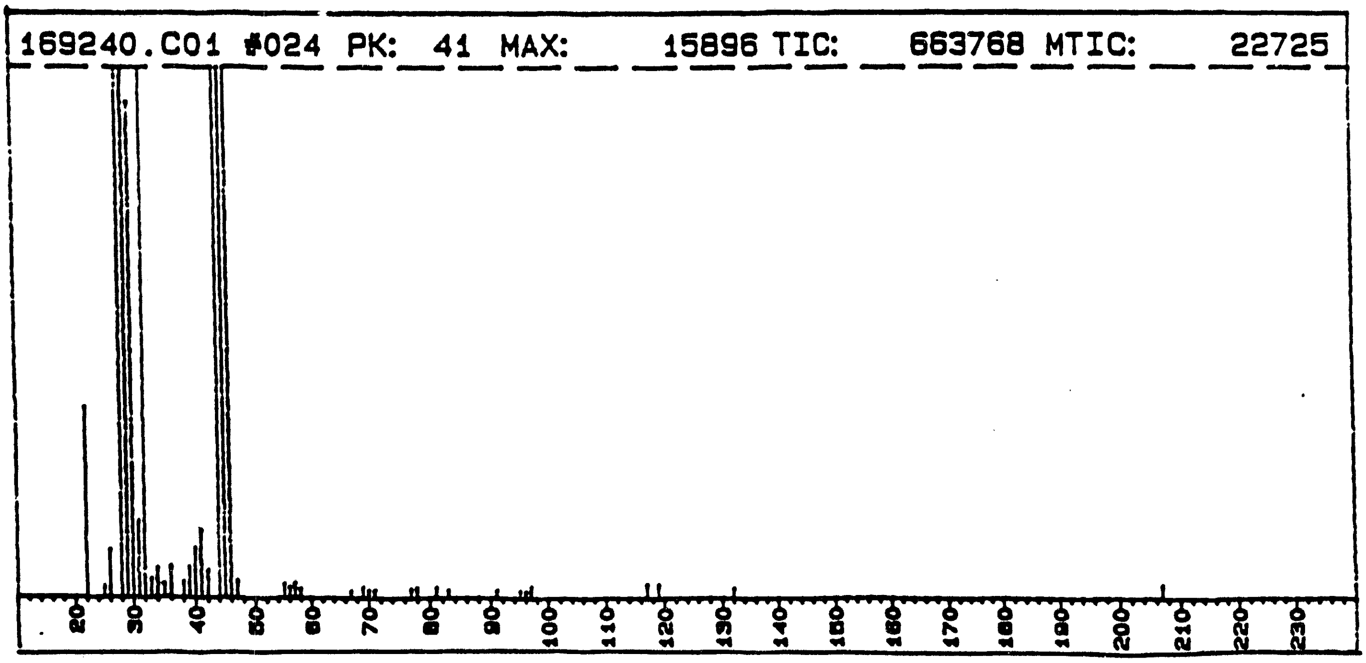


Figure B-5d. PY/MS spectrum - Site # 5 - 4 Weeks Exposure

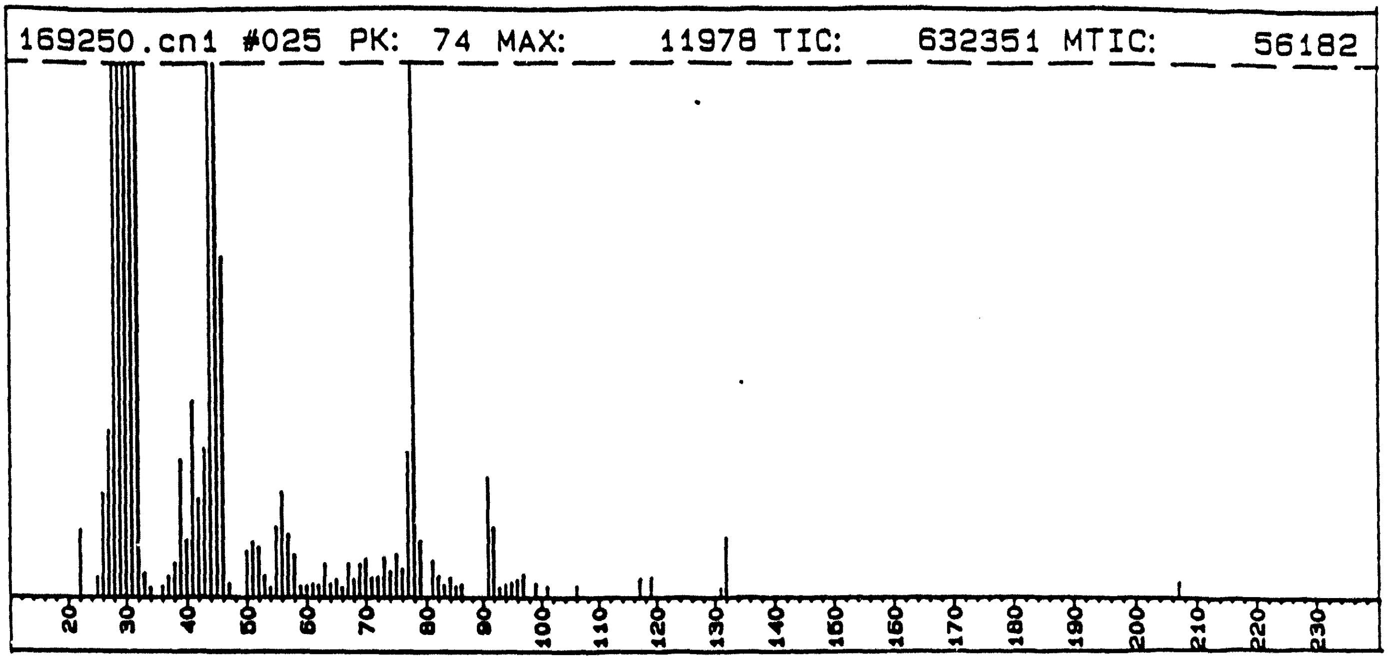
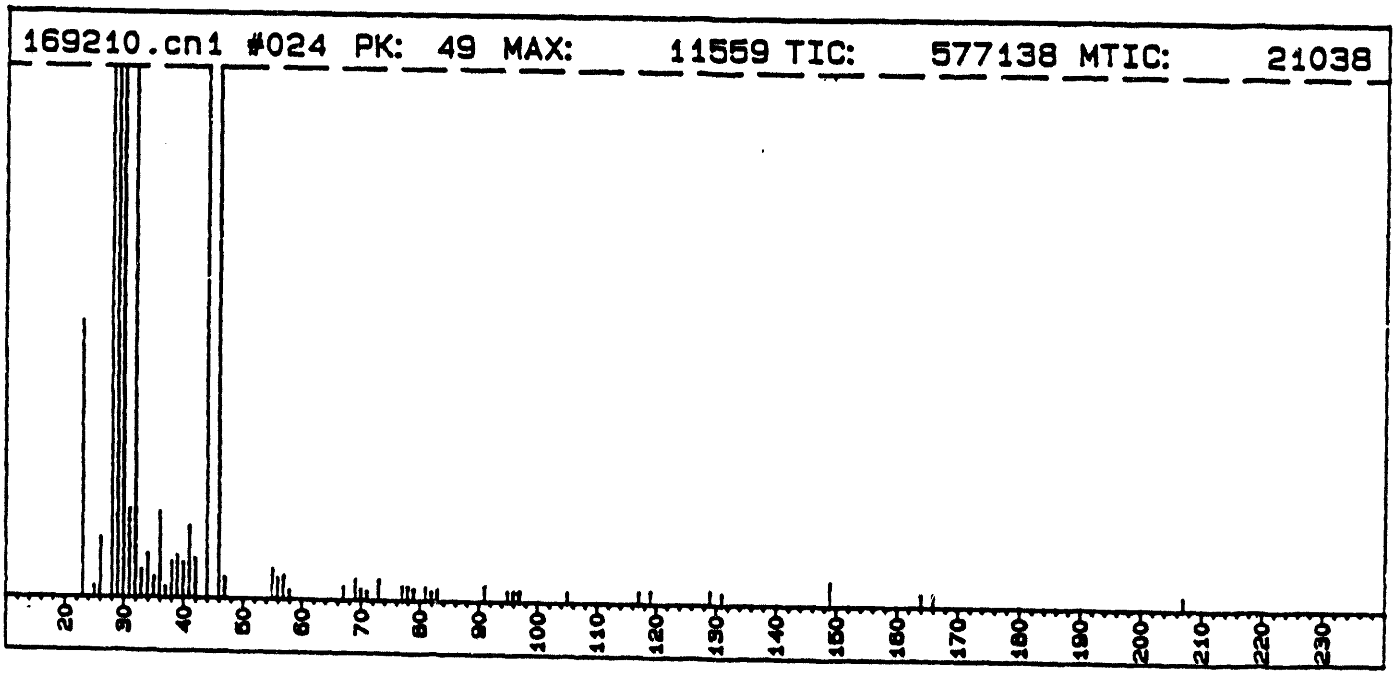
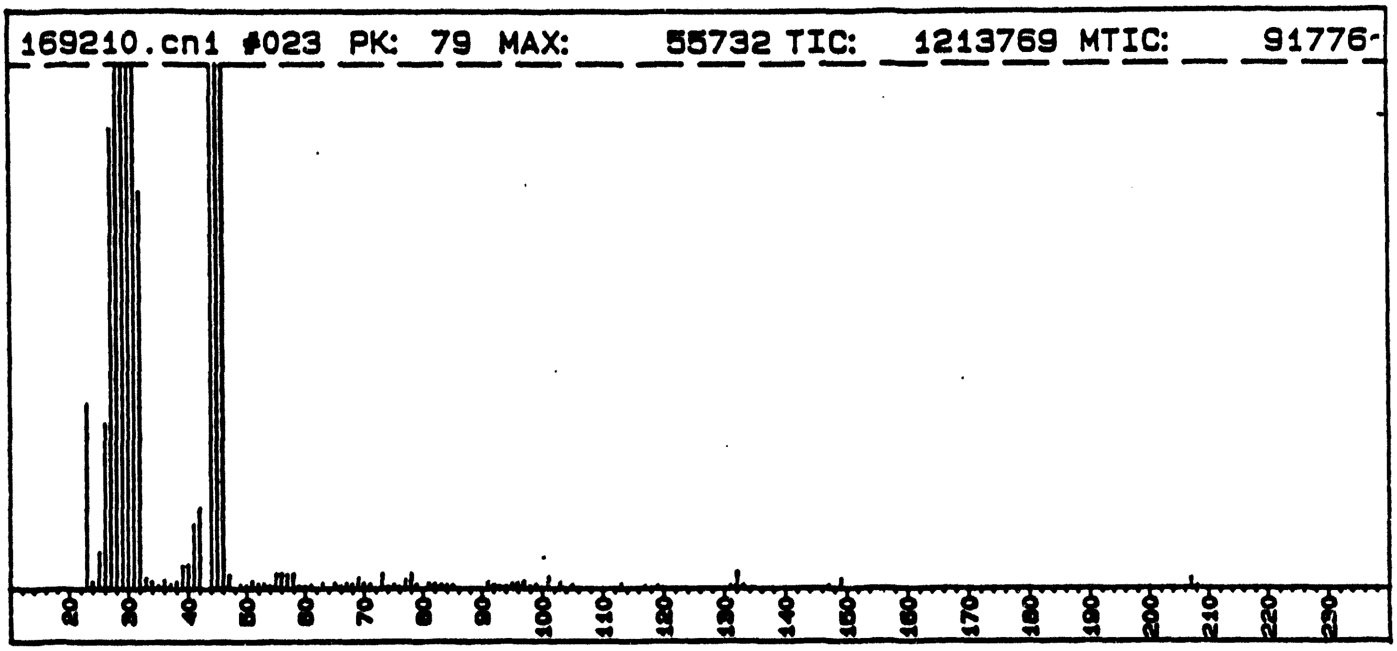


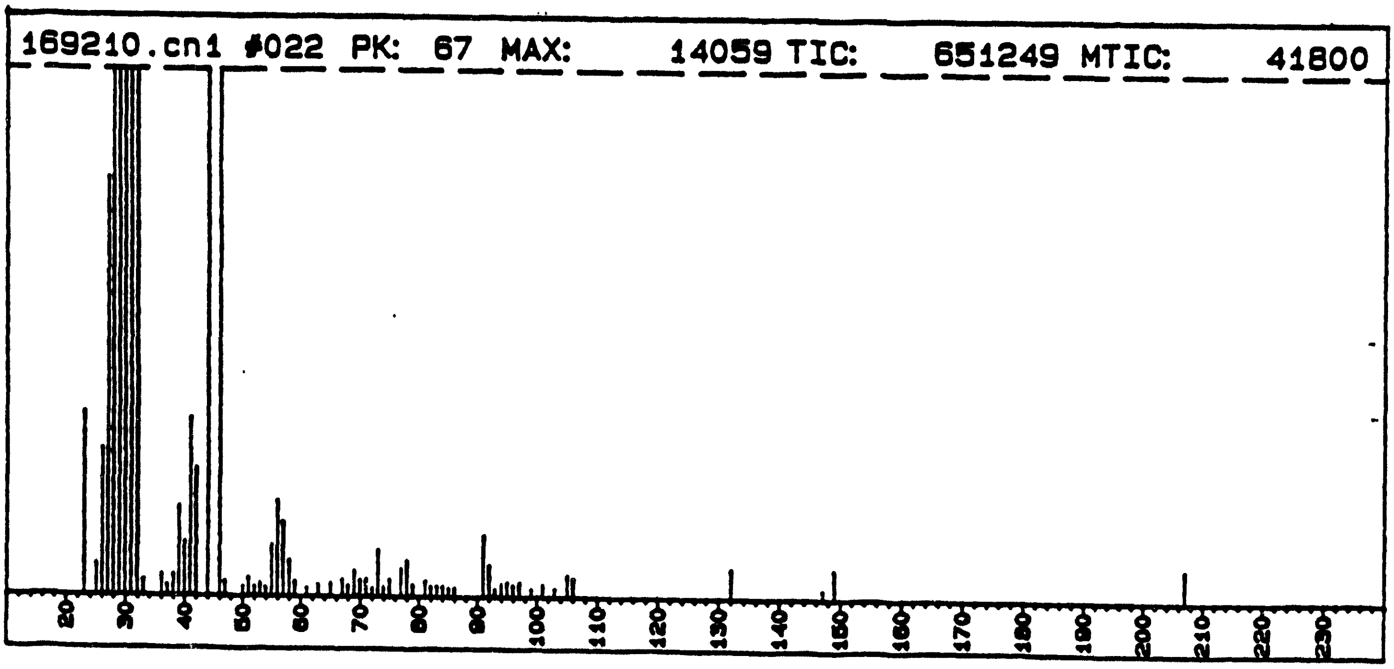
Figure B-5e. PY/MS Spectrum - Site # 5 - 5 Weeks Exposure

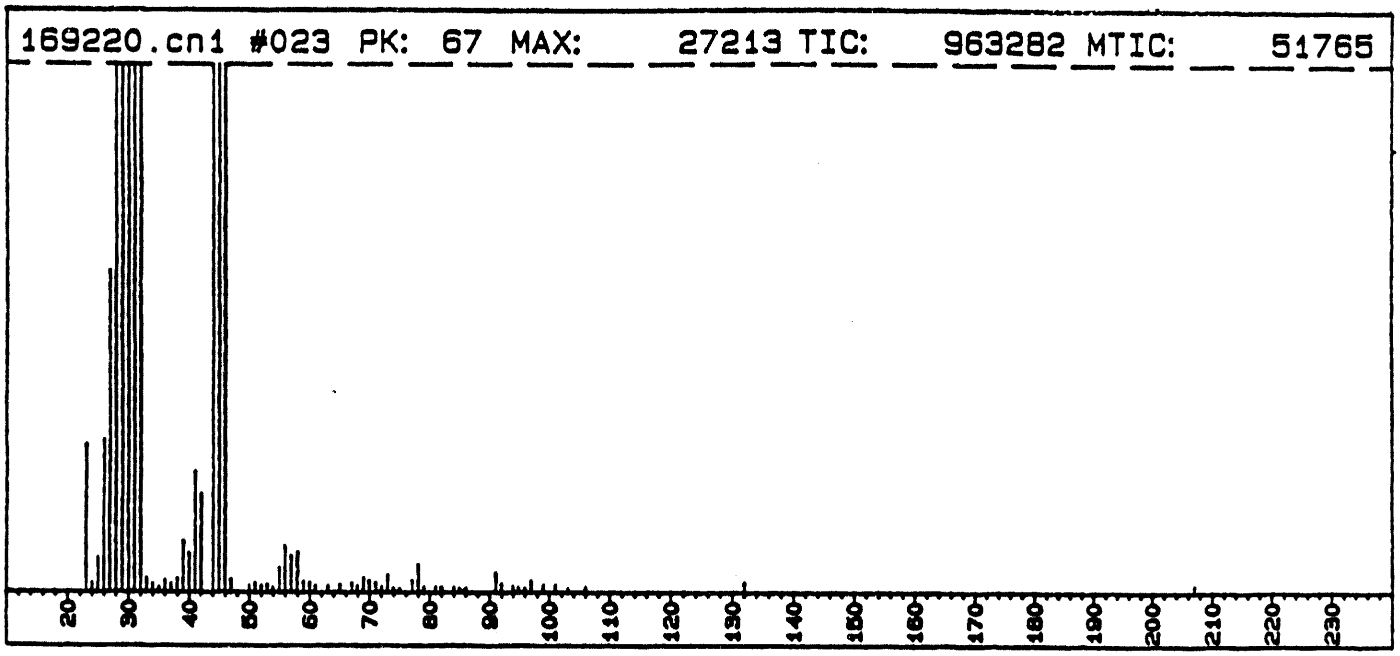


Duplicate of Sample #021

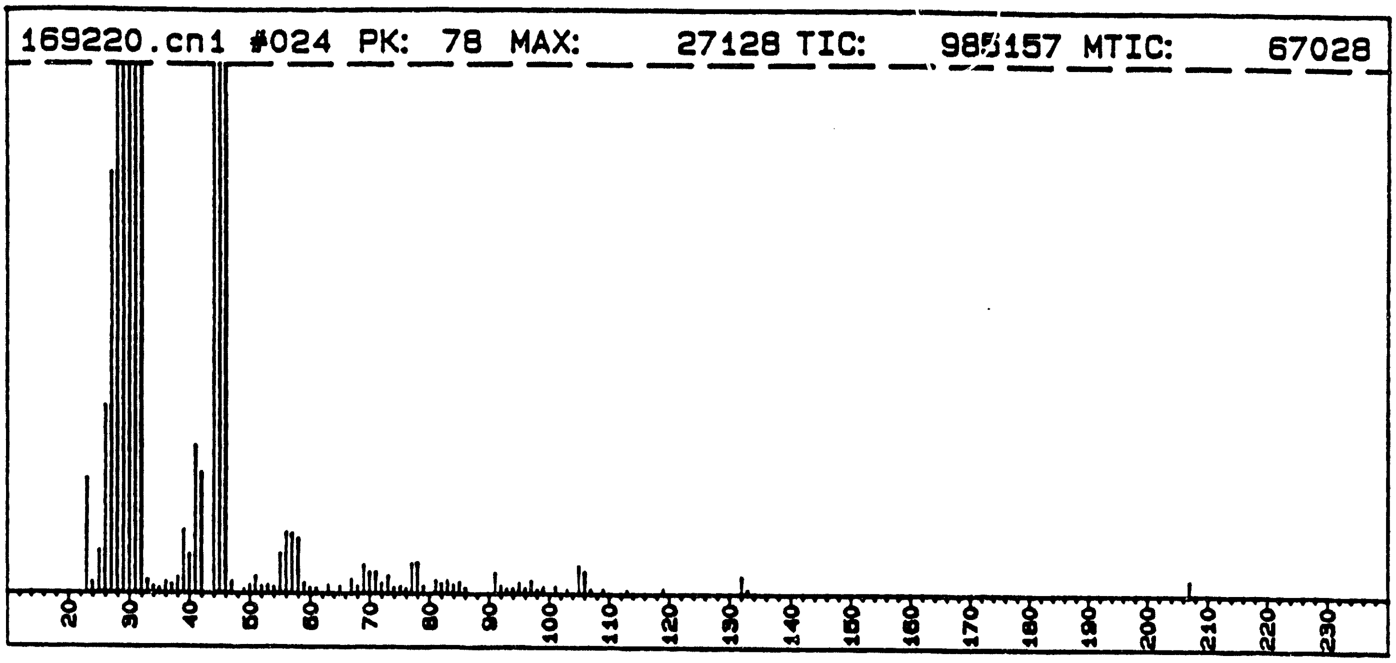


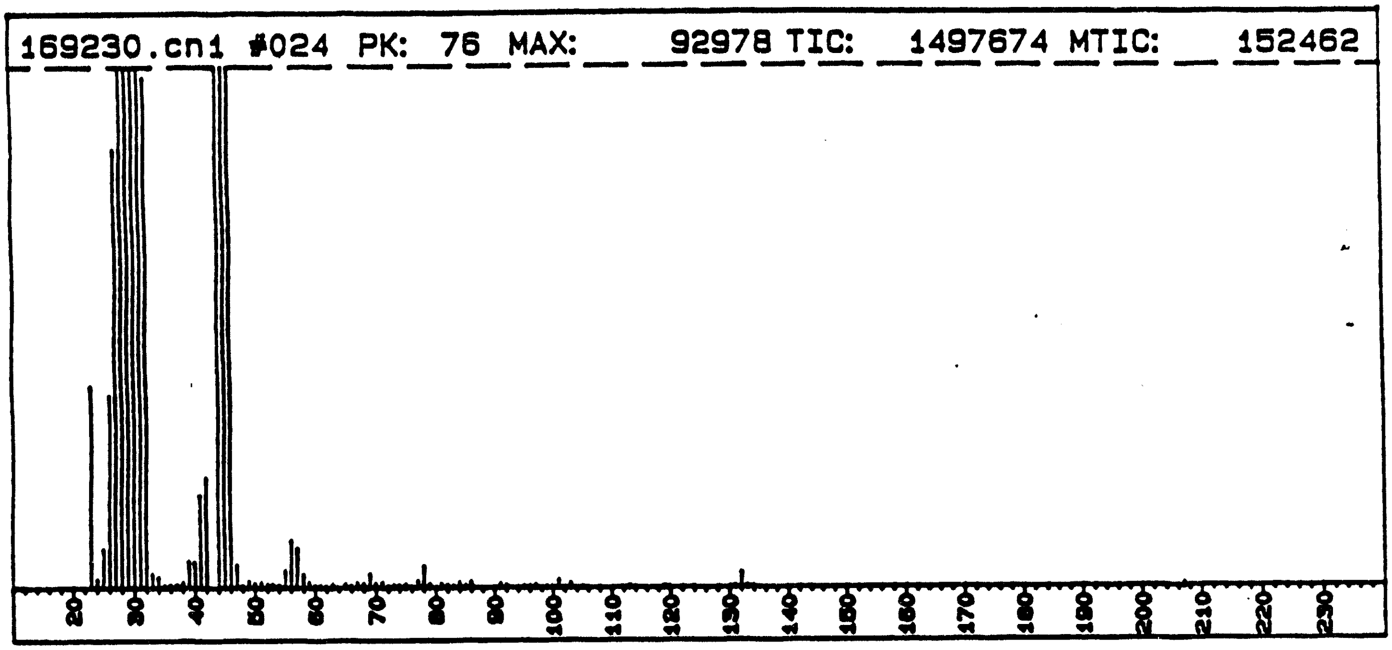
Week 1 Travel Blanks



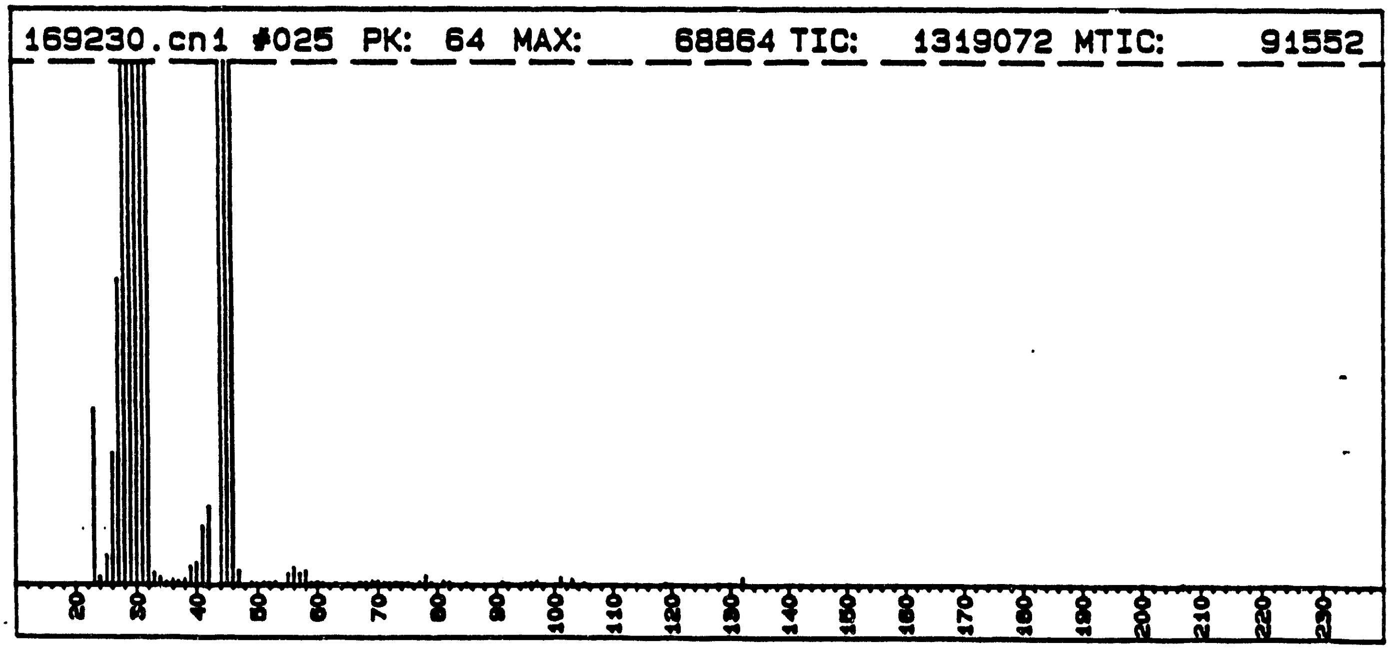


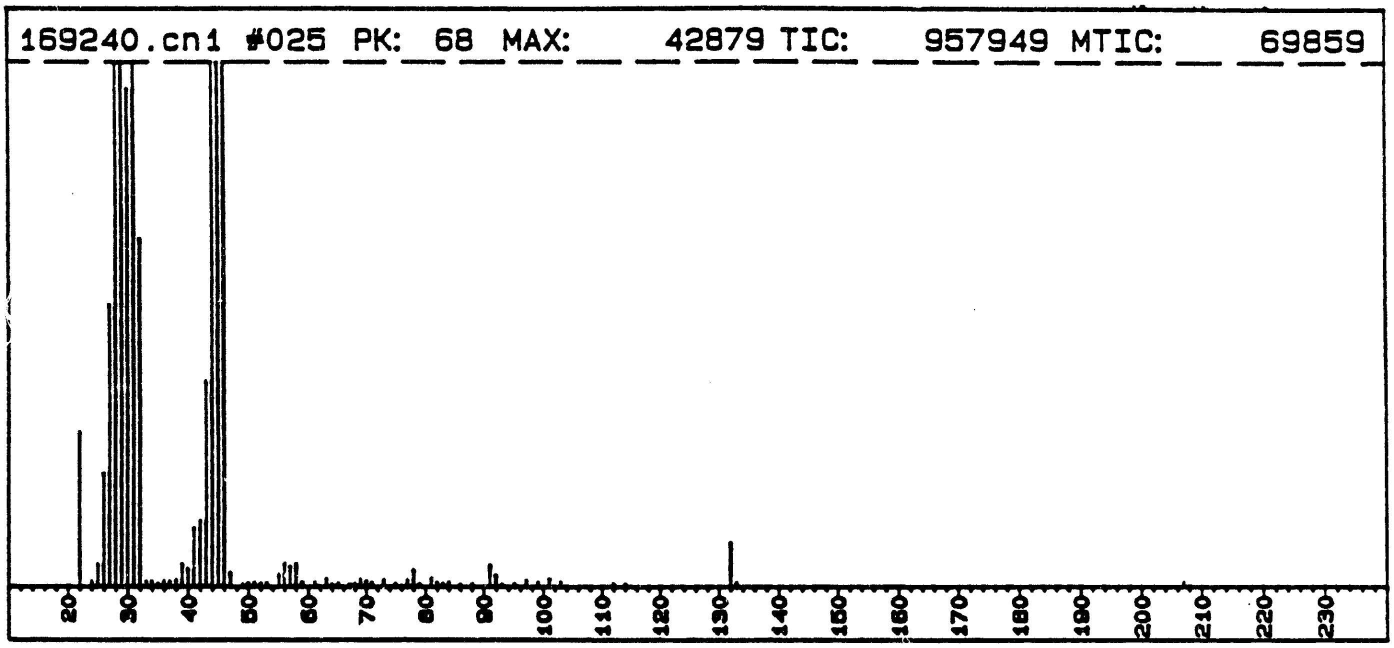
Week 2 Travel Blanks



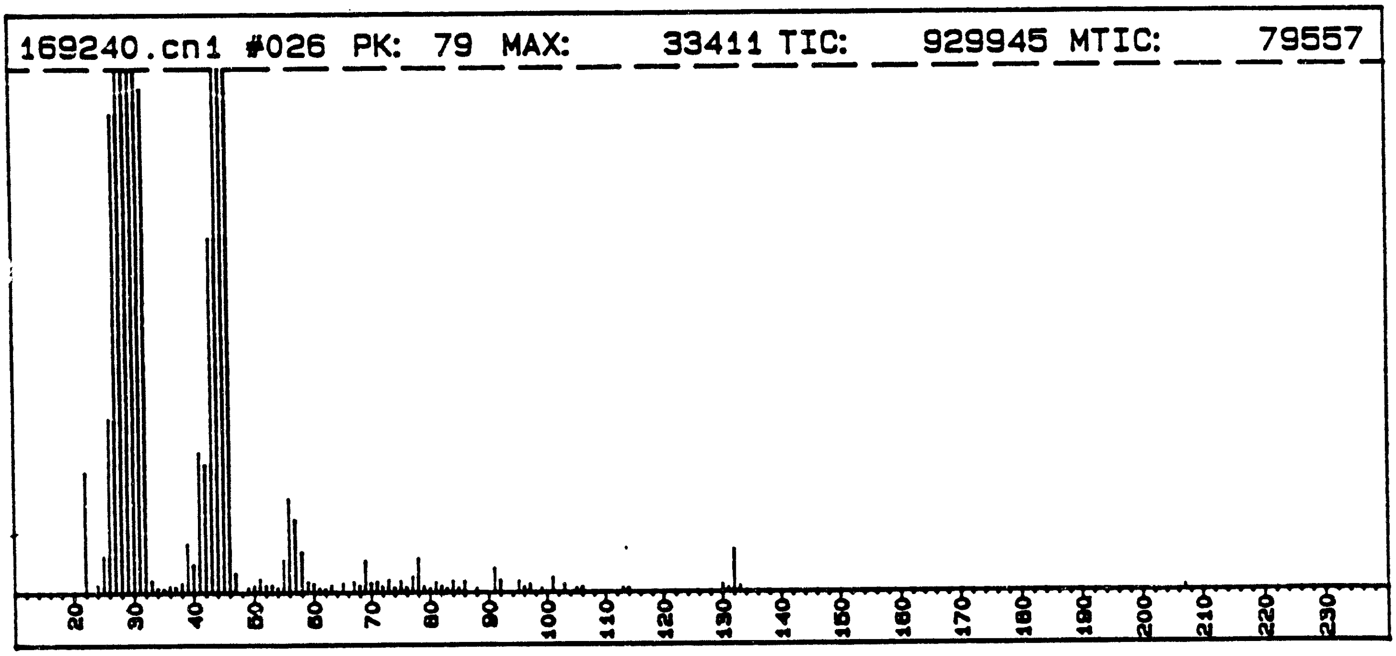


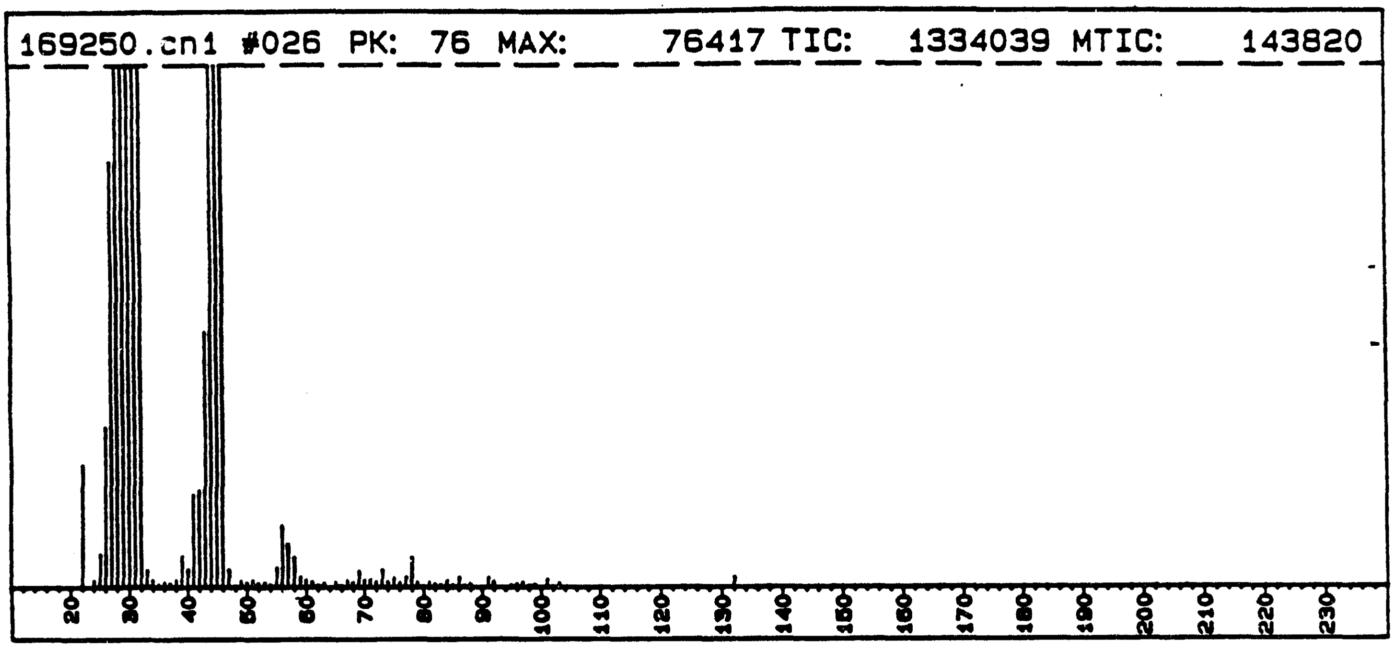
Week 3 Travel Blanks



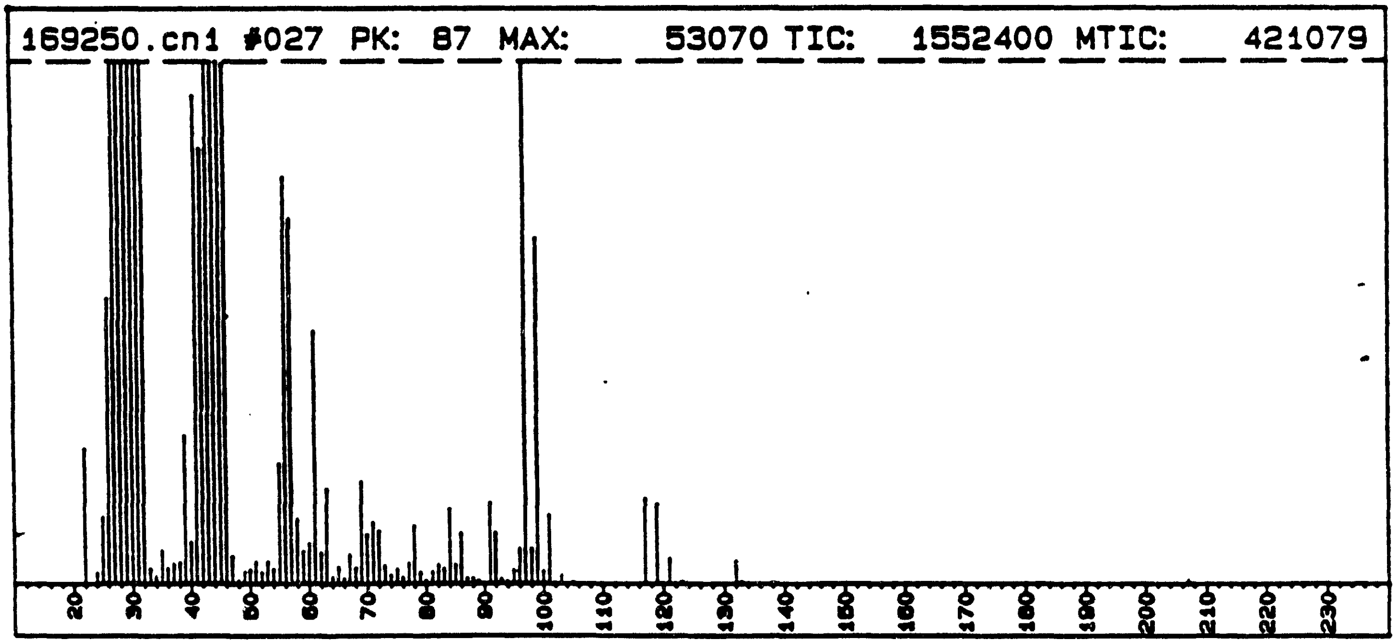


Week 4 Travel Blanks





Week 5 Travel Blanks



APPENDIX B

TABLE 3

TABLE 3
TD-MS DATA
For the Petrex Soil Gas Survey Conducted at the Department of Energy site in Hanford, Washington
April 8, 1993

(all values below are in units of ion counts derived from Thermal Desorption-Mass Spectromet

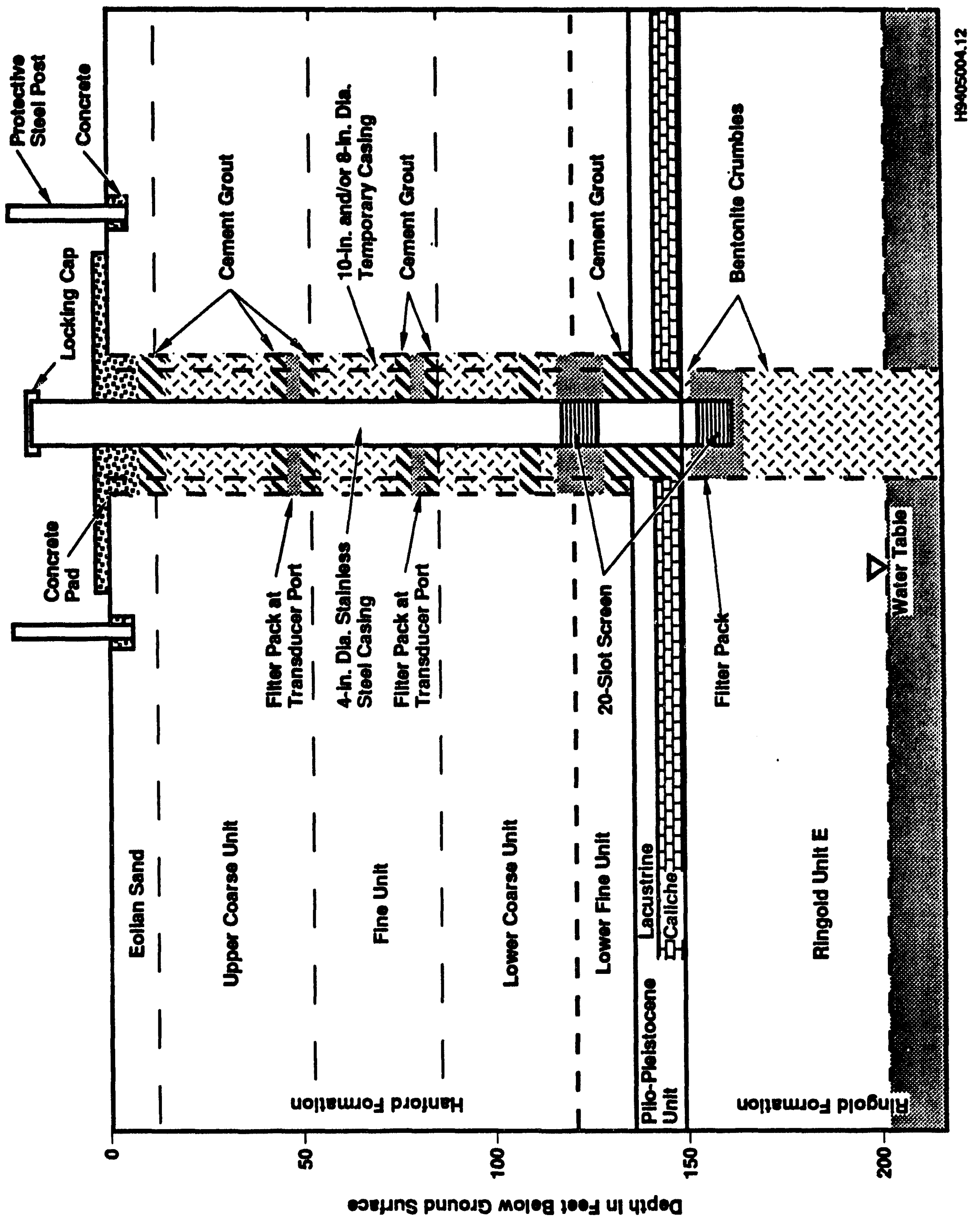
Site Number	Sample Number	Toluene	CCl4	Benzene	TCE	Chloroform	PCE
				WEEK 1			
Site 1	1	688	129688	2008	1299	21660	23693
Site 2	6	0	80088	507	1222	6821	16901
Site 3	11	309	79307	1189	3555	4063	10023
Site 4	16	630	7521	2514	0	636	2046
Site 5	21	394	321	717	0	1069	239
				WEEK 2			
Site 1	2	2141	119722	4662	3627	20876	99638
Site 2	7	0	109823	731	3310	15887	38627
Site 3	12	375	24462	864	1704	1833	12132
Site 4	17	419	3849	1602	0	359	1682
Site 5	22	0	0	312	0	0	0
				WEEK 3			
Site 1	3	2115	148962	4321	0	0	152635
Site 2	8	0	127762	877	10858	0	119372
Site 3	13	201	113508	1952	8234	13447	46583
Site 4	18	228	19425	5741	460	2253	4122
Site 5	23	0	0	464	0	0	0
				WEEK 4			
Site 1	4	1533	115139	4697	0	0	119676
Site 2	9	0	62139	412	3068	7430	42925
Site 3	14	0	63419	604	3766	5769	10919
Site 4	19	0	2260	1286	0	252	1392
Site 5	24	0	0	330	0	238	0
				WEEK 5			
Site 1	5	5332	130917	13419	0	57102	153725
Site 2	10	272	92321	2145	11439	42381	95495
Site 3	15	448	100544	1999	7632	11947	26515
Site 4	20	786	20448	7087	478	3044	2513
Site 5	25	1575	0	11978	0	278	0

Notes:
1. Toluene = Mass 92
2. CCl4 (Carbon Tetrachloride or Tetrachloromethane) = Mass 121
3. Benzene = Mass 78
4. TCE (Trichloroethene) = Mass 130
5. Chloroform = Mass 83
6. PCE (Tetrachloroethene) = Mass 164

APPENDIX F

SCHEMATIC WELL CONSTRUCTION DIAGRAMS AND COMPLETION SUMMARY TABLE

Figure F-1. Schematic Diagram of an FY 1993 Unsaturated Zone Monitoring/Vapor Extraction Well with Two Screened Intervals.



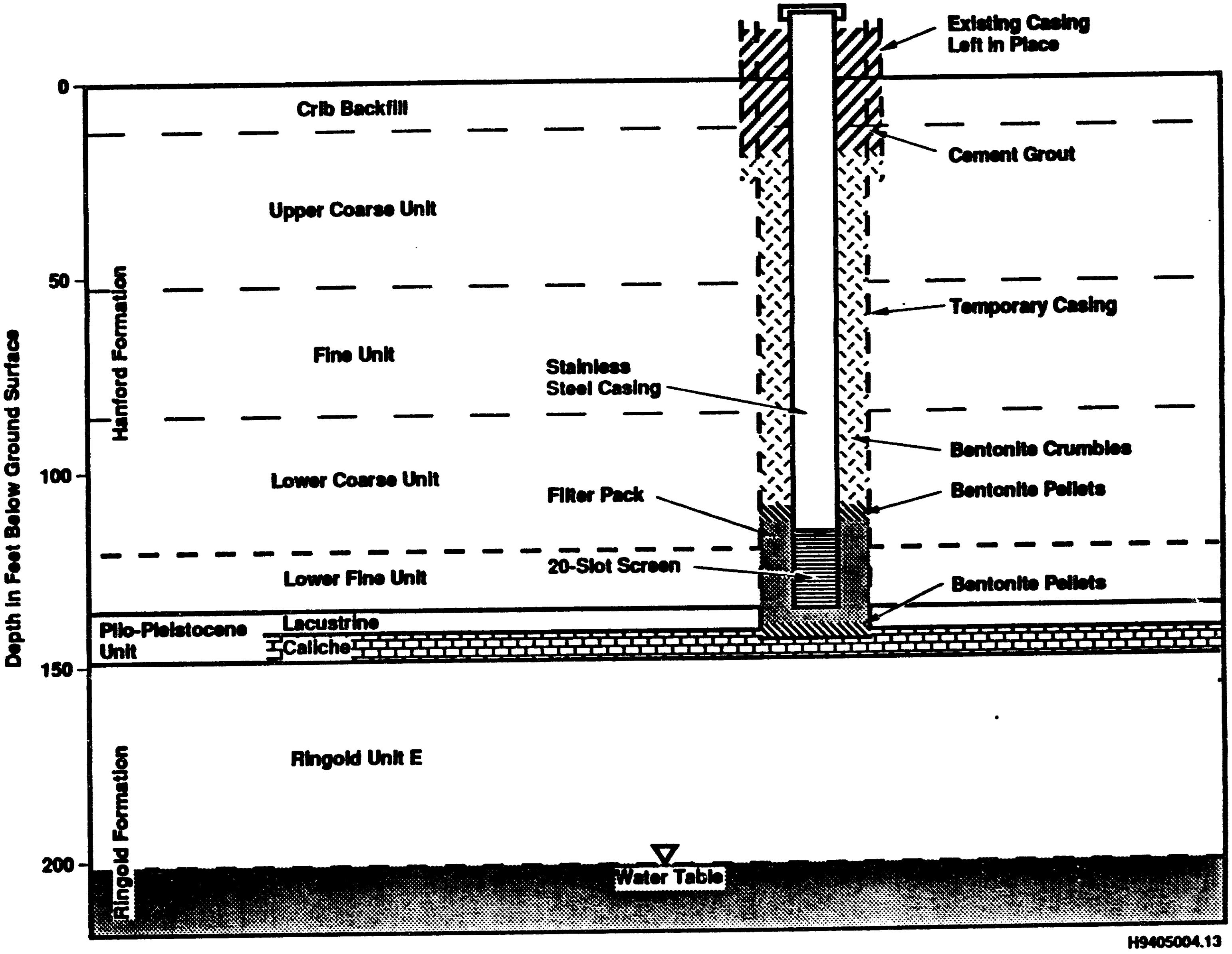


Figure F-2. Schematic Diagram of an FY 1993 Crib Monitoring/Vapor Extraction Well with One Screened Interval.

APPENDIX G

VOLATILE ORGANIC, CHEMICAL, AND RADIOLOGICAL ANALYSES OF SEDIMENT AND GROUNDWATER SAMPLES FROM THE FY 1993 BOREHOLES

Analytical Results VOLATILE ORGANIC COMPOUNDS 299-W15-218 (VEX-1)

Depth (ft)	Depth (m)	Sample Matrix	Drill / Sample Method	Sub-sample Method	Approx. %Fine: %Coarse: %Rock	Lab Notes	HEIS Sample Number	Methylene Chloride (ppb)	trans-1,2-Dichloroethylene (ppb)	1,1-Dichloroethane (ppb)	cis-1,2-Dichloroethylene (ppb)	Chloroform (ppb)	1,1,1-Trichloroethane (ppb)	CC14 (ppb)	1,2-Dichloroethane (ppb)	Benzene (ppb)	Trichloroethylene (ppb)	Toluene (ppb)	Tetrachloroethylene (ppb)	Ethylbenzene (ppb)	M&P-Xylene (ppb)	O-Xylene (ppb)	Acetone (ppb)	n-Butyl Benzene (ppb)
7.0	2.1	Sed	DB	NR	NR		B01MT6	<300	<20	<80	<20	<80	<80	82	<80	<20	<20	<20	<20	<20	<20	<20	ND	ND
10.0	3.0	Sed	DB	NR	NR		B01MT7	307 (a)	<30	<100	<30	<100	<100	<84 (b)	<100	<30	<30	<30	<30	<30	<30	<30	ND	ND
15.0	4.6	Sed	DB	NR	NR		B01MT9	<300	<40	<100	<40	<100	<100	<100 (c)	<100	<40	<40	<40	<40	<40	<40	<40	ND	ND
15.0	4.6	Sed	DB	NR	NR		B01MV0	<300	<50	<150	<50	<150	<150	<150 (d)	<150	<50	<50	<50	<50	<50	<50	<50	ND	ND
20.0	6.1	Sed	DB	NR	NR		B01MV1	<300	<50	<150	<50	<150	<150	<150 (e)	<150	<50	<50	<50	<50	<50	<50	<50	ND	ND
25.0	7.6	Sed	DB	NR	NR		B01MV3	<100	<10	<25	<10	<25	<25	36	<25	<10	<10	<10	<10	<10	<10	<10	ND	ND
27.0	8.2	Sed	DB	NR	NR		B01MV4	<100	<10	<25	<10	<25	<25	106	<25	<10	<10	<10	<10	<10	<10	<10	ND	~100 (f)
30.0	9.1	Sed	DB	NR	NR		B01MV5	<100	<10	<25	<10	<25	<25	96	<25	<10	<10	<10	<10	<10	<10	<10	ND	ND
30.0	9.1	Sed	DB	NR	NR		B01MV6	<100	<10	<25	<10	<25	<25	112	<25	<10	<10	<10	<10	<10	<10	<10	ND	ND
35.0	10.7	Sed	DB	NR	NR		B01MV7	<50	<5	<10	<5	<10	<10	~9	<10	<5	<5	<5	<5	<5	<5	<5	ND	ND
35.0	10.7	Sed	DB	NR	NR		B01MV8	<100	<10	<25	<10	<25	<25	~7 (g)	<25	<10	<10	<10	<10	<10	<10	<10	ND	ND
35.0	10.7	Sed	DB	NR	NR		B01MV9	<100	<10	<25	<10	<25	<25	~11 (g)	<25	<10	<10	<10	<10	<10	<10	<10	ND	ND
35.0	10.7	Sed	DB	NR	NR		B01MWC	<100	<10	<25	<10	<25	<25	~16 (g)	<25	<10	<10	<10	<10	<10	<10	<10	ND	ND
42.0	12.8	Sed	DB	NR	50:0:50		B01MW1	<100	<10	<20	<10	<20	<20	<20	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
51.0	15.5	Sed	DB	NR	50:0:50		B01MW2	<150	<15	<30	<15	<30	<30	40	<30	<15	<15	<15	<15	<15	<15	<15	ND	ND
52.5	16.0	Sed	DB	NR	100:0:0		B01NV3	<300	<30	<60	<30	~30 (g)	<60	1876	<60	<30	<30	<30	<30	<30	<30	<30	ND	ND
55.0	16.8	Sed	DB	NR	100:0:0		B01NV4	<200	<20	<40	<20	<40	<40	198	<40	<20	<20	<20	<20	<20	<20	<20	ND	~300
60.0	18.3	Sed	DB	NR	75:25:0		B01NV5	<200	<20	<40	<20	<40	<40	354	<40	<20	<20	<20	<20	<20	<20	<20	ND	ND
65.0	19.8	Sed	DB	NR	100:0:0	(1,2)	B01NV7	<200	<20	<40	<20	<40	<40	75	<40	<20	<20	<20	<20	<20	<20	<20	ND	ND
70.0	21.3	Sed	DB	NR	50:50:0		B01NV8	<150	<15	<30	<15	<30	<30	175	<30	<15	<15	<15	<15	<15	<15	<15	ND	ND
75.0	22.9	Sed	DB	NR	0:100:0		B01NV9	<150	<15	<30	<15	<30	<30	389	<30	<15	<15	<15	<15	<15	<15	<15	ND	ND
80.0	24.4	Sed	DB	NR	80:20:0		B01NW6	<125	<10	<25	<10	<25 (h)	<25	1334	25	<10	<10	<10	<10	<10	<10	<10	ND	ND
85.0	25.9	Sed	DB	NR	100:0:0		B01NW0	<450	<50	<100	<50	<100	<100	206	<100	<50	<50	<50	<50	<50	<50	<50	ND	ND
90.0	27.4	Sed	DB	NR	100:0:0		B01NW1	<100	<10	<20	<10	<20 (h)	<20	810	<20	<10	<10	<10	<10 (i)	<10	<10	<10	ND	ND
95.0	29.0	Sed	DB	NR	100:0:0		B01NW3	<100	<10	<20	<10	44	<20	11804 (j)	<20	<10	<10 (k)	<10	10 (l)	<10	<10	<10	ND	ND
100.0	30.5	Sed	DB	NR	90:10:0		B01NW2	<150	<15	<30	<15	<30 (m)	<30	1182	<30	<15	<15	<15	<15 (n)	<15	<15	<15	ND	ND
104.5	31.9	Sed	DB	NR	100:0:0		B01NW5	<250	<25	<50	<25	<50 (c)	<50	2600	<50	<25	<25	<25	<25 (n)	<25	<25	<25	ND	ND
110.0	33.5	Sed	DB	NR	100:0:0		B01NW4	<100	<10	<30	<10	93	<30	15794 (j)	<30	<10	<10 (m)	<10	<10 (n)	<10	<10	<10	ND	ND
116.5	35.5	Sed	DB	NR	75:25:0		B01P75	<100	<10	<25	<10	128	<85	6816 (j)	<25	<10	<10	<10	~9 (g)	<10	<10	<10	ND	ND
116.3	35.5	Sed	DB	NR	90:10:0		B01P76	<100	<10	<40	<10	166	<40	9932 (j)	<40	<10	<10	<10	12 (o)	<10	<10	<10	ND	ND
120.0	36.6	Sed	DB	NR	90:10:0	(3)	B01P77	<100	<10	<20	<10	<20	<20	31	<20	<10	<10	<10	<10	<10	<10	<10	ND	~25 (p)
125.0	38.1	Sed	HT	NR	80:20:0	(4)	B08435	206	<10	<25	<10	439	<25	<25	<25	<10	<10	<10	<10	<10	<10	<10	ND	ND
130.0	39.6	Sed	HT	NR	80:20:0	(4)	B08436	221	<10	<20	10	730	<20	19	<20	<10	<10	<10	<10 (q)	<10	<10	<10	ND	ND
135.0	41.1	Sed	HT	NR	Not Analyzed		B08437	* Container broken before arriving at lab.																
140.0	42.7	Sed	DB	NR	80:20:0		B01P79	<100	<10	<30	<10	<30 (r)	<30	244	<30	<10	<10	<10	<10	<10	<10	<10	ND	~500 (p)
145.0	44.2	Sed	DB	NR	100:0:0		B01P80	<100	<10	<25	<10	27	<25	3915 (j)	<25	<10	<10	<10	<10	<10	<10	<10	ND	ND
150.0	45.7	Sed	DB	NR	60:40:0	(5)	B01P81	<200	<20	<75	<20	<75	<75	81	<75	<20	<20	35 (e)	<20	<20	<20	<20	ND	~2000 (p)
155.0	47.2	Sed	DB	NR	50:30:20		B01P82	<100	<10	<25	<10	<25	<25	54	<10	<10	<10	<10	<10	<10	<10	<10	ND	ND
160.0	48.8	Sed	DB	NR	80:20:0		B01P83	<100	<15	<40	<15	<40	<40	~37 (g)	<40	<15	<15	<15	<15	<15	<15	<15	ND	ND
165.0	50.3	Sed	DB	NR	90:10:0	(5)	B01P84	<100	<15	<40	<15	<40 (h)	<40	175	<40	<15	<15	161 (f)	<15	<15	<15	<15	ND	~900 (p)
170.0	51.8	Sed	DB	NR	95:5:0		B01P85	<50	<5	<15	<15	<15	<15	<15 (r)	<15	<5	<5	<5	<5	<5	<5	<5	ND	ND
175.0	53.3	Sed	DB	NR	100:0:0	(3)	B01P86	<100	<15	<45	<15	<45	<45	<45 (s)	<45	<15	<15	~285	<15	<15	<15	<15	ND	~900 (p)
180.0	54.9	Sed	DB	NR	95:5:0	(6)	B01P87	<100	<50	<20	<50	<50	<50	<50	<50	<20	≤50	87 (u)	<50	<20	<20	<20	ND	~270 (p)
185.0	56.4	Sed	DB	NR	80:10:10		B01P89	<30	<15	<15	<15	<15	<15	<15 (t)	<15	<15	<15	207	<15	<5	5	8	ND	~170 (p)
190.0	57.9	Sed	DB	NR	90:10:0		B01P90	<50	<10	<25	<10	<25	<25	<25 (u)	<25	<10	<25	<10	<25	<10	<10	≤10	ND	ND
195.0	59.4	Sed	DB	NR	80:20:0		B01NX0	412 (v)	<15	<35	<15	<35	<35	38	<35	≤15	<35	33 (v)	<15	<15 (w)	<15 (w)	16	ND	ND
200.0	61.0	Sed	DB	NR	60:0:40		B08438	<30	<5	<15	<5	42	<15	323	<15	<5	<5	<5	<5	<5	<5	<5	ND	ND
205.0	62.5	Sed	DB	NR	70:0:30		B08439	<60	<10	<30	<10	61	<30	308	<30	<10	<10	13	<10	<10	<10	<10	ND	ND
205.0	62.5	Water	DB	TB	N/A		B01NQ8	16	<0.5	<2	<0.5	499 (j)	<2	6379 (j)	<2	<0.5	1.4	<0.5	5.7	<0.5	<0.5	<0.5	ND	ND

Analytical Results **VOLATILE ORGANIC COMPOUNDS** **299-W15-218 (VEX-1)**

Sample/Subsample Methods

DB = Drive Barrel

CB = Core borer
S = Scoopula
TB = Teflon Baller

ND = Not Detected
NR = Not Reported

N/A = Not Applicable

Lab Notes

(1) Methanol leaked from container in field.
(2) Observed large peak at n-Butylbenzene retention time.
(3) Total sediment weight was estimated. Container not weighed initially.
(4) Slurry, sediment around container threads causing vial to leak.
(5) Some methanol leaked from vial.
(6) Poor seal on septum. Sample exposed to atmosphere.

Analysis Notes

(a) Poor value because of the large amount observed in the methanol blank and dilution volume caused by the sample weight.
(b) ~84 observed, but below LDL's.
(c) ~15 observed, but below LDL's.
(d) ~23 observed. Below linear detection limits. ~3-5 gms of sediment needed in 10 mL of Methanol to lower < value.
(e) ~17 observed, but below LDL's.
(f) Non-calibrated estimate. Relative Retention Time to TCE indication only.
(g) Observed, but below LDL's.
(h) ~7 observed, but below LDL's.
(i) ~2 observed, but below LDL's.
(j) 1:200 dilution required
(k) ~6 ELCD, but below LDL's.
(l) ~11 on ELCD.
(m) ~10 observed, but below LDL's. but below LDL's.
(n) ~8 ave. from both detectors, but below LDL's.
(o) ~12 observed, but below LDL's.
(p) Non-calibrated estimate.
(q) ~4 observed, but below LDL's.
(r) ~11 observed, but below LDL's.
(s) ~25 observed, but below LDL's.
(t) ~3 observed, but below LDL's.
(u) ~9 observed, but below LDL's.
(v) Estimated background control.
(w) ~6 observed, but below LDL's.

Analytical Results VOLATILE ORGANIC COMPOUNDS 299-W15-219 (VEX-3)

Depth (ft)	Depth (m)	Sample Matrix	Drill / Sample Method	Sub-sample Method	Approx. %Fine: %Coarse: %Rock	Lab Notes	HEIS Sample Number	Methylene Chloride (ppb)	trans-1,2-Dichloroethylene (ppb)	1,1-Dichloroethane (ppb)	cis-1,2-Dichloroethylene (ppb)	Chloroform (ppb)	1,1,1-Trichloroethane (ppb)	CC14 (ppb)	1,2-Dichloroethane (ppb)	Benzene (ppb)	Trichloroethylene (ppb)	Toluene (ppb)	Tetrachloroethylene (ppb)	Ethylbenzene (ppb)	M+P-Xylene (ppb)	O-Xylene (ppb)	Acetone (ppb)	n-Butyl Benzene (ppb)
21.0	6.4	Sed	DB				B01NT4	Container broken in Lab - No Analysis.																
25.9	7.9	Sed	DB	S	50:50:0	(1)	B01NT5	<10	<5	<10	<5	<10	<10	10	<10	<10	<10	<5	<5	<5	<5	<5	ND	ND
29.5	9.0	Sed	DB	S	10:90:0	(1)	B01NT7	<10	<5	<10	<5	<10	<10	8	<10	<10	<10	<5	<5	<5	<5	<5	ND	ND
35.5	10.8	Sed	DB	S	10:90:0	(1)	B01NT8	<20	<10	<20	<10	<20	<20	<20 (a)	<20	<20	<20	<10	<10	<10	<10	<10	ND	ND
39.8	12.1	Sed	DB	S	60:0:40		B01NT6	<20	<5	<10	<5	<10	<10	<10	<10	<10	<10	<5	<5	<5	<5	<5	ND	ND
44.8	13.6	Sed	DB	S	100:0:0		B01NT9	<20	<10	<20	<10	<20	<20	117	<20	<20	<20	<10	<10	<10	<10	<10	ND	ND
49.5	15.1	Sed	DB	S	100:0:0		B01NV0	<10	<5	<10	<5	<10	<10	407	<10	<10	<10	<5	<5	<5	<5	<5	ND	ND
53.5	16.3	Sed	DB	CB	50:50:0		B01NV1	<20	<10	<20	<10	<20	<20	182	<20	<20	<20	<10	<10	<10	<10	<10	ND	ND
54.3	16.6	Sed	DB	CB	80:20:0		B01PW6	<15	<10	<15	<10	<15 (b)	<15	288	<15	<10	<10	<10	<10 (b)	<10	<10	<10	ND	ND
56.6	17.2	Sed	DB	CB	90:10:0		B01PW7	<20	<10	<20	<10	<20	<20	213	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
57.9	17.6	Sed	DB	CB	80:20:0		B01NV2	<15	<10	<15	<10	<15 (c)	<15	495	<15	<15	<15	<10	<10	<10	<10	<10	ND	ND
65.0	19.8	Sed	DB	CB	80:20:0		B01PR8	<30	<10	<15	<10	<15 (d)	<15	283	<15	<20	<20	<10	<10 (d)	<10	<10	<10	ND	ND
70.0	21.3	Sed	DB	CB	100:0:0		B01PR9	<20	<5	<10	<5	<10 (e)	<10	679 (f)	<10	<10	<10	<5	<10 (g)	<5	<5	<5	ND	ND
75.5	23.0	Sed	DB	CB	80:20:0		B01PS0	<40	<10	<20	<10	<20 (g)	<20	867	<20	<20	<20	<10	<10 (h)	<10	<10	<10	ND	ND
79.5	24.2	Sed	DB	CB	100:0:0		B01PS1	<40	<10	<20	<10	77	<20	9558 (i)	<20	<20	<20	<10	<10 (j)	<10	<10	<10	ND	ND
84.5	25.8	Sed	DB	CB	100:0:0		B01PS2	<40	<10	<20	<10	23	<20	2039 (f)	<20	<20	<20	<10	<10 (k)	<10	<10	<10	ND	ND
87.0	26.5	Sed	SB	CB	0:100:0		B01PW8	<30	<10	<15	<10	<15	<15	577	<15	<10	<10 (h)	<10	<10	<10	<10	<10	ND	ND
89.5	27.3	Sed	DB	CB	100:0:0		B01PS3	<60	<15	<30	<15	<30	<30	1557	<30	<30	<30	<15	<15	<15	<15	<15	ND	ND
91.0	27.7	Sed	SB	CB	80:20:0		B01PW9	<30	<15	<30	<15	<30 (l)	<30	3095 (f)	<30	<15	<15	<15	<15	<15	<15	<15	ND	ND
95.5	29.1	Sed	SB	CB	100:0:0		B01PX0	<30	<10	<15	<10	<15	<15	106	<15	<10	<10	<10	<10	<10	<10	<10	ND	ND
96.5	29.4	Sed	DB	CB	100:0:0		B01PS4	<40	<10	<20	<10	<20	<20	80	<20	<10	<10	<10	<10 (m)	<10	<10	<10	ND	ND
100.0	30.5	Sed	DB	CB	100:0:0		B01PS5	<40	<10	<20	<10	<20	<20	198	<20	<10	<10	<10	<10 (g)	<10	<10	<10	ND	ND
105.5	32.2	Sed	DB	CB	95:5:0		B01PS6	(n)	<10	<20	<10	<20	<20	276	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
109.5	33.4	Sed	DB	CB	95:5:0		B01PS7	(n)	<10	<10	<10	12	<10	606	<10	<10	<10	<10	<10 (b)	<10	<10	<10	ND	ND
111.1	33.9	Sed	SB	CB	100:0:0		B01PX1	<25	<15	<25	<15	<25	<25	288	<25	<15	<15	<15	<15	<15	<15	<15	ND	ND
114.5	34.9	Sed	SB	CB	100:0:0		B01PX2	<20	<10	<20	<10	57	<20	10488 (i)	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
114.5	34.9	Sed	SB	CB	100:0:0		B01PX3	<35	<20	<35	<20	53	<35	11688 (i)	<35	<20	<20	<20	<20	<20	<20	<20	ND	ND
114.9	35.0	Sed	DB	CB	100:0:0		B01PS8	<25	<25	<25	<25	61	<25	9866 (f)	<25	<25	<25	<25	<25	<15	<15	<15	ND	ND
120.0	36.6	Sed	DB	CB	100:0:0		B01PS9	<20	<20	<20	<20	39	<20	1349	<20	<20	<20	<20	<20	<10	<10	<10	ND	ND
124.5	37.9	Sed	HT	S	NR		B01PT0	<20	<5	<10	<5	168	<10	2345 (i)	<10	<10	<10	<10	<5	<5	<5	<5	ND	ND
129.5	39.5	Sed	HT	S	NR		B01PT1	<20	<10	<10	<10	241	<10	4905 (i)	<10	<10	<10	<10	<10	<10	<10	<10	ND	ND
131.5	40.1	Sed	DB	CB	NR		B01PT2	<20	<10	<10	<10	574	<10	574	<10	<10	<10	<10	<10	<5	<5	<5	ND	ND
140.0	42.7	Sed	HT	S	NR		B01PT3	<40	<20	<20	<20	595	<20	3752 (i)	<20	<20	<20	<20	<20	<10	<10	<10	ND	ND
145.0	44.2	Sed	DB	S	NR		B01PT4	<30	<15	<15	<15	19	<15	55	<15	<15	<15	<15	<15	<15	<15	<15	ND	ND
149.0	45.4	Sed	DB	CB	NR		B01PT5	<30	<30	<30	<30	65	<30	3798 (f)	<30	<30	<30	<15	<30	<15	<15	<15	ND	ND
150.3	45.8	Sed	SB	S	NR		B01PX4	<30	<15	<30	<15	<30 (o)	<30	172	<30	<15	<15	<15	<15	<15	<15	<15	ND	ND
153.4	46.8	Sed	SB	S	NR		B01PX5	<20	<10	<20	<10	<20	<20	23	<20	<10	<10	34	<10	<10	<10	<10	ND	ND
155.0	47.2	Sed	DB	CB	100:0:0		B01PT6	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	37	<25	<25	<25	<25	ND	ND
160.0	48.8	Sed	HT	S	100:0:0		B01PT7	<15	<15	<15	<15	162	<15	1305 (f)	<15	<15	<15	<15	<15	<15	<15	<15	ND	ND
165.0	50.3	Sed	DB	CB	100:0:0		B01PT8	<30	<15	<15	<15	230	<15	242	<15	<15	<15	<15	<15	<15	<15	<15	ND	ND
170.0	51.8	Sed	HT	S	100:0:0		B01PT9	<20	<10	<10	<10	703 (f)	<10	1311 (f)	<10	<10	<10	<10	<10	<10	<10	<10	ND	ND
175.0	53.3	Sed	HT	S	100:0:0		B01PV0	<20	<10	<10	<10	207	<10	1620 (f)	<10	<10	<10	<10	<10	<10	<10	<10	ND	ND
180.0	54.9	Sed	HT	S	100:0:0		B01PV1	<20	<15	<15	<15	130	<15	1418 (f)	<15	<15	<15	<15	<15	<15	<15	<15	ND	ND
185.0	56.4	Sed	HT	S	100:0:0		B01PV2	<10	<10	<10	<10	154	<10	876 (f)	<10	<10	<10	<10	<10	<10	<10	<10	ND	ND
187.0	57.0	Sed	DB	CB	100:0:0		B01PV3	<15	<15	<15	<15	164	<15	705	<15	<15	<15	<15	<15	<15	<15	<15	ND	ND
190.3	58.0	Sed	DB	S	100:0:0		B01PV4	<40	<20	<20	<20	<20	<20	<20 (g)	<20	<20	<20	47	<20	<20	<20	<20	ND	ND
195.0	59.4	Sed	DB	S	95:5:0		B01PV5	<30	<15	<15	<15	<15	<15	120	<15	<15	<15	>376 (p)	<15	<15	<15	<15	ND	ND
200.0	61.0	Sed	DB	CB	95:5:0		B01PV6	<60	<30	<30	<30	<30	<30	<30 (j)	<30	<30	<30	>1329 (q)	<30	<30	<30	<30	ND	ND
205.0	62.5	Sed	DB	CB	100:0:0		B01PV7	<30	<15	<15	<15	78	<15	382	<15	<15	<15	<15	<15	<15	<15	<15	ND	ND
210.5	64.2	Sed	DB	S	85:15:0		B01PV8	<30	<15	<15	<15	139	<15	107	<15	<15	<15	<15	<15	<15	<15	<15	ND	ND
211.0	64.3	Water	DB	TB	N/A		B07BS6	38	<0.5	<2	<0.5	862 (i)	<2	3862 (i)	<2	<0.5	1.1	<0.5	3.3	<0.5	<0.5	<0.5	ND	ND

Sample/Subsample Methods

DB = Drive Barrel
HT = Hard Tool
SB = Split-Barrel

CB = Core borer
S = Scoopula
TB = Teflon Bailer

Lab Notes

(1) Turbid sample.

ND = Not Detected
NR = Not Reported

N/A = Not Applicable

Analysis Notes

(a) ~12 observed, but below LDL's.
(b) ~3 observed, but below LDL's.
(c) ~6 observed, but below LDL's.
(d) ~4 observed, but below LDL's.
(e) ~8 observed, but below LDL's.
(f) 1:100 dilution necessary for CCl_4 analysis.
(g) ~5 observed, but below LDL's.
(h) ~7 observed, but below LDL's.
(i) 1:200 dilution necessary for CCl_4 analysis.
(j) ~9 observed, but below LDL's.
(k) ~10 observed, but below LDL's.
(l) ~13 observed, but below LDL's.
(m) ~11 observed, but below LDL's.
(n) CH_2Cl_2 impurity in lab.
(o) ~18 observed, but below LDL's.
(p) Above range. Could be slightly higher.
(q) Above range, but no other dilution run.

Analytical Results **VOLATILE ORGANIC COMPOUNDS** **299-W15-220 (VEX-2)**

Depth (ft)	Depth (m)	Sample Matrix	Drill / Sample Method	Sub-sample Method	Approx. %Fine: %Coarse: %Rock	Lab Notes	HEIS Sample Number	Methylene Chloride (ppb)	trans-1,2-Dichloroethylene (ppb)	1,1-Dichloroethane (ppb)	cis-1,2-Dichloroethylene (ppb)	Chloroform (ppb)	1,1,1-Trichloroethane (ppb)	CCl4 (ppb)	1,2-Dichloroethane (ppb)	Benzene (ppb)	Trichloroethylene (ppb)	Toluene (ppb)	Tetrachloroethylene (ppb)	Ethylbenzene (ppb)	M+P-Xylene (ppb)	O-Xylene (ppb)	Acetone (ppb)	n-Butyl Benzene (ppb)
24.8	7.6	Soil	DB	S	5:95:0		B07BT4	<20	<10	<20	<10	<20	<20	<20	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
29.7	9.1	Soil	DB	S	15:85:0		B07BT5	<20	<20	<20	<20	<20	<20	29	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
34.7	10.6	Soil	DB	S	15:85:0	(1)	B07BT6	<120	<120	<120	<120	<120	<120	<120 (a)	<120	<60	<60	<60	<60	<60	<60	<60	ND	ND
40.0	12.2	Soil	DB	S	50:50:0	(1)	B07BT7	<30	<30	<30	<30	<30	<30	<30	<30	<15	<15	<15	<15	<15	<15	<15	ND	ND
45.0	13.7	Soil	DB	CB	5:95:0	(1)	B07BT8	<120	<120	<120	<120	<120	<120	~133 (b)	<120	<60	<60	<60	<60	<60	<60	<60	ND	ND
50.0	15.2	Soil	DB	CB	100:0:0	(1)	B07BT9	<60	<60	<60	<60	<60	<60	1052	<60	<30	<30	<30	<30	<30	<30	<30	ND	ND
55.0	16.8	Soil	DB	CB	0:100:0	(1)	B07BV0	<60	<60	<60	<60	<60	<60	772	<60	<30	<30	<30	<30	<30	<30	<30	ND	ND
60.0	18.3	Soil	DB	CB	5:95:0		B07BV1	<25	<25	<25	<25	<25	<25	296	<25	<15	<15	<15	<15	<15	<15	<15	ND	ND
64.8	19.8	Soil	DB	CB	5:95:0		B07BV2	<20	<20	<20	<20	<20	<20	544	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
69.6	21.2	Soil	DB	CB	20:80:0		B07BV3	<15	<15	<15	<15	17	<15	729	<15	<10	<10	<10	<10	<10	<10	<10	ND	ND
75.0	22.9	Soil	DB	S	80:20:0		B07BV4	<30	<30	<30	<30	<30	<30	261	<30	<15	<15	<15	<15	<15	<15	<15	ND	ND
79.8	24.3	Soil	DB	S	80:20:0		B07BV5	<20	<20	<20	<20	<20	<20	174	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
84.6	25.8	Soil	DB	S	80:20:0		B07BV6	<50	<20	<20	<20	<20 (c)	<20	107	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
90.5	27.6	Soil	DB	S	95:5:0		B07BV7	<50	<20	<20	<20	<20 (c)	<20	1132	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
94.6	28.8	Soil	DB	CB	50:50:0		B07BV8	<50	<20	<20	<20	<20	<20	699	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
100.5	30.6	Soil	DB	CB	100:0:0		B07BV9	1171	<25	<25	<25	<25	<25	545	<25	<15	<15	<25	<15	<15	<15	<15	ND	ND
104.5	31.9	Soil	DB	CB	100:0:0		B07BW0	86	<25	<25	<25	<25 (d)	<25	56	<25	<15	<15	<25	<15	<15	<15	<15	ND	ND
107.8	32.9	Water	DB	PJ	Muddy		B07BT3	<5 (e)	<0.5	<2	<0.5	20	<2	200 (f)	<2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	ND	ND
109.6	33.4	Soil	DB	CB	100:0:0		B07BW1	560	<25	<25	<25	<25 (g)	<25	109	<25	<15	<15	<25	<15	<15	<15	<15	ND	ND
114.8	35.0	Soil	DB	S	100:0:0	(2)	B07BW2	<50	<25	<25	<25	<25	<25	<25	<25	<15	<15	59	<15	<15	<15	<15	ND	ND
120.0	36.6	Soil	DB	S	95:5:0		B07BW3	<50	<25	<25	<25	<25	<25	<25	<25	<15	<15	<15	<15	<15	<15	<15	ND	ND
123.0	37.5	Soil	DB	S	95:5:0		B07BW4	<50	<25	<25	<25	<25	<25	<25 (h)	<25	<15	<15	<25	<15	<15	<15	<15	ND	ND
127.0	38.7	Soil	DB	S	50:50:0		B07BW5	<40	<20	<20	<20	<20	<20	<20 (i)	<20	<10	<10	<20	<10	<10	<10	<10	ND	ND
133.0	40.5	Soil	DB	CB	80:20:0		B07BW6	<50	<25	<25	<25	<25	<25	<25 (c)	<25	<15	<15	29	<15	<15	<15	<15	ND	~1500 (j)
138.5	42.2	Soil	DB	S	30:70:0		B07BW7	<40	<20	<20	<20	<20	<20	<20	<20	<10	<10	22	<10	<10	<10	<10	ND	~600 (j)
146.0	44.5	Soil	DB	S	95:5:0		B07BW8	<40	<20	<20	<20	<20	<20	<20 (k)	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
150.0	45.7	Soil	DB	S	95:5:0		B07BW9	<40	<20	<20	<20	<20	<20	<20 (l)	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
155.0	47.2	Soil	DB	S	95:5:0		B07BX0	<20	<20	<20	<20	<20	<20	<20	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
160.0	48.8	Soil	DB	S	95:5:0		B07BX1	<30	<15	<15	<15	<15	<15	<15 (k)	<15	<10	<10	<10	<10	<10	<10	<10	ND	ND
164.5	50.1	Soil	DB	S	100:0:0		B07BX2	<30	<15	<15	<15	<15	<15	51	<15	<10	<10	<10	<10	<10	<10	<10	ND	ND
170.0	51.8	Soil	DB	S	95:0:5		B07BX3	<25	<25	<25	<25	<25	<25	25	<25	<15	<15	<15	<15	<15	<15	<15	ND	ND
175.0	53.3	Soil	DB	S	90:0:10		B07BX4	<20	<20	<20	<20	<20	<20	<20	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
180.5	55.0	Soil	DB	S	95:0:5		B07BX5	<20	<20	<20	<20	<20	<20	<20	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
185.0	56.4	Soil	DB	S	90:10:0		B07BX6	<25	<25	<25	<25	<25	<25	<25	<25	<15	<15	<15	<15	<15	<15	<15	ND	ND
190.0	57.9	Soil	DB	S	50:45:5		B07BX7	<25	<25	<25	<25	<25	<25	<26 (k)	<25	<15	<15	<15	<15	<15	<15	<15	ND	~500 (j)
195.0	59.4	Soil	DB	S	50:25:25		B07BX8	<15	<15	<15	<15	<15 (m)	<15	<15 (k)	<15	<10	<10	<10	<10	<10	<10	<10	ND	ND
200.0	61.0	Soil	DB	S	50:25:25		B07BX9	<10 (c)	<10	<10	<10	32	<10	101	<10	<5	<5	6	<5	<5	<5	<5	ND	ND
200.0	61.0	Water	DB	TB	N/A		B07CF4	32	<0.5	<0.5	<2	459	<2 (n)	915	<2	<0.5	0.6	<0.5 (o)	1.1	<0.5	<0.5	<0.5	~6 (j)	ND

Sample/Subsample Methods

DB = Drive Barrel

CB = Core borer
S = Scoopula
PJ = Plastic Jug
TB = Teflon Bailer

Lab Notes

(1) Power outage - sample rerun - required larger dilution volume.
(2) Turbid sample.

ND=Not Detected
N/A = Not Applicable

Analysis Notes

(a) Trace (~8), but below LDL's.
(b) Slightly below LDL's.
(c) ~4 observed, but below LDL's.
(d) ~12 observed, but below LDL's.
(e) ~1.6 observed, but below LDL's.
(f) 1:200 dilution necessary for CCl4 analysis.
(g) ~10 observed, but below LDL's.
(h) ~18 observed, but below LDL's.
(i) ~6 observed, but below LDL's.
(j) Non-calibrated suspect.
(k) ~5 observed, but below LDL's.
(l) ~8 observed, but below LDL's.
(m) ~2 observed, but below LDL's.
(n) ~0.3 observed, but below LDL's.
(o) ~0.4 observed, but below LDL's.

Analytical Results   VOLATILE ORGANIC COMPOUNDS   299-W15-223 (ID-6)

45° Depth (ft)	Vert. Depth (ft)	Sample Matrix	Drill / Sample Method	Sub-sample Method	Approx. %Fine: %Coarse: %Rock	Lab Name	HEIS Sample Number	Methylene Chloride (ppb)	trans-1,2-Dichloroethylene (ppb)	1,1-Dichloroethane (ppb)	cis-1,2-Dichloroethylene (ppb)	Chloroform (ppb)	1,1,1-Trichloroethane (ppb)	CC14 (ppb)	1,2-Dichloroethane (ppb)	Benzene (ppb)	Trichloroethylene (ppb)	Toluene (ppb)	Tetrachloroethylene (ppb)	Ethylbenzene (ppb)	M+P-Xylene (ppb)	O-Xylene (ppb)	Acetone (ppb)	Chloro-Benzene (ppb)
8.00	5.66	Soil	SB	S	100:0:0		B07CZ9	<20	<20	<20	<20	<20	<20	<20	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
8.00	5.66	Soil	SB	S	100:0:0		B07D00	<25	<25	<25	<25	<25	<25	<25	<25	<15	<15	<15	<15	<15	<15	<15	ND	ND
19.78	13.99	Soil	SB	S	95:5:0		B07D01	<20	<20	<20	<20	<20	<20	<20 (a)	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
19.78	13.99	Soil	SB	S	100:0:0		B07D02	<15	<15	<15	<15	<15	<15	<15 (a)	<15	<10	<10	<10	<10	<10	<10	<10	ND	ND
30.77	21.76	Soil	SB	S	5:95:0		B07D59	<20	<20	<20	<20	<20	<20	<20 (b)	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
30.77	21.76	Soil	SB	S	5:95:0		B07D60	<20	<20	<20	<20	<20	<20	20	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
40.17	28.40	Soil	SB	S	5:95:0		B07D03	<15	<15	<15	<15	<15	<15	<15 (b)	<15	<10	<10	<10	<10	<10	<10	<10	ND	ND
40.17	28.40	Soil	SB	S	5:95:0		B07D04	<20	<20	<20	<20	<20	<20	<20 (c)	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
50.26	35.54	Soil	SB	S	5:95:0		B07D05	<25	<25	<25	<25	<25	<25	<25 (d)	<25	<15	<15	<15	<15	<15	<15	<15	ND	ND
50.26	35.54	Soil	SB	S	5:95:0		B07D06	<20	<20	<20	<20	<20	<20	<20 (c)	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
60.99	43.13	Soil	SB	S	5:95:0		B07D61	<50	<25	<25	<25	<25	<25	36	<25	<15	<15	<15	<15 (e)	<15	<15	<15	ND	ND
60.99	43.13	Soil	SB	S	5:95:0		B07D62	<50	<25	<25	<25	<25	<25	33	<25	<15	<15	<15	<15 (a)	<15	<15	<15	ND	ND
70.04	49.53	Soil	SB	CB	20:80:0		B07D07	<15	<15	<15	<15	<15	<15	232	<15	<10	<10 (a)	<10	<10	<10	<10	<10	ND	ND
70.04	49.53	Soil	SB	CB	20:80:0		B07D08	<20	<20	<20	<20	<20 (a)	<20	308	<20	<10	<10	<10	<10 (a)	<10	<10	<10	ND	ND
80.29	56.77	Soil	SB	S	20:80:0		B07D09	<20	<20	<20	<20	<20	<20	70	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
80.29	56.77	Soil	SB	S	20:80:0		B07D10	<20	<20	<20	<20	<20	<20	61	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
80.29	56.77	Soil	SB	CB	10:90:0		B07D57	<20	<10	<10	<10	<10 (e)	<10	210	<10	<5	<5	<5	<5	<5	<5	<5	ND	ND
80.29	56.77	Soil	SB	CB	10:90:0		B07D58	<30	<15	<15	<15	<15	<15	142	<15	<10	<10	<10	<10	<10	<10	<10	~40 (f)	ND
88.32	62.45	Soil	DB	CB	30:70:0		B07D55	<30	<15	<15	<15	<15	<15	165	<15	<10	<10	<10	<10	<10	<10	<10	ND	~37 (f)
88.32	62.45	Soil	DB	CB	10:90:0		B07D56	<50	<25	<25	<25	<25	<25	266	<25	<15	<15	<15	<15 (a)	<15	<15	<15	ND	<15 (g)
89.25	63.11	Soil	SB	S	10:90:0		B07D63	<40	<20	<20	<20	<20	<20	59	<20	<10	<10	<10	<10 (a)	<10	<10	<10	ND	ND
89.25	63.11	Soil	SB	S	10:90:0		B07D64	<40	<20	<20	<20	<20	<20	53	<20	<10	<10	<10	<10 (e)	<10	<10	<10	ND	ND
89.25	63.11	Soil	SB	CB	5:95:0		B07D53	<40	<20	<20	<20	<20	<20	147	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
89.25	63.11	Soil	SB	CB	5:95:0		B07D54	<40	<20	<20	<20	<20	<20	73	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
96.32	68.11	Soil	DB	CB	5:95:0		B07D51	<20	<10	<10	<10	<10	<10	70	<10	<5	<5	<5	<5	<5	<5	<5	ND	~70 (h)
96.32	68.11	Soil	DB	CB	5:95:0		B07D52	<20	<10	<10	<10	<10	<10	149	<10	<5	<5	<5	<5	<5	<5	<5	ND	39
99.04	70.03	Soil	SB	S	95:5:0		B07D11	<20	<20	<20	<20	<20 (i)	<20	25	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
99.04	70.03	Soil	SB	S	95:5:0		B07D12	<25	<25	<25	<25	<25 (i)	<25	28	<25	<15	<15	<15	<15	<15	<15	<15	ND	ND
99.04	70.03	Soil	SB	CB	100:0:0		B07D49	<30	<15	<15	<15	<15 (i)	<15	75	<15	<10	<10	<10	<10	<10	<10	<10	ND	ND
99.04	70.03	Soil	SB	CB	100:0:0		B07D50	<20	<10	<10	<10	19	<10	93	<10	<5	<5	<5	<5	<5	<5	<5	ND	ND
100.42	71.01	Soil	SB	S	5:93:0		B07D13	<20	<20	<20	<20	<20	<20	96	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
100.42	71.01	Soil	SB	S	5:95:0		B07D14	<20	<20	<20	<20	<20	<20	119	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
100.42	71.01	Soil	SB	S	5:95:0		B07D47	<20	<20	<20	<20	<20	<20	107	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
100.42	71.01	Soil	SB	S	5:95:0		B07D48	<15	<15	<15	<15	<15	<15	114	<15	<10	<10	<10	<10 (a)	<10	<10	<10	ND	ND
110.04	77.81	Soil	SB	S	40:50:10		B07D15	<20	<20	<20	<20	<20	<20	46	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
110.04	77.81	Soil	SB	S	50:50:0		B07D16	<20	<20	<20	<20	<20	<20	40	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
110.04	77.81	Soil	SB	CB	30:70:0		B07D45	<30	<15	<15	<15	<15	<15	78	<15	<10	<10	<10	<10	<10	<10	<10	ND	ND
110.04	77.81	Soil	SB	CB	30:70:0		B07D99	<30	<15	<15	<15	<15	<15	66	<15	<10	<10	<10	<10 (a)	<10	<10	<10	ND	ND
118.63	83.88	Soil	DB	CB	40:60:0		B07D43	<30	<15	<15	<15	<15	<15	201	<15	<10	<10	<10	<10 (e)	<10	<10	<10	ND	ND
118.63	83.88	Soil	DB	CB	60:40:0		B07D44	<30	<15	<15	<15	<15 (e)	<15	289	<15	<10	<10	<10	<10 (e)	<10	<10	<10	ND	<10 (k)
120.85	85.45	Soil	SB	S	60:40:0		B07D65	<50	<25	<25	<25	<25 (e)	<25	221	<25	<15	<15	<15	<15 (i)	<15	<15	<15	ND	ND
120.85	85.45	Soil	SB	S	50:50:0		B07D66	<50	<25	<25	<25	<25	<25	164	<25	<15	<15	<15	<15 (e)	<15	<15	<15	ND	ND
120.85	85.45	Soil	SB	CB	50:50:0		B07D41	<40	<20	<20	<20	<20 (i)	<20	836	<20	<10	<10	<10	<10 (i)	<10	<10	<10	ND	ND
120.85	85.43	Soil	SB	CB	50:50:0		B07D42	<20	<10	<10	<10	<10 (e)	<10	263	<10	<5	<5	<5	<5 (e)	<5	<5	<5	ND	ND
122.39	86.54	Soil	DB	CB	20:80:0		B07D17	<20	<20	<20	<20	<20 (e)	<20	381	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
122.39	86.54	Soil	DB	CB	20:80:0		B07D18	<15	<15	<15	<15	<15	<15	327	<15	<10	<10	<10	<10	<10	<10	<10	ND	<10 (g)
128.39	90.79	Soil	DB	S	90:10:0		B07D67	<40	<20	<20	<20	<20	<20	282	<20	<10	<10	<10	<10 (a)	<10	<10	<10	ND	ND
128.39	90.79	Soil	DB	S	90:10:0		B07D68	<40	<20	<20	<20	<20	<20	331	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
128.39	90.79	Soil	DB	CB	20:80:0		B07D39	<20	<10	<10	<10	<10	<10	337	<10	<5	<5	<5	<5	<5	<5	<5	ND	ND
128.39	90.79	Soil	DB	CB	80:20:0		B07D40	<30	<15	<15	<15	<15	<15	401	<15	<10	<10	<10	<10	<10	<10	<10	ND	ND
131.99	93.33	Soil	SB	S	100:0:0		B07D69	<40	<20	<20	<20	<20	<20	166	<20	<10	<10	<10	<10 (e)	<10	<10	<10	ND	ND
131.99	93.33	Soil	SB	S	100:0:0		B07D70	<50	<25	<25	<25	<25 (e)	<25	209	<25	ND	<15	<15	<15 (e)	<15	<15	<15	ND	ND
131.99	93.33	Soil	SB	CB	100:0:0		B07D37	<30	<15	<15	<15	<15 (i)	<15	521	<15	<10	<10	<10	<10 (a)	<10	<10	<10	ND	ND
131.99	93.33	Soil	SB	CB	100:0:0		B07D38	<30	<15	<15	<15	<15 (i)	<15	580	<15	<10	<10	<10	<10	<10	<10	<10	ND	ND

Analytical Results VOLATILE ORGANIC COMPOUNDS 299-W15-223 (ID-6)

45° Depth (ft)	Vert. Depth (ft)	Sample Matrix	Drill / Sample Method	Sub-sample Method	Approx. %Fine: %Coarse: %Rock	Lab Notes	HEIS Sample Number	Methylene Chloride (ppb)	trans-1,2-Dichloroethylene (ppb)	1,1-Dichloroethane (ppb)	cis-1,2-Dichloroethylene (ppb)	Chloroform (ppb)	1,1,1-Trichloroethane (ppb)	CC14 (ppb)	1,2-Dichloroethane (ppb)	Benzene (ppb)	Trichloroethylene (ppb)	Toluene (ppb)	Tetrachloroethylene (ppb)	Ethylbenzene (ppb)	M+P-Xylene (ppb)	O-Xylene (ppb)	Acetone (ppb)	Chloro-Benzene (ppb)
135.25	95.64	Soil	SDB	CB	100:0:0		B07D33	<50	<25	<25	<25	<25 (l)	<25	209	<25	ND	<15	<15	<15	<15	<15	<15	ND	ND
135.25	95.64	Soil	SDB	CB	100:0:0		B07D34	<30	<15	<15	<15	<15 (a)	<15	295	<15	<10	<10	<10	<10 (e)	<10	<10	<10	ND	ND
138.25	97.76	Soil	SDB	S	100:0:0		B07D71	<30	<15	<15	<15 (e)	<15	<15	121	<15	<10	<10	<10	<10	<10	<10	<10	ND	ND
138.25	97.76	Soil	SDB	S	90:10:0		B07D72	<40	<20	<20	<20	<20	<20	88	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
138.25	97.76	Soil	SDB	CB	80:20:0		B07D35	<30	<15	<15	<15	<15	<15	211	<15	<10	<10	<10	<10	<10	<10	<10	ND	ND
138.25	97.76	Soil	SDB	CB	80:20:0		B07D36	<30	<15	<15	<15 (e)	<15	<15	228	<15	<10	<10	<10	<10 (e)	<10	<10	<10	ND	ND
141.40	99.98	Soil	SB	S	100:0:0		B07D73	<80	<40	<40	<40	<40	<40	204	<40	<20	<20	<20	<20	<20	<20	<20	ND	ND
141.40	99.98	Soil	SB	S	100:0:0		B07D74	<80	<40	<40	<40	<40	<40	345	<40	<20	<20	<20	<20	<20	<20	<20	ND	ND
141.40	99.98	Soil	SB	CB	100:0:0		B07D31	<40	<20	<20	<20	<20 (d)	<20	1049 (m)	<20	<10	<10	<10	<10 (a)	<10	<10	<10	ND	ND
141.40	99.98	Soil	SB	CB	100:0:0		B07D32	<40	<20	<20	<20	<20 (b)	<20	488	<20	<10	<10	<10	<10 (l)	<10	<10	<10	ND	ND
148.19	104.79	Soil	SDB	S	30:70:0		B07D75	<40	<20	<20	<20	<20	<20	69	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
148.19	104.79	Soil	SDB	S	30:70:0		B07D76	<40	<20	<20	<20	<20	<20	136	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
148.19	104.79	Soil	SDB	CB	60:40:0		B07D29	<40	<20	<20	<20	<20	<20	248	<20	<10	<10	<10	<10 (l)	<10	<10	<10	ND	ND
148.19	104.79	Soil	SDB	CB	60:40:0		B07D30	<40	<20	<20	<20	<20	<20	515	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
151.73	107.29	Soil	SB	S	20:80:0		B07D77	<30	<15	<15	<15	<15	<15	176	<15	<10	<10	<10	<10	<10	<10	<10	ND	ND
151.73	107.29	Soil	SB	S	20:80:0		B07D78	<40	<20	<20	<20	<20	<20	156	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
151.73	107.29	Soil	SB	CB	20:80:0		B07D27	<30	<15	<15	<15	<15 (l)	<15	684	<15	<10	<10	<10	<10	<10	<10	<10	ND	ND
151.73	107.29	Soil	SB	CB	20:80:0		B07D28	<30	<15	<15	<15	<15 (b)	<15	1232 (n)	<15	<10	<10	<10	<10	<10	<10	<10	ND	ND
154.14	108.99	Soil	SDB	CB	10:90:0		B07D23	<30	<15	<15	<15	<15	<15	213	<15	<10	<10	<10	<10	<10	<10	<10	ND	ND
154.14	108.99	Soil	SDB	CB	10:90:0		B07D24	<20	<10	<10	<10	<10	<10	210	<10	<5	<5	<5	<5	<5	<5	<5	ND	ND
157.64	111.47	Soil	SDB	S	100:0:0		B07D79	<60	<30	<30	<30	<30	<30	116	<30	<15	<15	<15	<15	<15	<15	<15	ND	ND
157.64	111.47	Soil	SDB	S	100:0:0		B07D80	<70	<35	<35	<35	<35	<35	80	<35	<15	<15	<15	<15	<15	<15	<15	ND	ND
157.64	111.47	Soil	SDB	CB	100:0:0		B07D25	<30	<30	<30	<30	<30	<30	228	<30	<15	<15	<15	<15	<15	<15	<15	ND	ND
157.64	111.47	Soil	SDB	CB	100:0:0		B07D26	<25	<25	<25	<25	<25	<25	183	<25	<15	<15	<15	<15	<15	<15	<15	ND	ND
166.99	118.08	Soil	SDB	CB	100:0:0		B07D19	<40	<20	<20	<20	<20 (l)	<20	633	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
166.99	118.08	Soil	SDB	CB	100:0:0		B07D20	<40	<20	<20	<20	<20 (l)	<20	609	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
167.49	118.43	Soil	SDB	S	40:40:20		B07D81	<40	<20	<20	<20	<20 (o)	<20	565	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
167.49	118.43	Soil	SDB	S	40:40:20		B07D82	<50	<25	<25	<25	<25 (o)	<25	731	<25	<15	<15	<15	<15	<15	<15	<15	ND	ND
167.49	118.43	Soil	SDB	CB	80:20:0		B07D21	<40	<20	<20	<20	<20	<20	834	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
167.49	118.43	Soil	SDB	CB	90:10:0		B07D22	<20	<20	<20	<20	<20 (p)	<20	841	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND

Sample/Subsample Methods

DB = Drive Barrel
SB = Split-Barrel
SDB = Split Drive Barrel

CB = Core borer
S = Scoopula

Analysis Notes

(a) ~3 observed, but below LDL's.
(b) ~6 observed, but below LDL's.
(c) ~9 observed, but below LDL's.
(d) ~10 observed, but below LDL's.
(e) ~2 observed, but below LDL's.
(f) Non-calibrated estimate.
(g) Observed.
(h) Estimate using response to TCE, verified Chlorobenzene by GCMS.
(i) ~4 observed, but below LDL's.
(j) ~13 observed, but below LDL's.
(k) Trace.
(l) ~5 observed, but below LDL's.
(m) 1:5 dilution necessary.
(n) 1:50 dilution necessary.
(o) ~11 observed, but below LDL's.
(p) ~16 observed, but below LDL's.

ND = Not Detected

Analytical Results **VOLATILE ORGANIC COMPOUNDS** **299-W18-252 (VEX-7)**

Depth (ft)	Depth (m)	Sample Matrix	Drill / Sample Method	Sub-sample Method	Approx. %Fines %Coarse %Rock	Lab Notes	HEIS Sample Number	Methylene Chloride (ppb)	trans-1,2-Dichloroethylene (ppb)	1,1-Dichloroethane (ppb)	cis-1,2-Dichloroethylene (ppb)	Chloroform (ppb)	1,1,1-Trichloroethane (ppb)	CCl4 (ppb)	1,2-Dichloroethane (ppb)	Benzene (ppb)	Trichloroethylene (ppb)	Toluene (ppb)	Tetrachloroethylene (ppb)	Ethylbenzene (ppb)	M+P-Xylene (ppb)	O-Xylene (ppb)	Acetone (ppb)	n-Butyl Benzene (ppb)
4.5	1.4	Soil	DB	CB	100:0:0		B01PH2	<40	<10	<20	<10	<20	<20	<20 (a)	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
9.5	2.9	Soil	DB	CB	100:0:0		B01PH3	<30	<10	<15	<10	<15	<15	<15 (b)	<15	<10	<10	<10	<10	<10	<10	<10	ND	ND
15.0	4.6	Soil	DB	CB	10:90:0		B01PC5	<10	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	ND	ND
20.0	6.1	Soil	DB	CB	90:10:0		B01PC4	<30	<10	<15	<10	<15	<15	15	<10	<10	<10	<10	<10	<10	<10	<10	ND	ND
25.0	7.6	Soil	DB	S	NR		B01PC6	<10	<5	<10	<5	<10	<10	<10 (c)	<10	<5	<5	11	<5	<5	<5	<5	ND	ND
30.6	9.3	Soil	DB	S	NR		B01PC7	<15	<10	<15	<10	<15	<15	<15 (c)	<15	<10	<10	12	<10	<10	<10	<10	ND	ND
35.0	10.7	Soil	DB	CB	NR		B01PC8	<10	<5	<10	<5	<10	<10	<10 (d)	<10	<5	<5	280	<5	<5	<5	<5	ND	ND
39.5	12.0	Soil	DB	CB	NR		B01PC9	<15	<10	<15	<10	<15	<15	57	<15	<10	<10	<10	<10	<10	<10	<10	ND	ND
44.7	13.6	Soil	DB	S	90:10:0		B01PH1	NR	<30	<30	<30	<30	<30	<30 (e)	<30	<15	<30	260	<30	<15	<15	<15	ND	ND
49.5	15.1	Soil	DB	S	100:0:0		B07BD5	<20	<20	<20	<20	<20	<20	<20	<20	<10	<20	<10	<20	<10	<10	<10	ND	ND
55.0	16.8	Soil	DB	S	20:80:0		B07BD6	<40	<20	<20	<20	<20	<20	<20 (f)	<20	<10	<20	17	<20	<10	<10	<10	ND	ND
59.5	18.1	Soil	DB	S	NR		B07BD7	<30	<15	<30	<15	<30	<30	<30 (c)	<30	<15	<15	<15	<15	<15	<15	<15	ND	ND
65.5	20.0	Soil	DB	S	NR		B07BD8	<40	<20	<40	<20	<40	<40	48	<40	<20	<20	37	<20	<20	<20	<20	ND	ND
70.5	21.5	Soil	DB	S	NR		B07BD9	<20	<10	<20	<10	<20	<20	77	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
75.5	23.0	Soil	DB	S	NR		B07BF0	<20	<10	<20	<10	<20	<20	62	<10	<10	<10	<10	<10	<10	<10	<10	ND	ND
80.2	24.4	Soil	DB	CB	NR		B07BF1	<35	<20	<35	<20	<35	<35	84	<35	<20	<20	<20	<20	<20	<20	<20	ND	ND
85.5	26.1	Soil	DB	CB	NR		B07BF2	<30	<15	<30	<15	<30	<30	<30 (g)	<30	<15	<15	<15	<15	<15	<15	<15	ND	ND
89.7	27.3	Soil	DB	S	NR		B07BF3	<20	<10	<20	<10	<20	<20	155	<10	<10	<10	<10	<10 (a)	<10	<10	<10	ND	ND
96.0	29.3	Soil	DB	S	NR		B07BF4	<30	<15	<30	<15	<30	<30	101	<30	<15	<15	<15	<15	<15	<15	<15	ND	ND
99.5	30.3	Soil	DB	CB	100:0:0		B07BF5	<20	<10	<20	<10	<20	<20	22	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
105.0	32.0	Soil	DB	S	80:0:20		B07BF6	<30	<15	<30	<15	<30	<30	<30 (h)	<30	<15	<15	151	<15	<15	<15	<15	ND	ND
115.0	35.1	Soil	DB	S	50:0:50		B07BF7	<15	<10	<15	<10	<15	<15	<15	<15	<10	<10	58	<10	<10	<10	<10	ND	ND
121.3	37.0	Soil	DB	S	60:0:40		B07BF8	<10	<10	<10	<10	<10	<10	<10 (n)	<10	<10	<10	<10	<10	<10	<10	<10	ND	ND
126.5	38.6	Soil	DB	S	100:0:0		B07BF9	<25	<25	<25	<25	<25 (h)	<25	519	<25	<15	<15	<15	<15	<15	<15	<15	ND	ND
129.5	39.5	Soil	DB	S	100:0:0		B07BG0	<25	<25	<25	<25	<25	<25	74	<25	<15	<15	<15	<15	<15	<15	<15	ND	ND
134.8	41.1	Soil	DB	S	100:0:0		B07BG1	<20	<20	<20	<20	36	<20	307	<20	<10	<10	21	<10	<10	<10	<10	ND	ND
142.1	43.3	Soil	DB	S	90:0:10		B07BG2	NR	<20	<20	<20	68	<20	53	<20	<10	<10	71	<10	<10	<10	<10	ND	ND
145.5	44.3	Soil	DB	S	75:25:0		B07BG3	NR	<30	<30	<30	<30 (i)	<30	140	<30	<15	<15	201	<15	<15	<15	<15	ND	ND
149.7	45.6	Soil	DB	S	50:50:0		B07BG4	NR	<35	<35	<35	<35 (i)	<35	56	<35	<20	<20	21	<20	<20	<20	<20	ND	ND
154.5	47.1	Soil	DB	S	50:50:0		B07BG5	<50	<25	<25	<25	<25	<25	281	<25	<15	<15	<15	<15	<15	<15	<15	ND	ND
159.5	48.6	Soil	DB	S	10:90:0		B07BG6	NR	<30	<30	<30	<30 (j)	<30	205	<30	<15	<15	53	<15	<15	<15	<15	ND	ND
164.5	50.1	Soil	DB	S	0:100:0		B07BG7	NR	<35	<35	<35	<35	<35	177	<35	<20	<20	<20	<20	<20	<20	<20	ND	ND
164.5	50.1	Soil	DB	S	0:100:0		B07BG8	NR	<30	<30	<30	<30	<30	377	<30	<15	<15	<15	<15	<15	<15	<15	ND	ND
172.0	52.4	Soil	DB	S	10:90:0		B07BG9	<20	<10	<20	<10	<20	<20	<20 (k)	<20	<10	<10	15	<10	<10	<10	<10	ND	ND
175.5	53.5	Soil	DB	S	NR		B07BH0	<20	<20	<20	<20	<20	<20	116	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
182.0	55.5	Soil	DB	S	50:50:0	(1)	B07BH1	<30	<15	<15	<15	<15	<15	<15	<15	<10	<15	15	<15	<10	<10	<10	ND	ND
185.1	56.4	Soil	DB	CB	100:0:0		B07BH2	<20	<20	<20	<20	<20	<20	159	<20	<10	<20	<20	<20	<10	<10	<10	ND	ND
191.7	58.4	Soil	DB	S	100:0:0		B07BH3	<25	<15	<25	<15	<25	<25	<25 (l)	<25	<15	<15	19	<15	<15	<15	<15	ND	ND
195.8	59.7	Soil	DB	S	100:0:0		B07BH4	<15	<10	<15	<10	<15	<15	<15	<15	<10	<10	<10	<10	<10	<10	<10	ND	ND
199.5	60.8	Soil	DB	S	100:0:0		B07BH5	68	<20	<35	<20	<35 (k)	<35	130	<35	<20	<20	626	<20	<20	<20	<20	ND	ND
206.1	62.8	Soil	DB	CB	100:0:0		B07BH6	<30	<30	<30	<30	<30	<30	<30 (m)	<30	<15	<15	<15	<15	<15	<15	<15	ND	ND
211.1	64.3	Soil	DB	S	95:5:0		B07C87	<25	<25	<25	<25	<25	<25	<25	<25	<15	<15	20	<15	<15	<15	<15	ND	ND
214.7	65.4	Soil	DB	S	95:5:0		B07C88	<40	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	ND	ND
220.2	67.1	Soil	HT	S	100:0:0		B07C89	<30	<15	<15	<15	<15	<15	<15	<15	<10	<15	<10	<15	<10	<10	<10	ND	ND
225.6	68.8	Soil	HT	S	95:5:0		B07C90	<20	<20	<20	<20	<20	<20	<20	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
227.4	69.3	Water	HT	TB	N/A		B07BS5	<5	<0.5	<2	<0.5	46	<2	1130 (n)	<2	<0.5	2.2	<0.5	0.6	<0.5	<0.5	<0.5	ND	ND

Sample/Subsample Methods

DB = Drive Barrel

CB = Core borer
S = Scoopula
TB = Teflon Bailer

Lab Notes

(1) No tare weight - so weight was estimated.
(2) Turbid sample.

ND = Not Detected N/A = Not Applicable
NR = Not Recorded

Analysis Notes

(a) ~6 observed, but below LDL's.
(b) ~<2
(c) None observed.
(d) ~7 observed, but below LDL's.
(e) ~18 observed, but below LDL's.
(f) ~16
(g) ~25 observed.
(h) ~9 observed, but below LDL's.
(i) ~12 observed, but below LDL's.
(j) ~11 observed, but below LDL's.
(k) ~10 observed, but below LDL's.
(l) ~8 observed, but below LDL's.
(m) ~24 observed, but below LDL's.
(n) 1:200 dilution necessary for CCl4 Analysis

Analytical Results **VOLATILE ORGANIC COMPOUNDS** **299-W18-96 (ID-4)**

Depth (ft)	Depth (m)	Sample Matrix	Drill/ Sample Method	Sub-sample Method	Approx. %Fine: %Coarse: %Rock	Lab Notes	HEIS Sample Number	Meth-ylene Chloride (ppb)	trans-1,2-Dichloro-ethylene (ppb)	1,1-Dichloro-ethane (ppb)	cis-1,2-Dichloro-ethylene (ppb)	Chloro-form (ppb)	1,1,1-Tri-chloro-ethane (ppb)	CC14 (ppb)	1,2-Di-chloro-ethane (ppb)	Benzene (ppb)	Trichloro-ethylene (ppb)	Toluene (ppb)	Tetra-chloro-ethylene (ppb)	Ethyl-benzene (ppb)	M+P-Xylene (ppb)	O-Xylene (ppb)	n-Butyl Benzene (ppb)
84.0	25.6	Sed	SB	CB	NR		B01NW7	<300	<10	<50	<10	<50	<50	89	<50	<10	<10	<10	<10	<10	<10	<10	ND
86.5	26.4	Sed	SB	CB	NR		B01NX1	<400	<25	<70	<25	<70	<70	79	<70	<25	<25	94	<25	<25	<25	<25	ND
86.5	26.4	Sed	SB	CB	NR		B01NX3	<250	<15	<50	<15	<50	<50	93	<50	<15	<15	<15	<15	<15	<15	<15	ND
90.0	27.4	Sed	DB	S	NR		B01NW8	<150	<10	<25	<10	<25 (a)	<25	332	<25	<10	<10	<10	<10	<10	<10	<10	ND
90.0	27.4	Sed	DB	CB	NR		B01NW9	<150	<30	<30	<30	<30 (b)	<30	440	<30	<15	<15	<15	<15	<15	<15	<15	ND
92.4	28.1	Sed	SB	S	NR		B01NX5	<100	<10	<25	<10	<25	<25	99	<25	<10	<10	<10	<10	<10	<10	<10	ND
92.4	28.1	Sed	SB	CB	NR		B01NX7	<100	<10	<25	<10	<25	<25	56	<10	<10	<10	<10	<10	<10	<10	<10	ND
95.0	29.0	Sed	DB	S	NR		B01NX8	<100	<10	<25	<10	<25	<25	124	<10	<10	<10	<10	<10	<10	<10	<10	ND
98.0	29.9	Sed	DB	S	NR		B01NY1	<150	<10	<25	<10	<25	<25	111	<25	<10	<10	<10	<10	<10	<10	<10	ND
98.0	29.9	Sed	DB	S	NR		B01NY2	150.0	<10	<25	<10	<25	<25	193	<25	<10	<10	<10	<10	<10	<10	<10	ND
100.5	30.6	Sed	SB	CB	NR		B01NX9	<100	<10	<25	<10	<25	<25	242	<25	<10	<10	<10	<10	<10	<10	<10	ND
100.5	30.6	Sed	SB	S	NR		B01NY0	<70	<10	<20	<10	<20	<20	127	<20	<10	<10	<10	<10	<10	<10	<10	ND
104.0	31.7	Sed	DB	S	NR		B01NY3	<100	<10	<20	<10	<20	<20	140	<20	<10	<10	<10	<10	<10	<10	<10	ND
110.2	33.6	Sed	DB	S	60:40:0		B01NY4	<100	<10	<20	<10	<20	<20	<20 (c)	<20	<10	<10	<10	<10	<10	<10	<10	ND
110.2	33.6	Sed	DB	S	70:30:0		B01NY5	<70	<10	<15	<10	<15	<15	<15 (d)	<15	<10	<10	<10	<10	<10	<10	<10	ND
116.0	35.4	Sed	DB	S	90:10:0		B01NY6	<40	<5	<10	<5	<10	<10	12	<10	<5	<5	<5	<5	<5	<5	<5	ND
119.0	36.3	Sed	DB	S	50:0:50		B01NY9	<80	<5	<15	<5	<15	<15	<15 (e)	<15	<5	<5	<5	<5	<5	<5	<5	ND
120.0	36.6	Sed	SB	S	80:0:20		B01NY7	<80	<5	<15	<5	<15	<15	<15 (f)	<15	<5	<5	14	<5	<5	<5	<5	ND
120.0	36.6	Sed	SB	S	90:0:10		B01NY8	<70	<5	<15	<5	<15	<15	<15 (g)	<15	<5	<5	<5	<5	<5	<5	<5	ND
123.5	37.6	Sed	SB	CB	60:0:40		B01NZ1	<40	<5	<10	<5	<10	<10	41	<10	<5	<5	12	<5	<5	<5	<5	ND
123.5	37.6	Sed	SB	S	50:0:50		B01NZ2	<70	<5	<15	<15	<15	<15	52	<15	<5	<5	<5	<5	<5	<5	<5	ND
125.5	38.3	Sed	SB	CB	100:0:0		B01P91	61.0	<5	<10	<5	<10	<10	41	<10	<5	<5	<5	<5	<5	<5	<5	~13 (h,i)
125.5	38.3	Sed	SB	S	95:0:5		B01P92	<50	<5	<10	<5	<10	<10	68	<10	<5	<5	<5	<5	<5	<5	<5	ND
125.5	38.3	Sed	SB	CB	80:20:0		B01P93	<75	<5	<15	<5	<15	<15	<15 (j)	<15	<5	<5	55	<5	<5	<5	<5	ND
125.5	38.3	Sed	SB	S	90:10:0		B01P94	85.0	<5	<15	<15	<15	<15	<15 (k)	<15	<5	<5	54	<5	<5	<5	<5	ND
129.0	39.3	Sed	DB	CB	100:0:0		B01NZ9	<100	<10	<20	<10	<20	<20	65	<20	<10	<10	<10	<10	<10	<10	<10	ND
129.0	39.3	Sed	DB	CB	100:0:0		B01P00	<140	<10	<30	<10	<30	<30	43	<30	<10	<10	<10	<10	<10	<10	<10	ND
129.0	39.3	Sed	DB	S	100:0:0		B01P01	<70	<5	<15	<5	<15	<15	28	<15	<5	<5	<5	<5	<5	<5	<5	ND
129.0	39.3	Sed	DB	S	100:0:0		B01P02	<50	<5	<10	<5	<10	<10	39	<10	<5	<5	<5	<5	<5	<5	<5	ND
130.5	39.8	Sed	SB	CB	100:0:0		B01NZ5	<60	<5	<15	<5	<15	<15	16	<15	<5	<5	7	<5	<5	<5	<5	ND
130.5	39.8	Sed	SB	CB	95:5:0		B01NZ6	<50	<5	<10	<5	<10	<10	14	<10	<5	<5	12	<5	<5	<5	<5	ND
130.5	39.8	Sed	SB	S	80:20:0		B01NZ7	182.0	<5	<15	<5	<15	<15	<15 (j)	<15	<5	<5	84	<5	<5	<5	<5	~8 (i)
130.5	39.8	Sed	SB	S	90:10:0		B01NZ8	<100	<10	<20	<10	<20	<20	<20	<20 (d)	<10	<10	<10	<10	<10	<10	<10	ND
134.5	41.0	Sed	DB	CB	100:0:0		B01P05	<120	<10	<25	<10	44	<25	111	<25	<10	<10	15	<10	<10	<10	<10	ND
134.5	41.0	Sed	DB	CB	100:0:0		B01P06	<100	<15	<40	<15	<40	<40	<40 (l)	<40	<15	<15	25	<15	<15	<15	<15	ND
136.5	41.6	Sed	SB	CB	100:0:0	(1)	B01P03	<100	<10	<20	<10	<20 (f)	<20	786	<20	<10	<10	<10	<10	<10	<10	<10	ND
136.5	41.6	Sed	SB	CB	95:5:0		B01P04	<70	<5	<15	<5	<15 (j)	<15	759	<15	<5	<5	<5	<5	<5	<5	<5	ND
138.5	42.2	Sed	SB	CB	100:0:0		B01NZ3	<100	<10	<30	<10	<30 (d)	<30	334	<30	<10	<10	12	<10	<10	<10	<10	ND
138.5	42.2	Sed	SB	S	100:0:0		B01NZ4	<70	<5	<15	<5	<15 (d)	<15	494	<15	<5	<5	13	<5	<5	<5	<5	ND
143.8	43.8	Sed	SB	CB	100:0:0		B01P95	<100	<10	<25	<10	<25 (j)	<25	861	<25	<10	<10	<10	<10	<10	<10	<10	ND
143.8	43.8	Sed	SB	CB	90:10:0		B01P96	<100	<10	<20	<10	<20 (d)	<20	714	<20	<10	<10	<10	<10	<10	<10	<10	ND
143.8	43.8	Sed	SB	S	100:0:0		B01P98	<75	<5	<15	<5	<15	<15	626	<15	<5	<5	<5	<5	<5	<5	<5	ND
144.5	44.0	Sed	SB	CB	100:0:0		B01PB0	<100	<10	<25	<10	<25 (d)	<25	<25 (m)	<25	<10	<10	<10	<10	<10	<10	<10	ND
144.5	44.0	Sed	SB	S	100:0:0		B01PB1	<100	<10	<20	<10	<20 (n)	<20	28	<20	<10	<10	<10	<10	<10	<10	<10	ND
146.5	44.7	Sed	SB	CB	100:0:0		B01P99	<100	<10	<20	<10	<20	<20	33	<20	<10	<10	<10	<10	<10	<10	<10	ND
146.5	44.7	Sed	SB	S	100:0:0		B01PB2	<75	<5	<15	<5	<15	<15	33	<15	<5	<5	<5	<5	<5	<5	<5	ND

Sample/Subsample Methods

DB = Drive Barrel
SB = Split-Barrel

CB = Core borer
S = Scoopula

Lab Notes

(1) Possibly clay.

ND = Not Detected
NR = Not Reported

Analysis Notes

(a) ~16 observed, but below LDL's.
(b) ~21 observed, but below LDL's.
(c) ~10 observed, but below LDL's.
(d) ~4 observed, but below LDL's.
(e) ~6 observed, but below LDL's.
(f) ~7 observed, but below LDL's.
(g) ~2 observed, but below LDL's.
(h) Possibly n-Butyl Benzene.
(i) Non-calibrated estimate.
(j) ~5 observed, but below LDL's.
(k) ~8 observed, but below LDL's.
(l) ~17 observed, but below LDL's.
(m) ~24 observed, but below LDL's.
(n) ~3 observed, but below LDL's.

Analytical Results **CHEMICAL** **299-W18-96 (ID-4)**

Depth (ft)	Depth (m)	HEIS Sample Number	IONS Fluoride (F) (µg/Kg)	Chloride (Cl) (µg/Kg)	Nitrate Ion (NO3) (µg/Kg)	Nitrite Ion (NO2) (µg/Kg)	Bromide (Br) (µg/Kg)	Phosphate Ion (PO4) (µg/Kg)	Sulfate (SO4) (µg/Kg)	Cyanide (CN) (µg/Kg)	Mercury (Hg) (µg/Kg)	Lead (Pb) (µg/Kg)	ABN (SVOA) o-cresol (µg/Kg)	m-cresol (µg/Kg)	p-cresol (µg/Kg)	Decane (µg/Kg)	Dodecane (µg/Kg)
Limit of Detection =>			200	400	400	400	500	800	1000	3000	400	500	660	660	660	660	660
84.0	25.6	B01NW7	4700	22000	4400000	1900	ND	ND	22000	ND	ND	5300	ND	ND	ND	ND	ND
86.5	26.4	B01NX1	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
86.5	26.4	B01NX3	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
90.0	27.4	B01NW9	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
92.4	28.1	B01NX5	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
95.0	29.0	B01NX8	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
98.0	29.9	B01NY1	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
100.5	30.6	B01NX9	1000	6300	990000	ND	ND	ND	8800	ND	ND	4800	ND	ND	ND	ND	ND
104.0	31.7	B01NY3	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
110.2	33.6	B01NY4	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
116.0	35.4	B01NY6	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
119.0	36.3	B01NY9	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
120.0	36.6	B01NY7	1800	3800	12000	ND	ND	ND	19000	ND	ND	2900	ND	ND	ND	ND	ND
123.5	37.6	B01NZ1	400	3900	11000	600	ND	ND	15000	ND	ND	3900	ND	ND	ND	ND	ND
125.5	38.3	B01P91	900	3400	6800	ND	ND	ND	18000	ND	ND	1800	ND	ND	ND	ND	ND
125.5	38.3	B01P93	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
129.0	39.3	B01NZ9	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
129.0	39.3	B01P00	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
130.5	39.8	B01NZ5	700	1800	2400	ND	ND	ND	8800	ND	ND	3200	ND	ND	ND	ND	ND
130.5	39.8	B01NZ6	700	1800	1800	ND	600	ND	8800	ND	ND	6100	ND	ND	ND	ND	ND
134.5	41.0	B01P05	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
136.5	41.6	B01P03	300	900	1200	ND	ND	ND	3800	ND	ND	12000	ND	ND	ND	ND	ND
138.5	42.2	B01NZ3	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
143.8	43.8	B01P95	600	1900	1400	ND	ND	800	4800	ND	ND	18000	ND	ND	ND	ND	ND
144.5	44.0	B01PB1	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
146.5	44.7	B01P99	300	1600	1200	ND	ND	1100	3200	ND	ND	5400	ND	ND	ND	ND	ND

Depth (ft)	Depth (m)	HEIS Sample Number	ABN (SVOA) Tetradecane (µg/Kg)	Naphthalene (µg/Kg)	Pentachlorophenol (µg/Kg)	Phenol (µg/Kg)	Tributyl Phosphate (µg/Kg)	2-Fluorophenol (µg/Kg)	Phenol, d6 (µg/Kg)	Nitrobenzene d5 (µg/Kg)	Fluorobiphenyl (µg/Kg)	2,4,6-Tribromophenol (µg/Kg)	Terphenyl d14 (µg/Kg)	ICP METALS Aluminum (Al) (µg/Kg)	Antimony (Sb) (µg/Kg)	Barium (Ba) (µg/Kg)	Beryllium (Be) (µg/Kg)
Limit of Detection =>			660	660	3300	660	640							20000	20000	2000	300
84.0	25.6	B01NW7	ND	ND	ND	ND	ND	5900	6300	2800	2900	4800	3400	•	ND	87000	400
86.5	26.4	B01NX1	ND	ND	ND	ND	ND	5900	6000	2800	2600	3800	3100	•	•	•	•
86.5	26.4	B01NX3	ND	ND	ND	ND	ND	7100	7000	3300	3100	4600	3200	•	•	•	•
90.0	27.4	B01NW9	ND	ND	ND	ND	ND	6400	6200	3800	2800	4200	3100	•	•	•	•
92.4	28.1	B01NX5	ND	ND	ND	ND	ND	8700	8400	4100	3600	5900	3900	•	•	•	•
95.0	29.0	B01NX8	ND	ND	ND	ND	ND	7500	7300	3700	3100	4300	3500	•	•	•	•
98.0	29.9	B01NY1	ND	ND	ND	ND	ND	7300	7000	3400	3800	4600	3500	•	•	•	•
100.5	30.6	B01NX9	ND	ND	ND	ND	ND	6100	6200	3800	2900	49[illegible]	3300	•	ND	73000	400
104.0	31.7	B01NY3	ND	ND	ND	ND	ND	7200	6800	3200	2900	4400	3000	•	•	•	•
110.2	33.6	B01NY4	ND	ND	ND	ND	ND	7200	7300	3800	3200	5100	3200	•	•	•	•
116.0	35.4	B01NY6	ND	ND	ND	ND	ND	7300	6900	3300	2900	4200	3800	•	•	•	•
119.0	36.3	B01NY9	ND	ND	ND	ND	ND	6800	6300	3100	2900	4600	3200	•	•	•	•
120.0	36.6	B01NY7	ND	ND	ND	ND	ND	6700	6800	3400	3100	4900	3200	•	ND	87000	300
123.5	37.6	B01NZ1	ND	ND	ND	ND	ND	2800	4000	2000	2100	3200	2600	12000000	ND	9000	420
125.5	38.3	B01P91	ND	ND	ND	ND	ND	6800	7200	3400	3100	4800	3100	•	ND	70000	ND
125.5	38.3	B01P93	ND	ND	ND	ND	ND	7200	7200	3600	3300	5400	3300	•	•	•	•
129.0	39.3	B01NZ9	ND	ND	ND	ND	ND	6700	7100	3400	3200	4900	3300	•	•	•	•
129.0	39.3	B01P00	ND	ND	ND	ND	ND	7400	7800	3800	3300	5300	3400	•	•	•	•
130.5	39.8	B01NZ5	ND	ND	ND	ND	ND	6200	6600	3300	3000	4600	3300	•	ND	86000	300
130.5	39.8	B01NZ6	ND	ND	ND	ND	ND	7000	7200	3600	3300	5200	3200	•	ND	84000	400
134.5	41.0	B01P05	ND	ND	ND	ND	ND	7300	7600	3600	3300	5300	3400	•	•	•	•
136.5	41.6	B01P03	ND	ND	ND	ND	ND	8100	8400	3800	3700	6100	3900	•	ND	110000	600
138.5	42.2	B01NZ3	ND	ND	ND	ND	ND	4100	4700	2200	2300	4800	3100	•	•	•	•
143.8	43.8	B01P95	ND	ND	ND	ND	ND	3900	4900	2200	2400	5300	3000	13000000	ND	88000	580
144.5	44.0	B01PB1	ND	ND	ND	ND	ND	3800	4400	2100	2300	3000	2900	•	•	•	•
146.5	44.7	B01P99	ND	ND	ND	ND	ND	4000	5100	2200	2400	5000	2800	9300000	ND	78000	530

Depth (ft)	Depth (m)	HEIS Sample Number	ICP METALS Cadmium (Cd) (µg/Kg)	Calcium (Ca) (µg/Kg)	Chromium (Cr) (µg/Kg)	Cobalt (Co) (µg/Kg)	Copper (Cu) (µg/Kg)	Iron (Fe) (µg/Kg)	Magnesium (Mg) (µg/Kg)	Manganese (Mn) (µg/Kg)	Nickel (Ni) (µg/Kg)	Potassium (K) (µg/Kg)	Silver (Ag) (µg/Kg)	Sodium (Na) (µg/Kg)	Tin (Sn) (µg/Kg)	Vanadium (V) (µg/Kg)	Zinc (Zn) (µg/Kg)
Limit of Detection =>			1000	10000	2000	2000	2000	2000	10000	1000	3000	30000	2000	30000	10000	3000	1000
84.0	25.6	B01NW7	ND	ND	12000	9000	16000	ND	5000000	420000	14000	1400000	ND	1300000	ND	54000	39000
86.5	26.4	B01NX1	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
86.5	26.4	B01NX3	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
90.0	27.4	B01NW9	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
92.4	28.1	B01NX5	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
95.0	29.0	B01NX8	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
98.0	29.9	B01NY1	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
100.5	30.6	B01NX9	ND	8400000	13000	7000	13000	ND	5300000	330000	12000	2800000	ND	170000	ND	30000	37000
104.0	31.7	B01NY3	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
110.2	33.6	B01NY4	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
116.0	35.4	B01NY6	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
119.0	36.3	B01NY9	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
120.0	36.6	B01NY7	ND	9500000	14000	9800	14000	ND	4600000	270000	12000	980000	ND	440000	ND	57000	43000
123.5	37.6	B01NZ1	ND	12000000	22000	18000	30000	28000000	4800000	330000	14000	730000	ND	970000	ND	77000	74000
125.5	38.3	B01P91	ND	6300000	18000	9800	14000	ND	3800000	220000	18000	630000	ND	450000	ND	47000	31000
125.5	38.3	B01P93	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
129.0	39.3	B01NZ9	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
129.0	39.3	B01P00	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
130.5	39.8	B01NZ5	ND	8600000	13000	7000	13000	ND	3800000	230000	13000	790000	ND	420000	ND	49000	36000
130.5	39.8	B01NZ6	ND	8800000	16000	7000	13000	ND	5600000	330000	28000	1900000	ND	200000	ND	37000	42000
134.5	41.0	B01P05	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
136.5	41.6	B01P03	ND	ND	17000	9800	28000	ND	7800000	330000	17000	2100000	ND	170000	ND	33000	54000
138.5	42.2	B01NZ3	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
143.8	43.8	B01P95	ND	11000000	28000	7700	21000	19000000	7300000	280000	16000	2200000	ND	200000	ND	34000	52000
144.5	44.0	B01PB1	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
146.5	44.7	B01P99	ND	23000000	22000	6800	15000	28000000	5900000	260000	14000	1200000	ND	400000	ND	67000	41000

ND = Not Detected • = Not Analyzed

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RADIONUCLIDE ANALYSES FOR SOILS FROM WELL NO. 299-W18-96 (ID-4)

		HEIS	Alpha	Beta	Gamma								PUIS		Sr-90	Am-241
Depth (ft)	Depth (m)	Sample Number	(pci/g)	(pci/g)	Co-60 (pci/g)	Ru-106 (pci/g)	Sb-125 (pci/g)	Cs-137 (pci/g)	Pb-212 (pci/g)	Pb-214 (pci/g)	Ra-226 (pci/g)	Ra-224 (pci/g)	U-238 (pci/g)	U-239/40 (pci/g)	(pci/g)	(pci/g)
84.0	25.6	B01NW7	7.73	3.79	-0.00526	0.11	0.0177	-0.0113	0.864	0.695	0.669	0.899	0.0000419	0.00187	0.0059	0.000199
86.0	26.2	B01NX2	4.53	22.10	-0.014	-0.592	-0.0497	-0.0387	1.76	1.45	1.31	1.83	-0.000161	0.000492	0.00731	0.0016
86.5	26.4	B01NX4	9.35	17.10	-0.00165	-0.164	0.0632	0.00647	0.955	0.731	0.85	0.993	-8.39E-05	0.000336	0.00582	0.000246
91.4	27.9	B01NX6	4.61	18.90	0.017	0.038	0.0382	0.00757	0.761	0.611	0.638	0.791	0.0000451	0.000194	0.00802	0.000557
100.5	30.6	B01NX9	2.04	21.60	0.00302	-0.127	-0.034	-0.00352	0.719	0.585	0.544	0.747	-1.46E-06	0.000132	-0.0018	-0.0000649
120.0	36.6	B01NY7	7.94	13.70	0.00945	-0.389	0.00413	-0.00914	0.636	0.475	0.607	0.658	-5.33E-05	0.000588	-8.22E-05	0.000468
123.5	37.6	B01NZ1	1.30	2.31	0.00351	0.228	0.11	-0.00461	0.381	0.39	0.448	0.394	0.0000547	0.000913	-0.00585	0.0000319
125.5	38.3	B01P91	6.44	13.70	-0.0175	-0.125	0.0515	-0.0295	0.391	0.27	0.377	0.404	-2.86E-05	0.000233	-0.00372	0.0129
130.5	39.8	B01NZ5	1.53	13.80	0.00228	-0.34	-0.0102	-0.0174	0.523	0.477	0.472	0.539	0.0000164	0.00379	-0.00513	0.000718
136.5	41.6	B01P03	7.68	6.89	0.0348	-0.0106	0.00217	-0.000873	1.22	1.12	0.839	1.25	-2.87E-05	0.000242	-0.000278	-0.000219
143.8	43.8	B01P95	10.40	27.10	-0.00828	-0.0414	0.00293	0.00144	1.29	0.975	0.863	1.53	-0.000401	0.00153	-0.0024	-0.0000838
146.5	44.7	B01P99	12.50	15.80	0.0073	0.0756	-0.0483	-0.00353	1.03	0.758	0.745	1.22	-2.88E-05	-3.28E-06	0.00253	0.00061

Depth (ft)	Depth (m)	Sample Matrix	Drill / Sample Method	Sub-sample Method	Approx. %Fine: %Coarse: %Rock	Lab Notes	HEIS Sample Number	Methylene Chloride (ppb)	trans-1,2-Dichloro-ethylene (ppb)	1,1-Dichloro-ethane (ppb)	cis-1,2-Dichloro-ethylene (ppb)	Chloro-form (ppb)	1,1,1-Tri-chloro-ethane (ppb)	CC14 (ppb)	1,2-Di-chloro-ethane (ppb)	Benzene (ppb)	Trichloro-ethylene (ppb)	Toluene (ppb)	Tetra-chloro-ethylene (ppb)	Ethyl-benzene (ppb)	M+P Xylene (ppb)	O-Xylene (ppb)	Methyl Ethyl Ketone (ppb)	Methyl Iso Butyl Ketone (ppb)
53.0	16.2	Sed	DB	S	100:0:0		B01PF0	<60	<10	<30	<10	<30	<30	31	<30	<10	<10	<10	<10	<10	<10	<10	~165 (a)	ND
53.0	16.2	Sed	DB	CB	100:0:0		B01PF1	<80	<10	<40	<10	<40	<40	<40 (b)	<40	<10	<10	<10	<10	<10	<10	<10	~165 (a)	ND
56.0	17.1	Sed	SB	S	100:0:0		B01PH4	<80	<15	<40	<15	<40	<40	41	<40	<15	<15	<15	<15	<15	<15	<15	~170 (a)	ND
56.0	17.1	Sed	SB	CB	100:0:0		B01PH5	<80	<15	<40	<15	<40	<40	95	<40	<15	<15	<15	<15	<15	<15	<15	~180 (a)	ND
57.5	17.5	Sed	DB	S	see note	(1)	B01PK8	<20	<5	<10	<5	<10	<10	75	<10	<5	<5	<5	<5	<5	<5	<5	ND	ND
57.5	17.5	Sed	DB	CB	100:0:0	(2)	B01PK9	<30	<5	<15	<5	<15 (c)	<15	143	<15	<5	<5	<5	5	<5	<5	<5	ND	ND
61.0	18.6	Sed	DB	S	NR		B01PL0	<30	<5	<15	<5	<15	<15	83	<15	<5	<5	<5	<5 (d)	<5	<5	<5	ND	ND
61.0	18.6	Sed	DB	CB	100:0:0	(2)	B01PL1	<30	<5	<15	<5	<15	<15	126	<15	<5	<5	<5	7	<5	<5	<5	ND	ND
65.8	20.0	Sed	DB	S	100:0:0		B01PL2	<30	<5	<15	<5	<15	<15	69	<15	<5	<5	<5	<5	<5	<5	<5	ND	ND
66.0	20.1	Sed	DB	CB	100:0:0	(2)	B01PL3	<40	<10	<20	<10	<20	<20	150	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
71.3	21.7	Sed	DB	S	100:0:0	(2)	B01PF2	<30	<5	<15	<5	<15	<15	52	<15	<5	<5	6	<5	<5	<5	<5	~60 (a)	ND
71.5	21.8	Sed	DB	CB	100:0:0	(2)	B01PF3	<30	<5	<15	<5	20	<15	349	<15	<5	<5	40	<5 (d)	<5	<5	<5	~74 (a)	ND
74.5	22.7	Sed	SB	S	100:0:0	(2)	B01PH6	<50	<10	<25	<10	<25	<25	151	<25	<10	<10	<10	<10	<10	<10	<10	ND	~85 (a)
74.5	22.7	Sed	SB	CB	100:0:0	(2)	B01PH7	<70	<15	<35	<15	<35	<35	337	<35	<15	<15	<15	<15	<15	<15	<15	ND	~156 (a)
75.8	23.1	Sed	DB	S	see note	(3)	B01PL4	<20	<5	<10	<5	<10 (e)	<10	67	<10	<5	<5	<5	<5 (f)	<5	<5	<5	ND	ND
76.0	23.2	Sed	DB	S	100:0:0		B01PL5	<20	<5	<10	<5	<10	<10	73	<10	<5	<5	<5	<5	<5	<5	<5	ND	~42 (a)
80.5	24.5	Sed	DB	S	95:5:0		B01PL6	<80	<15	<40	<15	<40	<40	56	<40	<15	<15	<15	<15	<15	<15	<15	ND	ND
80.6	24.6	Sed	DB	CB	90:10:0		B01PL7	<80	<15	<40	<15	<40	<40	51	<40	<15	<15	<15	<15	<15	<15	<15	ND	ND
86.1	26.2	Sed	DB	S	100:0:0		B01PL8	<70	<10	<35	<10	<35	<35	35	<35	<10	<10	<10	<10	<10	<10	<10	ND	ND
86.6	26.4	Sed	DB	CB	100:0:0		B01PL9	<50	<10	<25	<10	<25	<25	60	<25	<10	<10	<10	<10	<10	<10	<10	ND	ND
90.5	27.6	Sed	DB	S	80:10:10	(2)	B01PF4	<40	<10	<20	<10	<20	<20	<20 (g)	<20	<10	<10	<10	<10	<10	<10	<10	~138 (a)	ND
90.5	27.6	Sed	DB	S	80:10:10	(2)	B01PF5	<50	<10	<25	<10	<25	<25	<25 (e)	<25	<10	<10	<10	<10	<10	<10	<10	~52 (a)	ND
93.5	28.5	Sed	SB	S	10:90:0		B01PH8	(h)	<20	<25	<20	(h)	(h)	<25 (l)	<25	(h)	<20	(h)	<20 (h)	<20 (h)	<20	<20	ND	ND
93.5	28.5	Sed	SB	CB	10:90:0		B01PH9	(h)	<15	<30	<15	<30 (h)	<30 (h)	<30 (l)	<30	<15 (h)	<15	<15 (h)	<15 (h)	<15 (h)	<15	<15	ND	ND
96.0	29.2	Sed	DB	S	80:20:0		B01PM0	(h)	<15	<30	<15	<30 (h)	<30 (h)	<30 (l)	<30	(h)	<15	(h)	<15 (h)	<15 (h)	<15	<15	ND	ND
96.0	29.2	Sed	DB	S	80:20:0		B01PM1	(h)	<20	<40	<20	<40 (h)	<40 (h)	<40 (k)	<40	(h)	<20	(h)	<20 (h)	(h)	<20	<20	ND	ND
101.1	30.8	Sed	DB	S	see note	(1)	B01PF6	<20	<5	<5	<5	<5	<5	<5 (f)	<5	<5	<5	<5	<5	<5	<5	<5	ND	ND
101.1	30.8	Sed	DB	S	see note	(1)	B01PF7	<20	<5	<5	<5	<5	<5	<5 (l)	<5	<5	<5	<5	<5	<5	<5	<5	ND	ND
105.0	32.0	Sed	DB	S	80:20:0	(2)	B01PM2	<40	<10	<20	<10	<20	<20	<20 (f)	<20	<10	<10	<10	<10	<10	<10	<10	~8 (a,m)	ND
105.0	32.0	Sed	DB	S	80:20:0	(2)	B01PM3	<50	<10	<25	<10	<25	<25	<25 (n)	<25	<10	<10	<10	<10	<10	<10	<10	~8 (a)	ND
111.5	34.0	Sed	DB	S	100:0:0	(2)	B01PM4	<100 (o)	<15	<30	<15	<30	<30	<30 (p)	<30	<15 (o)	<15	<15 (o)	<15	<15	<15	<15	ND	ND
111.5	34.0	Sed	DB	CB	100:0:0	(2)	B01PM5	<150 (q)	<15	<30	<15	<30	<30	109	<30	<30 (q)	<15	<30 (q)	<15	<15	<15	<15	ND	ND
114.2	34.8	Sed	SB	S	100:0:0		B01PJ0	<200 (q)	<10	<20	<10	<20	<30 (q)	[illegible]	<20	<20 (q)	<10	<20 (q)	<10	<10	<10	<10	ND	ND
114.2	34.8	Sed	SB	CB	100:0:0		B01PJ1	<200 (q)	<10	<20	<10	<30 (q)	<30 (q)	498	<20	<20 (q)	<10	<20 (q)	<10	<10	<10	<10	ND	ND
115.8	35.3	Sed	DB	S	100:0:0	(2)	B01PM6	<225 (q)	<10	<25	<10	<25	<40 (q)	34	<25	<15 (q)	<10	<15 (q)	<10	<10	<10	<10	ND	ND
116.1	35.4	Sed	DB	CB	100:0:0	(2)	B01PM7	<225 (q)	<10	<20	<10	<30 (q)	<35 (q)	230	<30	<20 (q)	<20	<20 (q)	<10	<10	<10	<10	ND	ND
118.5	36.1	Sed	SB	S	50:50:0	(2)	B01PJ2	<150 (q)	<10	<20	<10	<20	<30 (q)	37	<20	<20 (q)	<10	<20 (q)	<10	<10	<10	<10	ND	ND
118.5	36.1	Sed	SB	CB	50:50:0	(2)	B01PJ3	<120	<5	<10	<5	<10	<15 (q)	68	<10	<10 (q)	<5	<10 (q)	<5	<5	<5	<5	ND	ND
122.1	37.2	Sed	DB	S	100:0:0		B01PF8	<40	<10	<20	<10	<20	<20	20	<20	<10	<10	<10	<10	<10	<10	<10	ND	ND
122.1	37.2	Sed	DB	S	100:0:0		B01PN4	<100 (q)	<10	<15	<10	<15	<15	26	<15	<20 (q)	<10	<20 (q)	<10	<10	<10	<10	ND	ND
122.2	37.2	Sed	DB	CB	95:0:5		B01PF9	<50	<10	<25	<10	40	<25	427	<25	<10	<10	<10	<10	<10	<10	<10	ND	ND
122.2	37.2	Sed	DB	CB	95:0:5		B01PN5	<150 (q)	<15	<25	<15	85	<25	357	<25	<25 (q)	<15	<25 (q)	<15	<15	<15	<15	ND	ND
124.9	38.1	Sed	SB	S	80:0:20		B01PJ4	<100 (q)	<10	<15	<10	<15	<15	789	<15	<20 (q)	<10	<20 (q)	<10	<10	<10	<10	ND	ND
124.9	38.1	Sed	SB	S	80:0:20		B01PN2	<100 (q)	<10	<15	<10	<15	<15	796	<15	<20 (q)	<10	<20 (q)	<10	<10	<10	<10	ND	ND
124.9	38.1	Sed	SB	CB	95:0:5		B01PJ5	<100 (q)	<15	<25	<15	<25 (k)	<25	1247	<25	<30 (q)	<15	<30 (q)	<15	<15	<15	<15	ND	ND
124.9	38.1	Sed	SB	CB	90:0:10		B01PN3	<100 (q)	<10	<20	<10	<20	<20	890	<20	<20 (q)	<10	<20 (q)	<10	<10	<10	<10	ND	ND
126.8	38.6	Sed	DB	S	40:60:0		B01PO0	<40	<10	<20	<10	38	<20	749	<20	<10	31	<10	24	<10	<10	<10	ND	ND
127.1	38.7	Sed	DB	CB	100:0:0		B01PO1	<40	<10	<20	<10	120	<20	6561 (r)	<20	<10	41	<10	29	<10	<10	<10	ND	ND
128.9	39.3	Sed	SB	S	100:0:0		B01PJ6	<200 (q)	<5	<15	<5	63 (q)	<15	3088 (r)	<15	<10 (q)	42	<10 (q)	33	<5	<5	<5	ND	ND
128.9	39.3	Sed	SB	CB	100:0:0		B01PJ7	<200 (q)	<10	<25	<10	95 (q)	<25	4124 (r)	<25	<20 (q)	68	<20 (q)	50	<10	<10	<10	ND	ND
130.4	39.7	Sed	DB	S	50:50:0		B01PO2	<40	<10	<20	<10	50	<20	374	<20	<10	44	<10	34	<10	<10	<10	ND	ND
131.0	39.9	Sed	DB	CB	50:50:0		B01PO3	<60	<10	<30	<10	135	<30	317	<30	<10	61	<10	47	<10	<10	<10	ND	ND

Sample/Subsample Methods

DB = Drive Barrel
SB = Split-Barrel

CB = Core borer
S = Scoopula

Lab Notes

(1) Too much soil added / turbid.
(2) Turbid
(3) Possibly fines. Too much sample (soil).

ND = Not Detected
NR = Not Reported
N/A = Not Applicable

Analysis Notes

(a) Non-calibrated estimate, Suspect.
(b) ~28 observed, but below LDL's.
(c) ~8 observed, but below LDL's.
(d) ~4 observed, but below LDL's.
(e) ~6 observed, but below LDL's.
(f) ~3 observed, but below LDL's.
(g) ~18 observed, but below LDL's.
(h) Problem's with purge & trap grade Methanol for 03/17/93 batch.
(i) ~13 observed, but below LDL's.
(j) ~15 observed, but below LDL's.
(k) ~19 observed, but below LDL's.
(l) ~2 observed, but below LDL's.
(m) MEK impurity in purge & trap Methanol ~ 1/2 amount observed in sample.
(n) None observed.
(o) High CH_3Cl_2, benzene, and toluene in purge & trap grade Methanol.
(p) ~24 observed, but below LDL's.
(q) Observed higher organic impurities in this Methanol batch. (Reordered)
(r) 200:1 dilution required.

Analytical Results CHEMICAL 299-W18-174 (BD-5)

Depth (ft)	Depth (m)	HEIS Sample Number	Fluoride (F) (ug/Kg)	Chloride (Cl) (ug/Kg)	Nitrate Ion (NO3) (ug/Kg)	Nitrite Ion (NO2) (ug/Kg)	Bromide (Br) (ug/Kg)	Phosphate Ion (PO4) (ug/Kg)	Sulfate (SO4) (ug/Kg)	Cyanide (CN) (ug/Kg)	Mercury (Hg) (ug/Kg)	Lead (Pb) (ug/Kg)	o-cresol (ug/Kg)	m-cresol (ug/Kg)	p-cresol (ug/Kg)	Decane (ug/Kg)	Dodecane (ug/Kg)
Limit of Detection =>			200	400	400	400	500	800	1000	3000	400	500	660	660	660	66000	66000
53.0	16.2	B01FF1	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
56.0	17.1	B01FH5	15000	6300	250000	600	ND	1000	10000	ND	ND	6800	ND	ND	ND	ND	ND
57.5	17.5	B01FK9	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
61.0	18.6	B01FL1	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
66.0	20.1	B01FL3	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
71.5	21.8	B01FF3	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
74.5	22.7	B01FH7	3300	1000	4600	ND	ND	ND	2800	ND	ND	2300	ND	ND	ND	ND	ND
76.0	23.2	B01FL5	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
80.6	24.6	B01FL7	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
86.6	26.4	B01FL9	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
90.5	27.6	B01FF5	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
93.5	28.5	B01FH9	7300	1300	7200	900	ND	ND	5900	ND	ND	1000	ND	ND	ND	ND	ND
96.0	29.2	B01FM1	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
101.1	30.8	B01FF7	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
105.0	32.0	B01FM3	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
111.5	34.0	B01FM5	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
114.2	34.8	B01FJ1	7900	700	3300	ND	ND	ND	3000	ND	ND	6800	ND	ND	ND	ND	ND
116.1	35.4	B01FM7	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
118.5	36.1	B01FJ3	7500	600	13000	ND	ND	ND	1600	ND	ND	4100	ND	ND	ND	ND	ND
122.2	37.2	B01FF9	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
124.9	38.1	B01FJ5	16000	3400	8000	ND	ND	ND	7700	ND	ND	3900	ND	ND	ND	ND	ND
124.9	38.1	B01FN6	15000	3100	8100	ND	ND	ND	6900	ND	ND	11000	ND	ND	ND	ND	ND
127.1	38.7	B01FO1	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND
128.9	39.3	B01FJ7	16000	2300	7300	ND	ND	ND	8300	ND	ND	4600	ND	ND	ND	ND	ND
131.0	39.9	B01FO3	•	•	•	•	•	•	•	•	•	•	ND	ND	ND	ND	ND

Depth (ft)	Depth (m)	HEIS Sample Number	Tetradecane (ug/Kg)	Naphthalene (ug/Kg)	Pentachlorophenol (ug/Kg)	Phenol (ug/Kg)	Tributyl Phosphate (ug/Kg)	2-Fluorophenol (ug/Kg)	Phenol, d6 (ug/Kg)	Nitrobenzene d5 (ug/Kg)	Fluoro-Biphenyl (ug/Kg)	2,4,6-Tribromophenol (ug/Kg)	Terphenyl, d14 (ug/Kg)	Antimony (Sb) (ug/Kg)	Barium (Ba) (ug/Kg)	Beryllium (Be) (ug/Kg)	Cadmium (Cd) (ug/Kg)
Limit of Detection =>			66000	660	3300	660	660							20000	2000	300	1000
53.0	16.2	B01FF1	ND	ND	ND	48	ND	4700	4700	2400	2400	4000	3400	•	•	•	•
56.0	17.1	B01FH5	ND	ND	ND	ND	ND	4400	4800	2500	2600	3400	3400	ND	120000	700	ND
57.5	17.5	B01FK9	ND	ND	ND	ND	ND	5000	4900	2800	3100	4300	3900	•	•	•	•
61.0	18.6	B01FL1	ND	ND	ND	ND	ND	5300	5100	2800	3000	4400	3700	•	•	•	•
66.0	20.1	B01FL3	ND	ND	ND	ND	ND	5000	4800	2800	3100	4100	3300	•	•	•	•
71.5	21.8	B01FF3	ND	ND	ND	ND	ND	5500	5100	2700	3000	4600	3700	•	•	•	•
74.5	22.7	B01FH7	ND	ND	ND	ND	ND	5400	5000	2600	3200	4000	3600	ND	93000	600	ND
76.0	23.2	B01FL5	ND	ND	ND	ND	ND	5100	4800	2700	3100	4000	3900	•	•	•	•
80.6	24.6	B01FL7	ND	ND	ND	ND	ND	4900	4600	2500	2900	4000	3200	•	•	•	•
86.6	26.4	B01FL9	ND	ND	ND	ND	ND	4600	4900	2200	2700	3800	3300	•	•	•	•
90.5	27.6	B01FF5	ND	ND	ND	ND	ND	4600	4500	2500	2900	4000	3300	•	•	•	•
93.5	28.5	B01FH9	ND	ND	ND	ND	ND	5300	4800	2500	3000	4100	3300	ND	63000	500	ND
96.0	29.2	B01FM1	ND	ND	ND	ND	ND	5600	5000	2500	3000	3800	3300	•	•	•	•
101.1	30.8	B01FF7	ND	ND	ND	ND	ND	5100	4700	2300	2700	4900	3200	•	•	•	•
105.0	32.0	B01FM3	ND	ND	ND	ND	ND	4700	4600	2500	2900	4000	3200	•	•	•	•
111.5	34.0	B01FM5	ND	ND	ND	ND	ND	4600	4600	2400	2900	4100	2700	•	•	•	•
114.2	34.8	B01FJ1	ND	ND	ND	ND	ND	5100	4800	2600	2900	4700	3100	ND	79000	600	ND
116.1	35.4	B01FM7	ND	ND	ND	ND	ND	5100	5000	2700	2900	4700	3200	•	•	•	•
118.5	36.1	B01FJ3	ND	ND	ND	ND	ND	4100	5000	2100	2400	3800	2800	ND	140000	600	ND
122.2	37.2	B01FF9	ND	ND	ND	ND	ND	4600	4600	2600	2700	4000	3100	•	•	•	•
124.9	38.1	B01FJ5	ND	ND	ND	ND	ND	5400	5300	2800	3100	5300	3400	ND	110000	700	ND
124.9	38.1	B01FN6	ND	ND	ND	ND	ND	5500	5300	2900	3000	5200	3400	ND	110000	700	ND
127.1	38.7	B01FO1	ND	ND	ND	ND	ND	5400	5500	2900	3200	5400	3600	•	•	•	•
128.9	39.3	B01FJ7	ND	ND	ND	ND	ND	5500	5300	2700	3300	4900	3200	ND	79000	500	ND
131.0	39.9	B01FO3	ND	ND	ND	ND	ND	5600	4900	2600	2900	4400	3800	•	•	•	•

Depth (ft)	Depth (m)	HEIS Sample Number	Calcium (Ca) (ug/Kg)	Chromium (Cr) (ug/Kg)	Cobalt (Co) (ug/Kg)	Copper (Cu) (ug/Kg)	Iron (Fe) (ug/Kg)	Magnesium (Mg) (ug/Kg)	Manganese (Mn) (ug/Kg)	Nickel (Ni) (ug/Kg)	Potassium (K) (ug/Kg)	Silver (Ag) (ug/Kg)	Sodium (Na) (ug/Kg)	Tin (Sn) (ug/Kg)	Vanadium (V) (ug/Kg)	Zinc (Zn) (ug/Kg)
Limit of Detection =>			10000	2000	2000	2000	2000	10000	1000	3000	30000	2000	30000	10000	3000	1000
53.0	16.2	B01FF1	•	•	•	•	•	•	•	•	•	•	•	•	•	•
56.0	17.1	B01FH5	11000000	15000	9000	24000	21000000	6300000	430000	13000	2700000	ND	1300000	ND	46000	52000
57.5	17.5	B01FK9	•	•	•	•	•	•	•	•	•	•	•	•	•	•
61.0	18.6	B01FL1	•	•	•	•	•	•	•	•	•	•	•	•	•	•
66.0	20.1	B01FL3	•	•	•	•	•	•	•	•	•	•	•	•	•	•
71.5	21.8	B01FF3	•	•	•	•	•	•	•	•	•	•	•	•	•	•
74.5	22.7	B01FH7	9500000	10000	7000	10000	19000000	4900000	340000	9000	1400000	ND	550000	ND	46000	30000
76.0	23.2	B01FL5	•	•	•	•	•	•	•	•	•	•	•	•	•	•
80.6	24.6	B01FL7	•	•	•	•	•	•	•	•	•	•	•	•	•	•
86.6	26.4	B01FL9	•	•	•	•	•	•	•	•	•	•	•	•	•	•
90.5	27.6	B01FF5	•	•	•	•	•	•	•	•	•	•	•	•	•	•
93.5	28.5	B01FH9	11000000	11000	10000	23000	23000000	5400000	270000	15000	1100000	ND	1400000	ND	52000	48000
96.0	29.2	B01FM1	•	•	•	•	•	•	•	•	•	•	•	•	•	•
101.1	30.8	B01FF7	•	•	•	•	•	•	•	•	•	•	•	•	•	•
105.0	32.0	B01FM3	•	•	•	•	•	•	•	•	•	•	•	•	•	•
111.5	34.0	B01FM5	•	•	•	•	•	•	•	•	•	•	•	•	•	•
114.2	34.8	B01FJ1	9900000	14000	7000	21000	17000000	5400000	320000	14000	1600000	ND	510000	ND	36000	41000
116.1	35.4	B01FM7	•	•	•	•	•	•	•	•	•	•	•	•	•	•
118.5	36.1	B01FJ3	12000000	19000	7000	16000	19000000	5900000	340000	12000	1800000	ND	590000	ND	43000	48000
122.2	37.2	B01FF9	•	•	•	•	•	•	•	•	•	•	•	•	•	•
124.9	38.1	B01FJ5	13000000	16000	9000	18000	19000000	7400000	330000	15000	2200000	ND	680000	ND	31000	47000
124.9	38.1	B01FN6	13000000	15000	8000	17000	19000000	7200000	310000	15000	2100000	ND	580000	ND	30000	45000
127.1	38.7	B01FO1	•	•	•	•	•	•	•	•	•	•	•	•	•	•
128.9	39.3	B01FJ7	10000000	17000	9000	16000	15000000	6100000	240000	16000	1900000	ND	410000	ND	28000	33000
131.0	39.9	B01FO3	•	•	•	•	•	•	•	•	•	•	•	•	•	•

ND = Not Detected • = Not Analyzed

Page 1 of 1

299-W18-174 47.3 ft

```
 MPLE STATUS REPORT FOR  E 8232. E-BLANK      B08484    TIME:  3/29/93   8:4
 ISPATCHED:  3/26/93   8:11      SAMPLE HAS NOT BEEN SLURPED
RECEIVED:    3/26/93  10:23

                                                         OUT OF GOOD CHARG
EXT.  DETER.    RESULTS OR STATUS                        RANGE? ANS?  CODE
****  ********  ************************************     ***    ***  *****
2172  GEA-SOIL    7.53000E 02 pCi/gWETwt Am-241          N      Y    VOGEL
2172  GEA-SOIL    3.00000E 01 pCi/gWETwt Np-237          N      Y    VOGEL
2172  GEA-SOIL    3.12000E 01 pCi/gWETwt Pa-233          N      Y    VOGEL
2172  GEA-SOIL  < 5.57000E-01 pCi/gWETwt Cs-137          N      Y    VOGEL
4271  TOT-ACT   < 5.00000E 01 pCi/G                      N      Y    VOGEL

          END OF REPORT
```

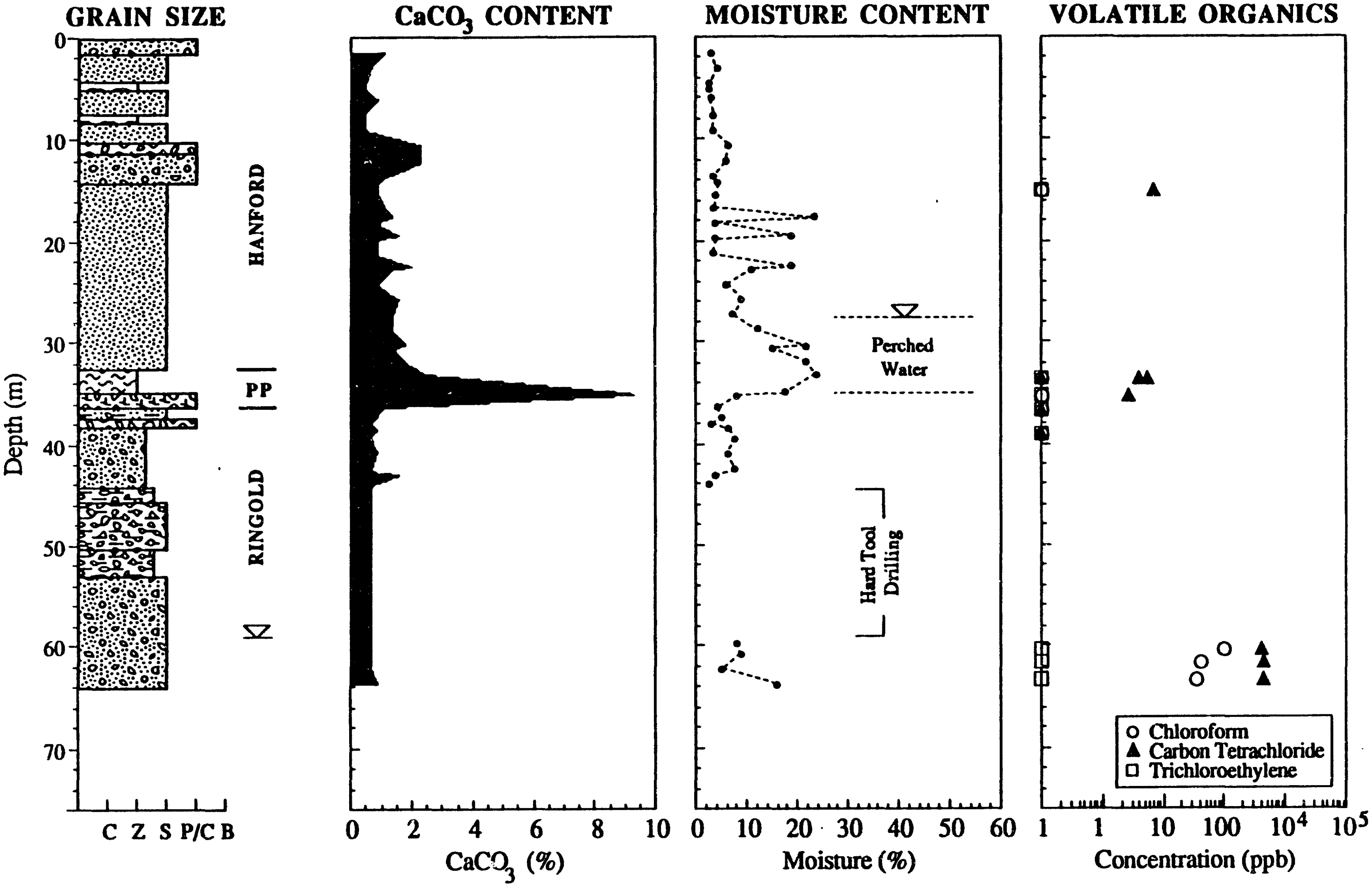
299-W18-174 48.0 ft

```
SAMPLE STATUS REPORT FOR  E 8233. E-BLANK      B08485    TIME:  3/29/93   8
DISPATCHED:  3/26/93   8:11      SAMPLE HAS NOT BEEN SLURPED
RECEIVED:    3/26/93  10:23

                                                              OUT OF  GOOD  CHARGE
EXT.  DETER.     RESULTS OR STATUS                            RANGE?  ANS?   CODE
****  ********   ***********************************           ***    ***   ******
2172  GEA-SOIL     1.92000E 03 pCi/gWETwt Am-241                N      Y    VOGEL
2172  GEA-SOIL     4.00000E 01 pCi/gWETwt Np-237                N      Y    VOGEL
2172  GEA-SOIL     3.67000E 01 pCi/gWETwt Pa-233                N      Y    VOGEL
2172  GEA-SOIL   < 6.56000E-01 pCi/gWETwt Cs-137                N      Y    VOGEL
4271  TOT-ACT      1.71850E 02 pCi/G                            N      Y    VOGEL

         END OF REPORT
```

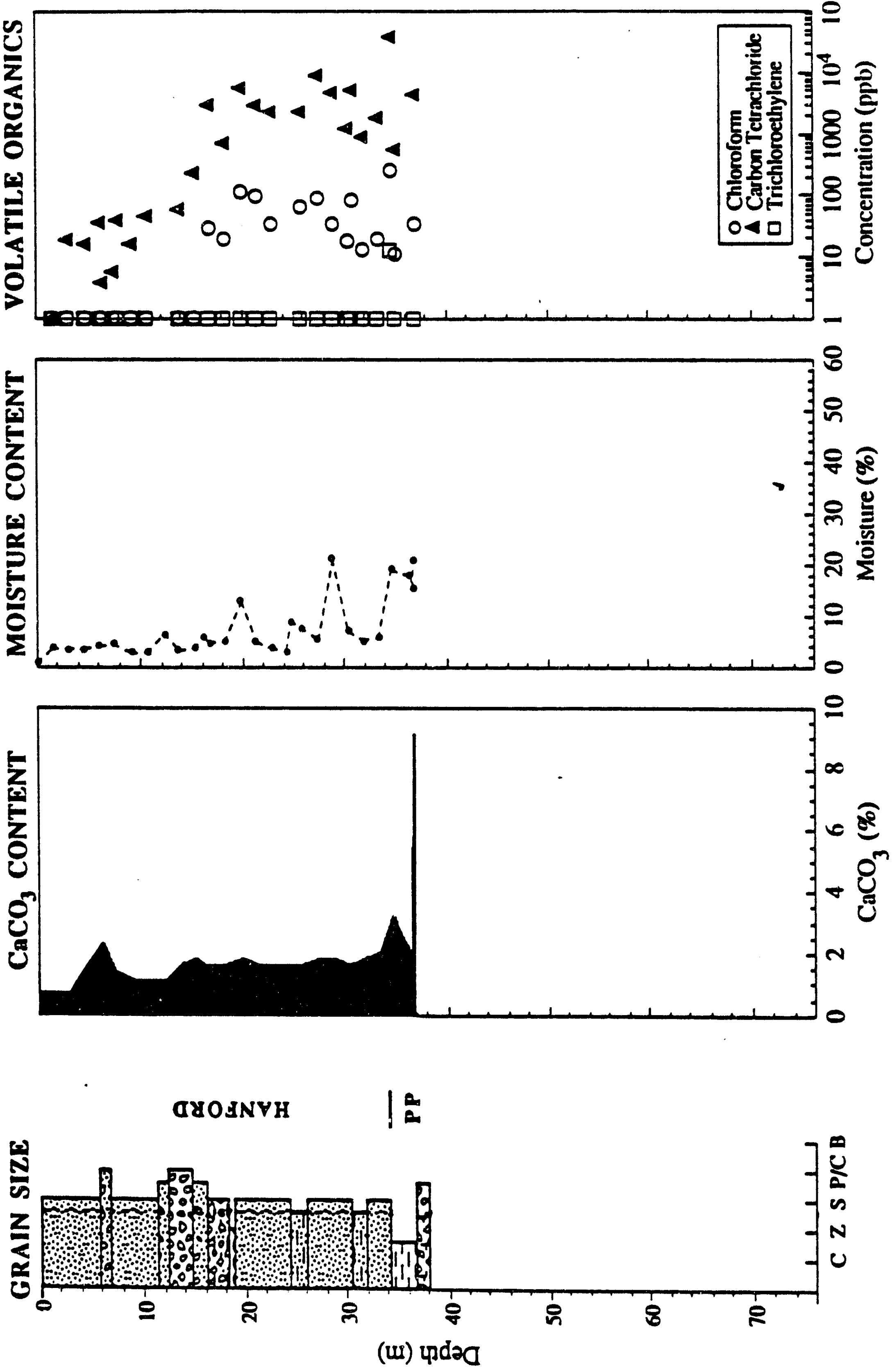
APPENDIX H

VERTICAL CONCENTRATION PROFILES OF CARBON TETRACHLORIDE AND SELECTED VOLATILE ORGANIC COMPOUNDS IN 1992 - 1993 Z CRIB AREA WELLS

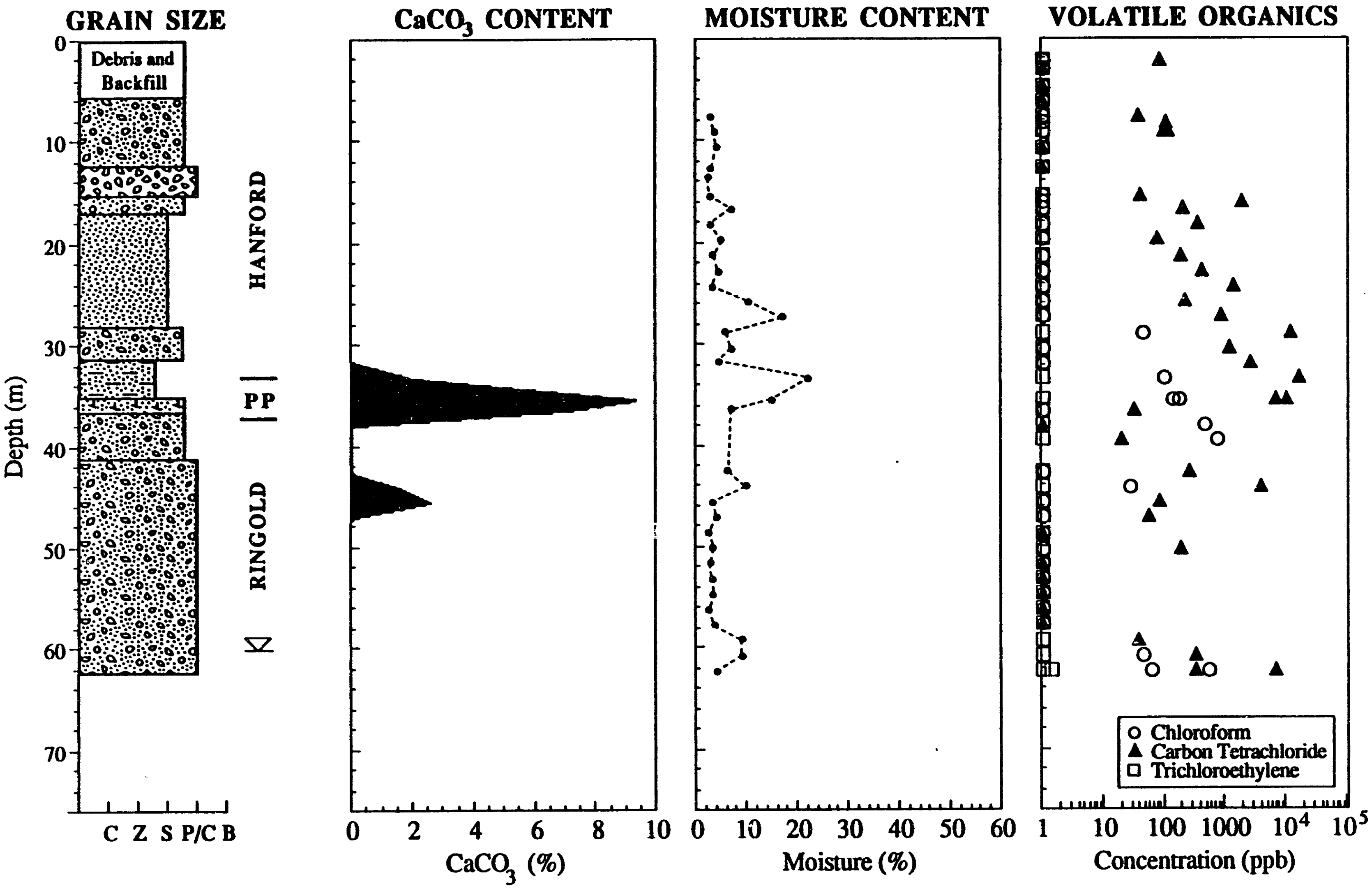
Well No. 299-W15-216



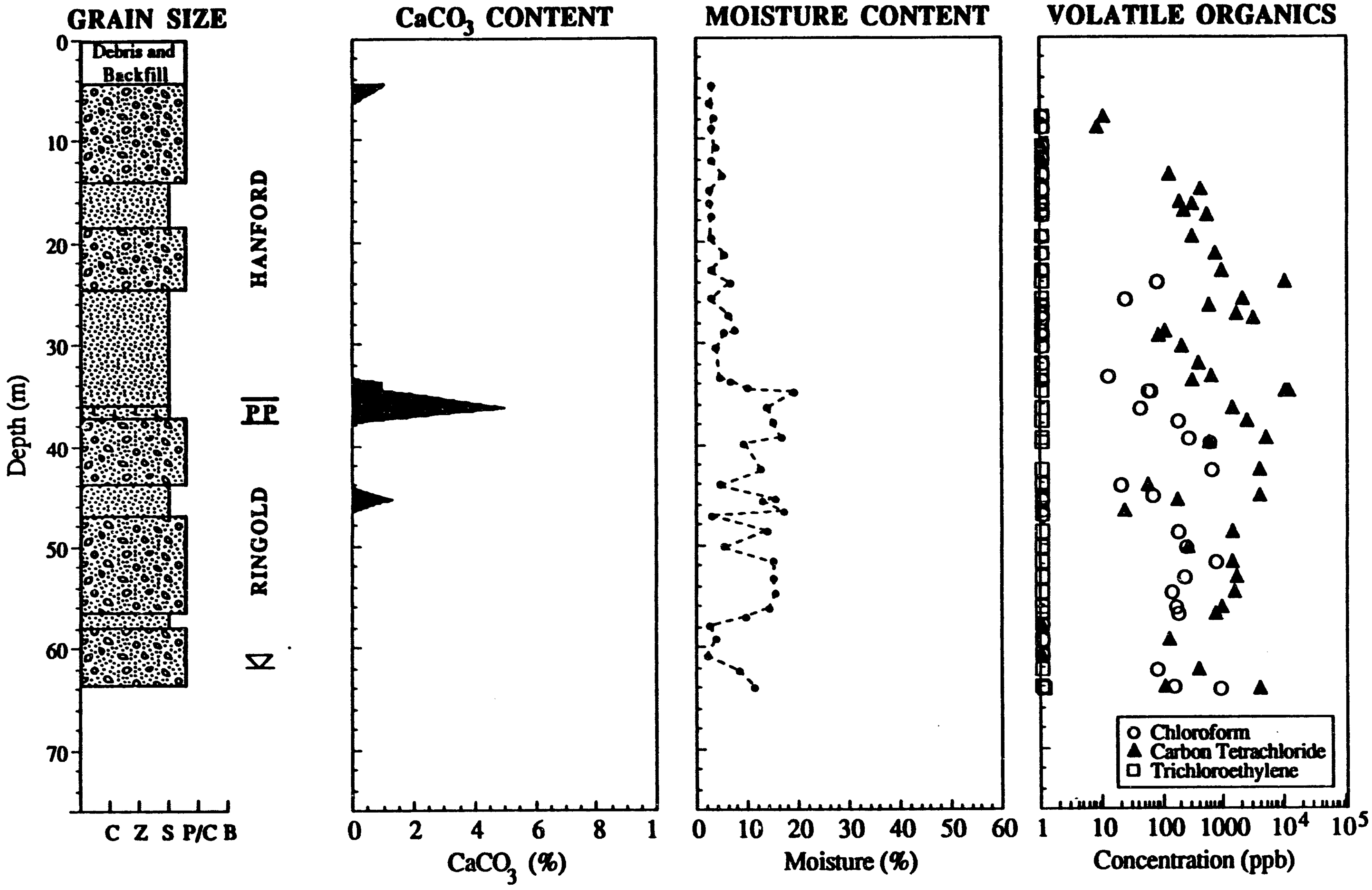
Well No. 299-W15-217

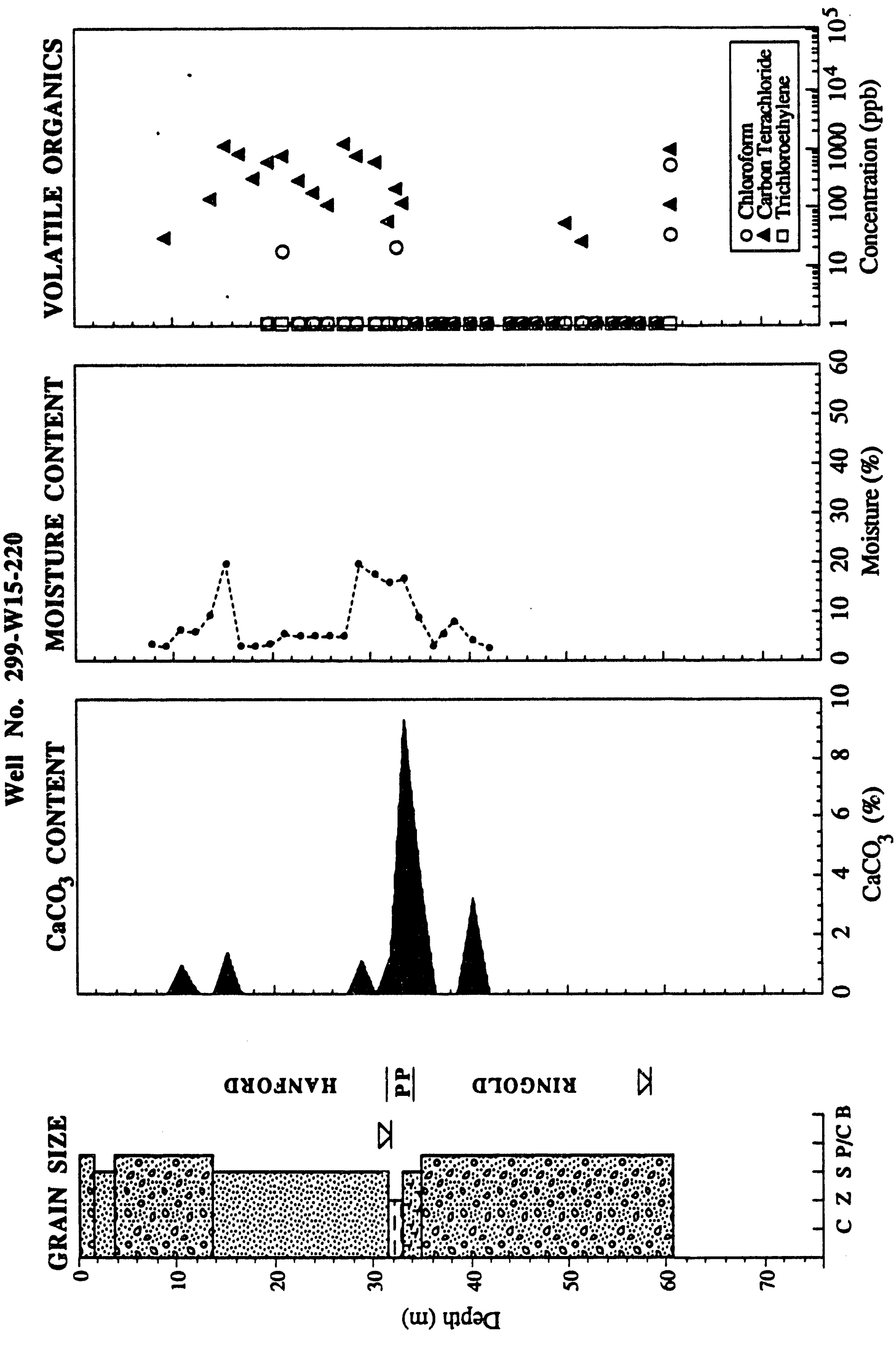


Well No. 299-W15-218

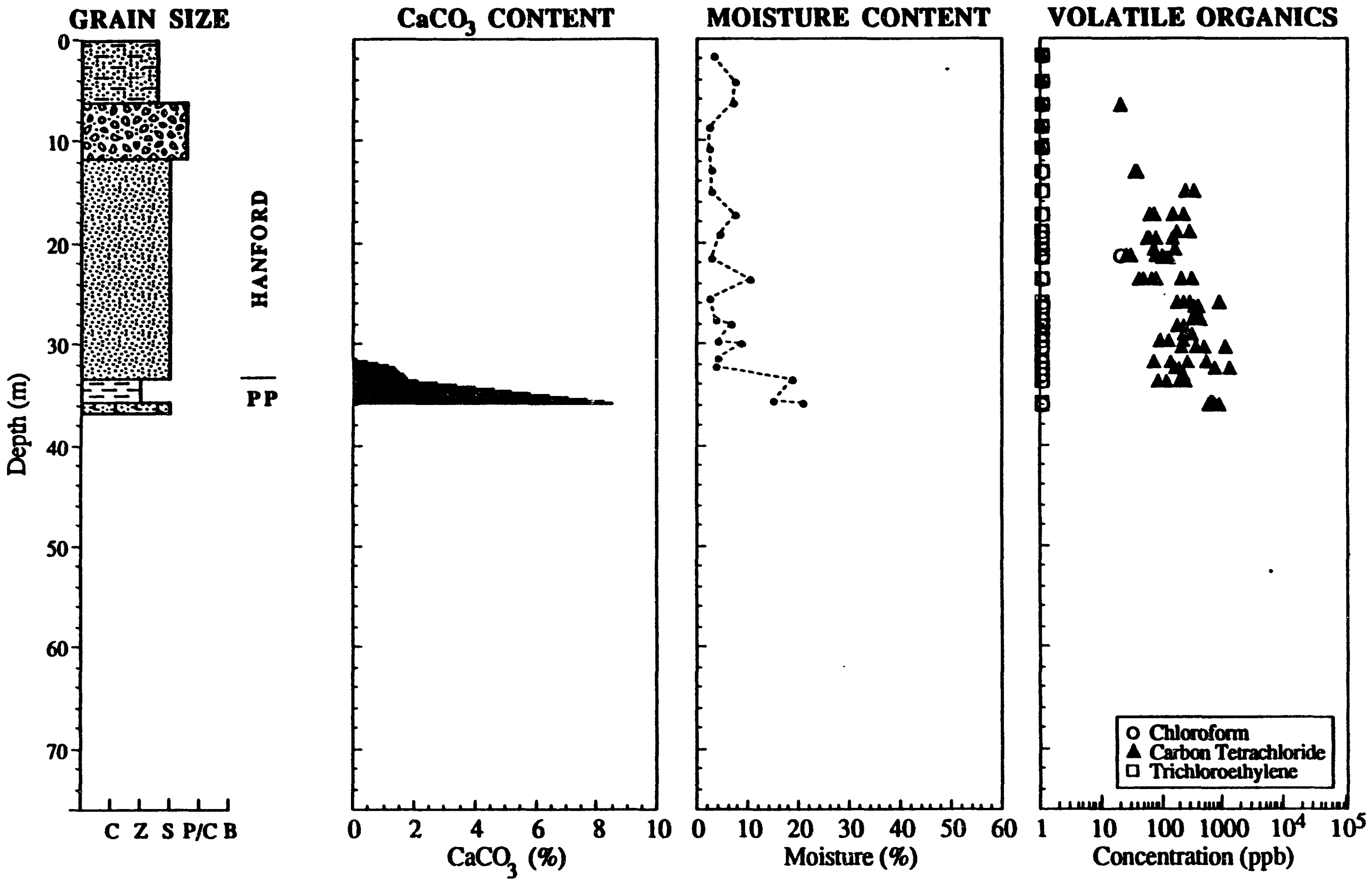


Well No. 299-W15-219

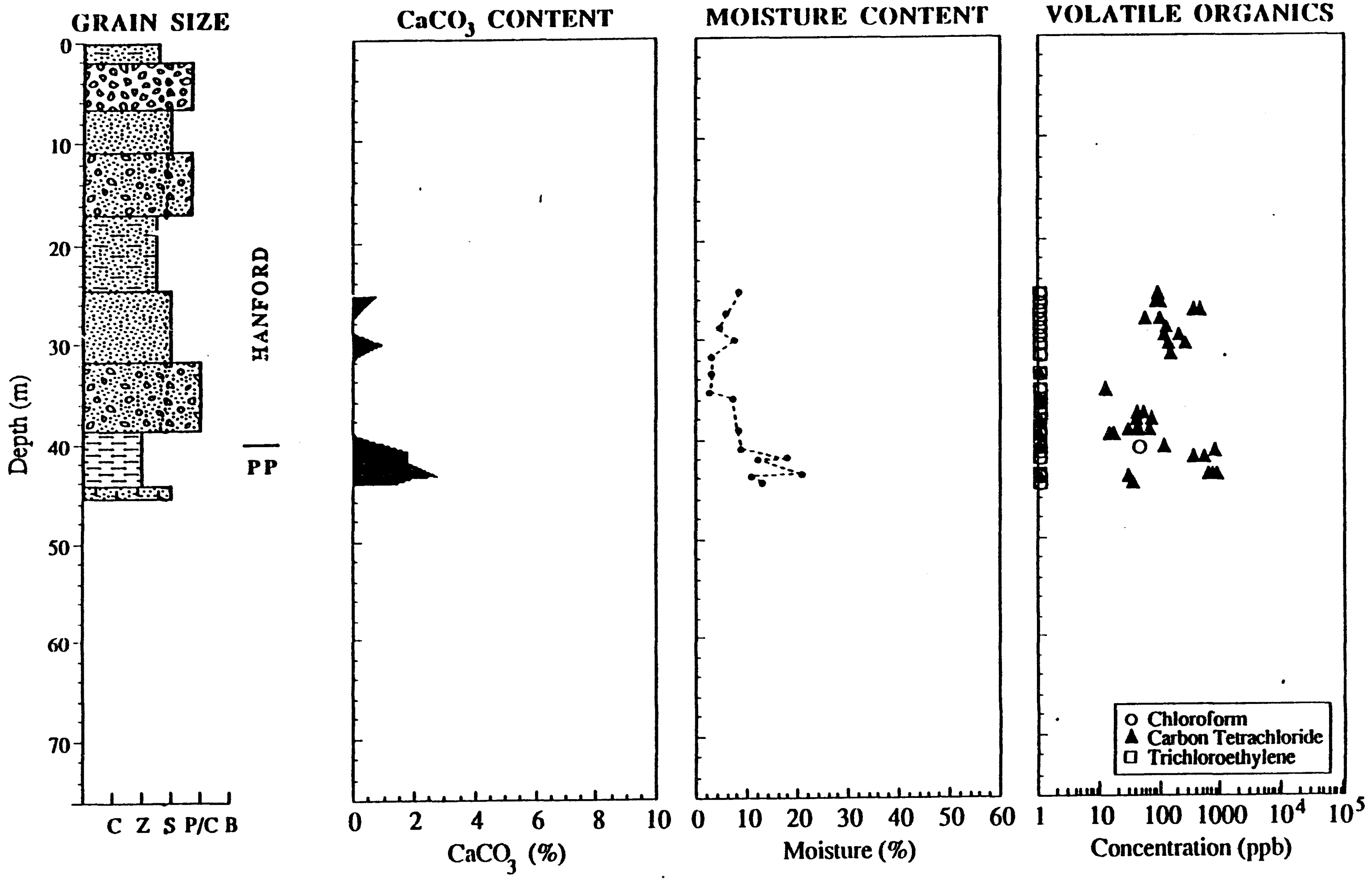



Well No. 299-W15-220
GRAIN SIZE
C Z S P/C B
HANFORD
PP
RINGOLD
Depth (m)
0
10
20
30
40
50
60
70
CaCO$_3$ CONTENT
CaCO$_3$ (%)
0
2
4
6
8
10
MOISTURE CONTENT
Moisture (%)
0
10
20
30
40
50
60
VOLATILE ORGANICS
Concentration (ppb)
1
10
100
1000
10^4
10^5
○ Chloroform
▲ Carbon Tetrachloride
□ Trichloroethylene

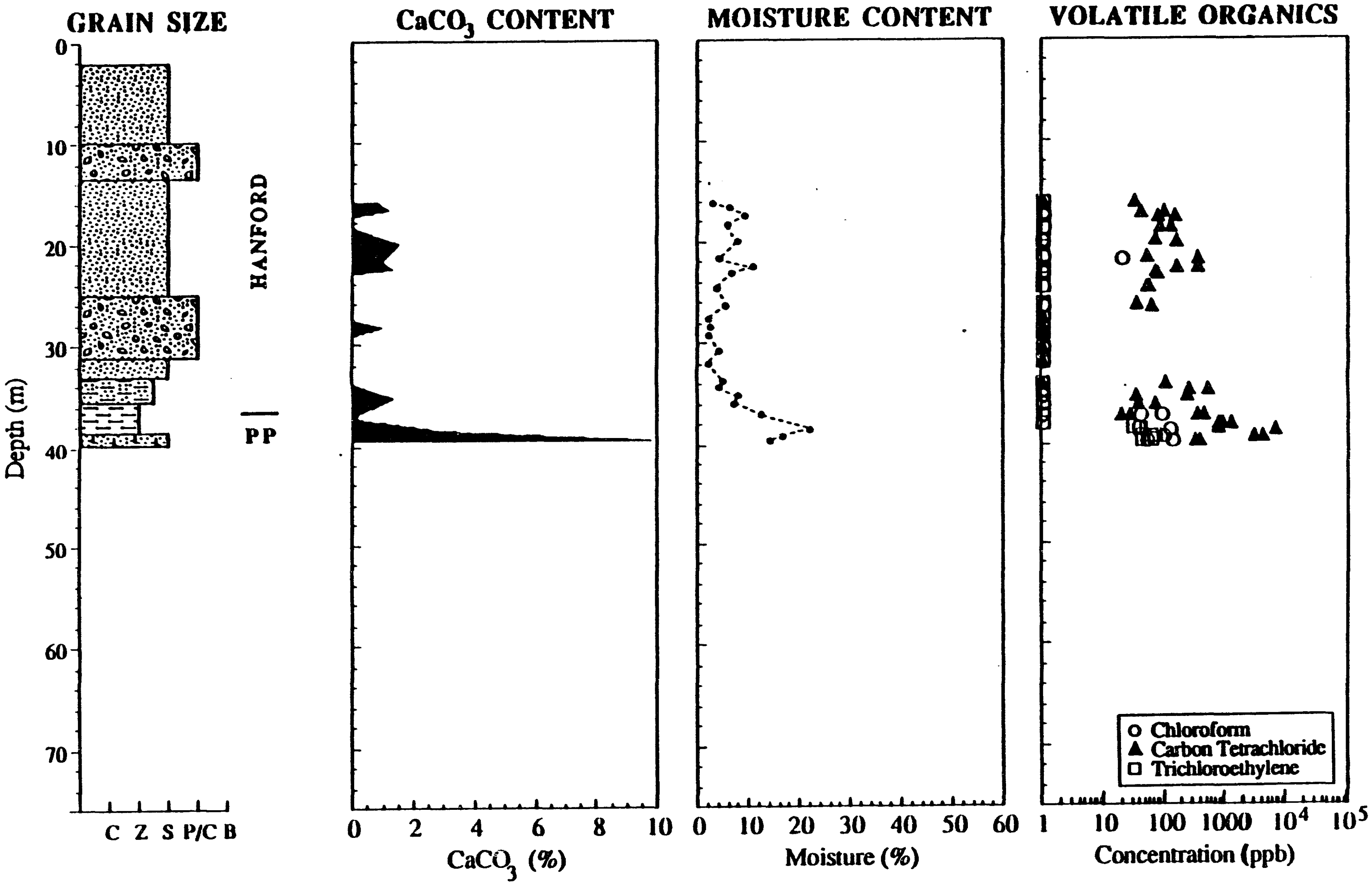
Well No. 299-W15-223



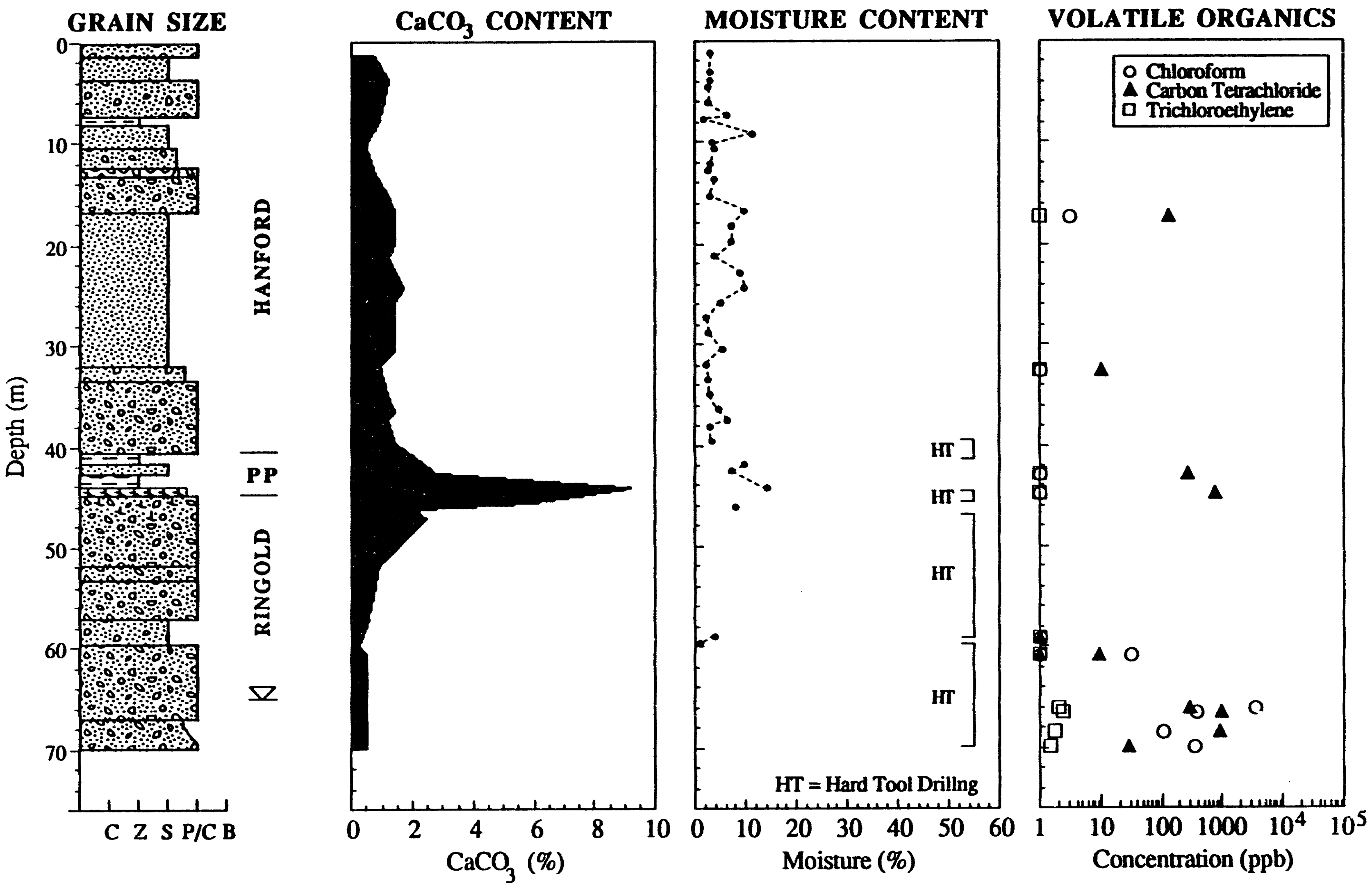
Well No. 299-W18-96



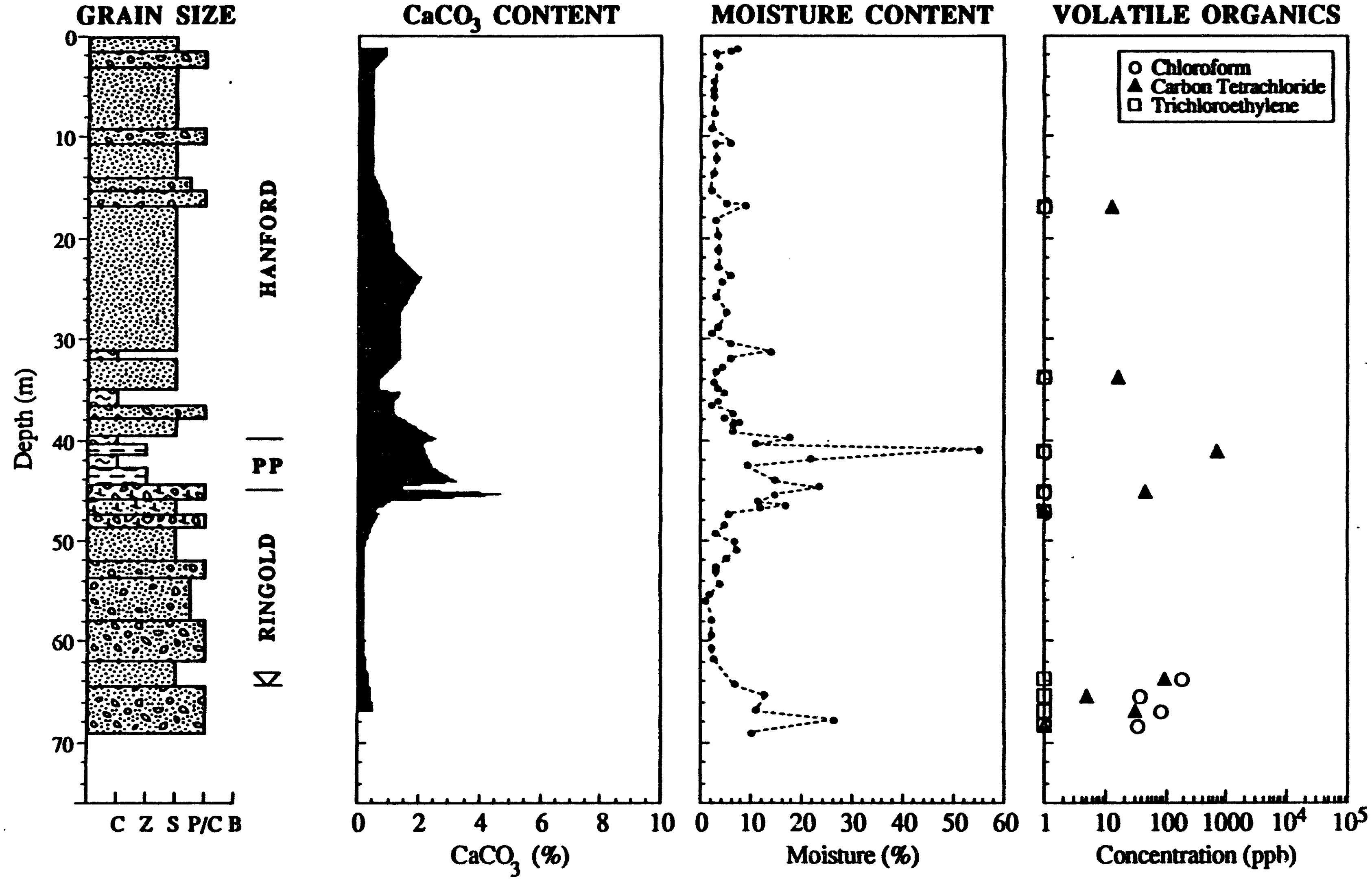
Well No. 299-W18-174



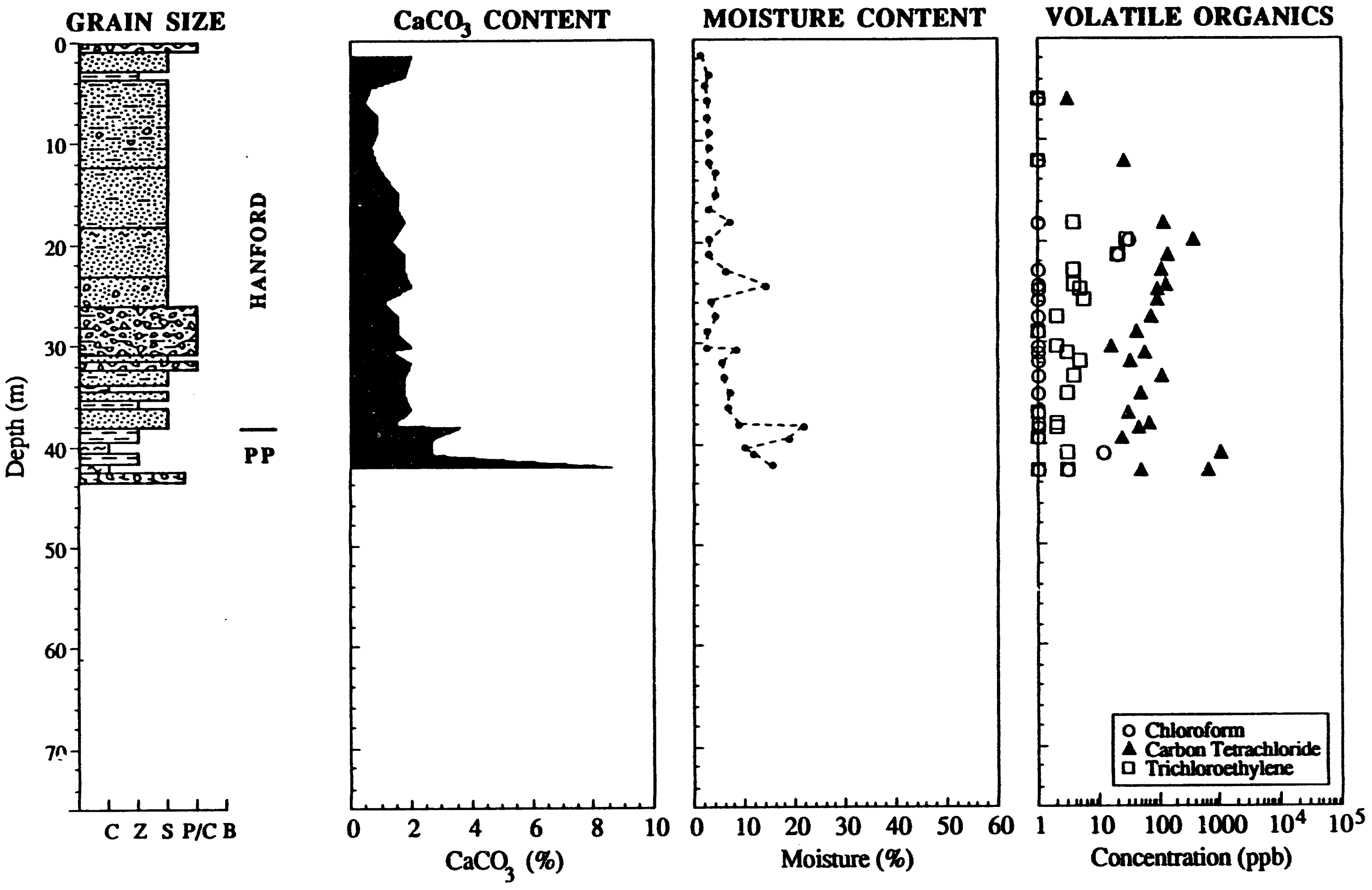
Well No. 299-W18-246

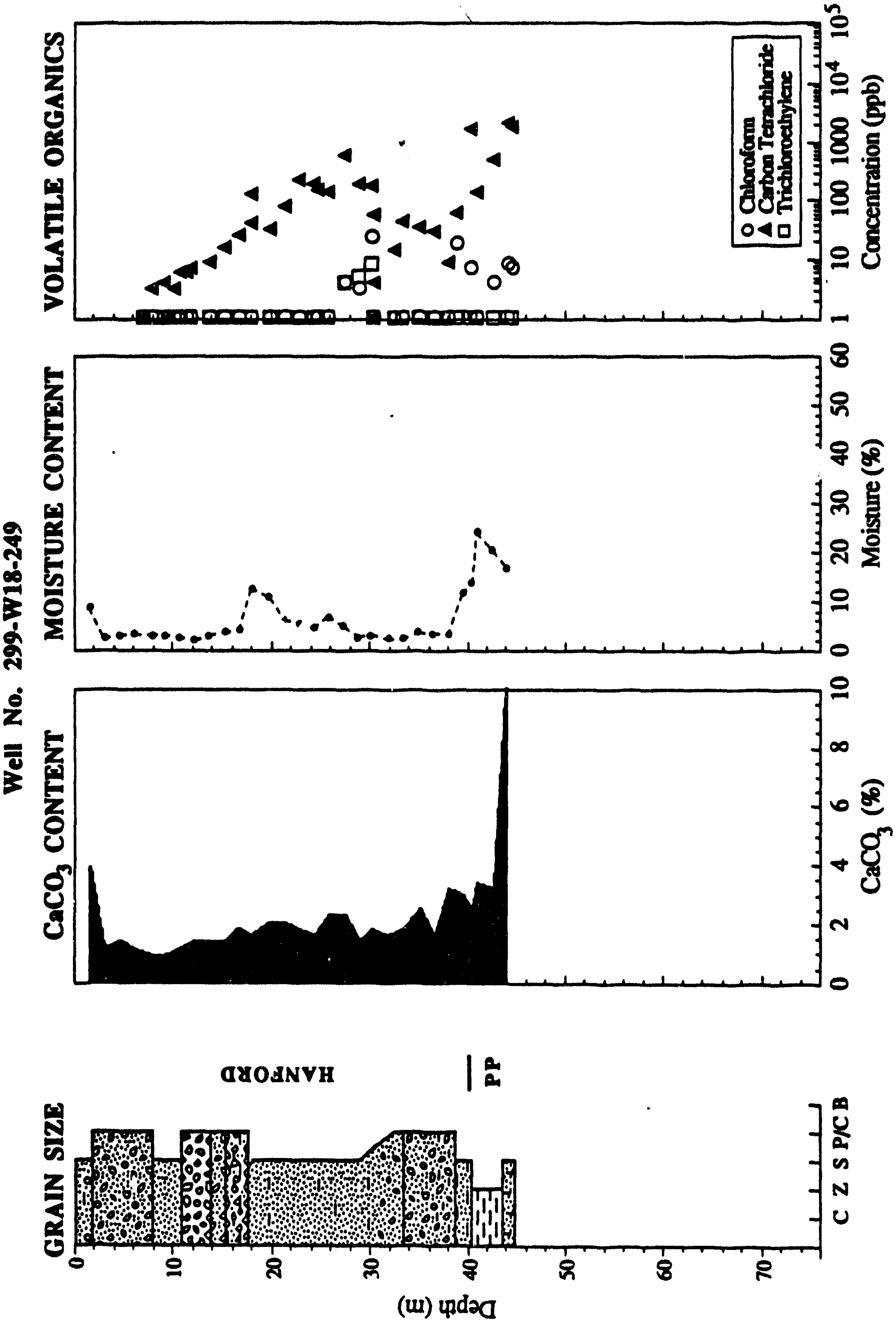


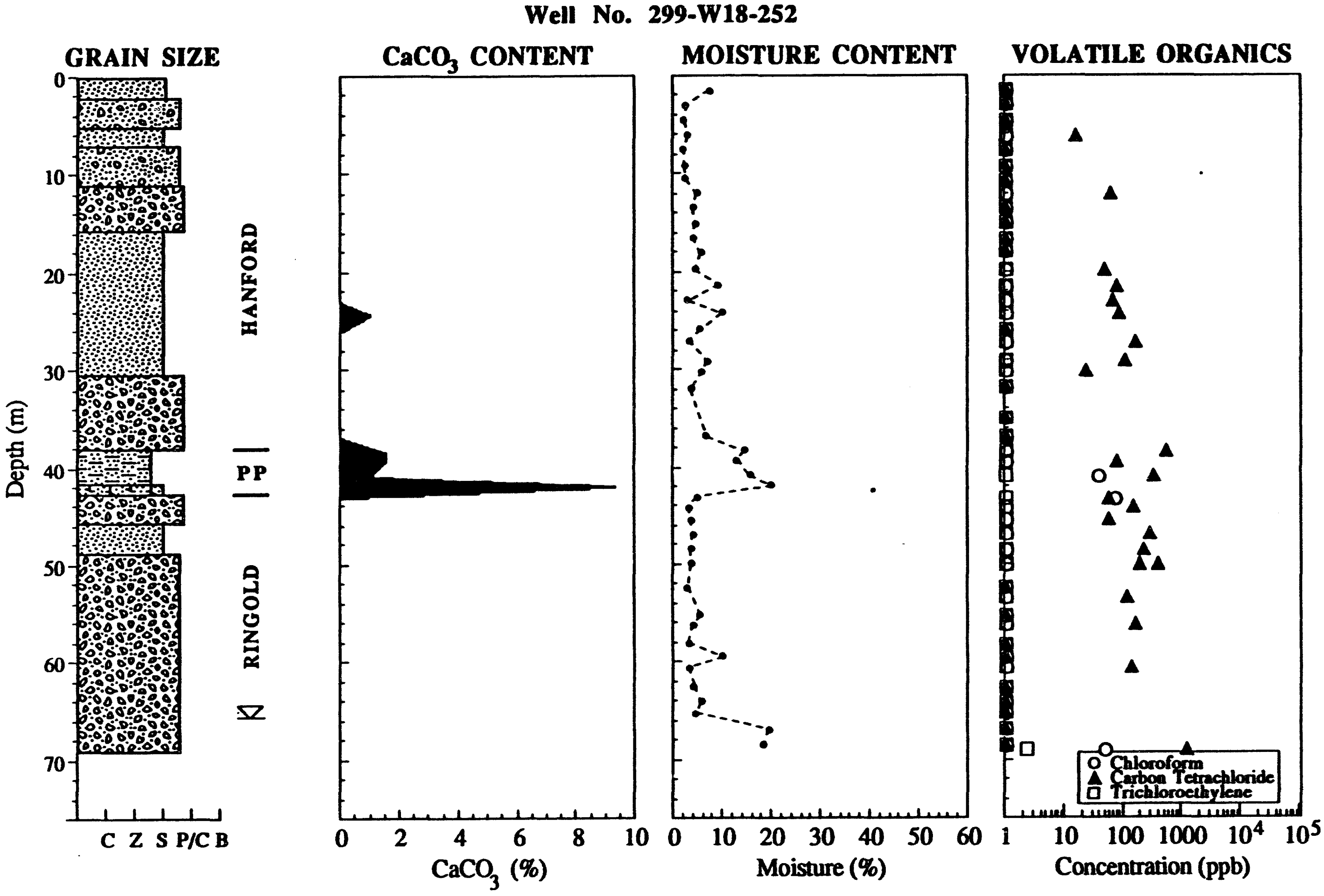
Well No. 299-W18-247



Well No. 299-W18-248




Well No. 299-W18-249
GRAIN SIZE
HANFORD
PP
C Z S P/C B
Depth (m)
0
10
20
30
40
50
60
70
CaCO$_3$ CONTENT
CaCO$_3$ (%)
0
2
4
6
8
10
MOISTURE CONTENT
Moisture (%)
0
10
20
30
40
50
60
VOLATILE ORGANICS
Concentration (ppb)
1
10
100
1000
10^4
10^5
○ Chloroform
▲ Carbon Tetrachloride
□ Trichloroethylene


Well No. 299-W18-252
GRAIN SIZE
CaCO$_3$ CONTENT
MOISTURE CONTENT
VOLATILE ORGANICS
Depth (m)
0
10
20
30
40
50
60
70
HANFORD
PP
RINGOLD
C Z S P/C B
0 2 4 6 8 10
CaCO$_3$ (%)
0 10 20 30 40 50 60
Moisture (%)
1 10 100 1000 10^4 10^5
Concentration (ppb)
○ Chloroform
▲ Carbon Tetrachloride
□ Trichloroethylene

APPENDIX I

SUMMARY OF 200 WEST AREA GROUNDWATER CONCENTRATION DATA FOR CARBON TETRACHLORIDE AND CHLOROFORM
(1/1/92 - 10/1/93)

APPENDIX I

Table I-1. Sumary of 200 West Area Groundwater Concentration Data for Carbon Tetrachloride and Chloroform (1/1/92 - 10/1/93). (sheet 1 of 3)

Lambert Coordinates East (m)	North (m)	Well Number	Carbon Tetrachloride (µg/L)	Chloroform (µg/L)
567214.3	137510.1	299-W6-1	550	6
566938.7	137351.4	299-W6-2	104	2
567118.2	137299.1	299-W6-3		2
567132.2	137290.5	299-W6-4	230	17
567493.3	137638.6	299-W6-5	273	12
567311.3	137638.8	299-W6-7	217	6
567028.8	137638.8	299-W6-8	5	2
567031.6	137363.1	299-W6-9	240	3
567413.3	137453	299-W6-10	920	45
567162.9	137635	299-W6-11	56	2
566915.9	137635.3	299-W6-12	5	2
565932.6	137647.3	299-W7-1	5	2
566303.1	137638.5	299-W7-2	5	2
566408.7	137308.2	299-W7-4	416	6
566476	137635.7	299-W7-5	68	3
566658.4	137636.5	299-W7-6	5	2
566567.1	137636.3	299-W7-7	5	2
566761.7	137637	299-W7-8	6	2
565844.8	137646.6	299-W7-9	5	2
566858.6	137457.7	299-W7-10	5	2
566186.2	137636	299-W7-11	5	2
566040.8	137636.3	299-W7-12	5	2
565749.7	137646.9	299-W8-1	5	2
565657.6	137024	299-W9-1	5	2
566663.4	136734.8	299-W10-1		13
566735	136578.3	299-W10-4	2150	11
566579.1	136466	299-W10-5	820	13
566748.6	136799	299-W10-9		5
566027.7	136607.2	299-W10-13	16	2
566017.7	136609	299-W10-14		2
566770.7	136808.3	299-W10-15	1252	8
566781.2	136606.9	299-W10-16	762	9
566775.4	136491.2	299-W10-17		18
566846.9	136396.3	299-W10-18	1100	11
566346.2	137037.1	299-W10-19	740	23

Table I-1. Sumary of 200 West Area Groundwater Concentration Data for Carbon Tetrachloride and Chloroform (1/1/92 - 10/1/93). (sheet 2 of 4)

Lambert Coordinates			Carbon Tetrachloride	Chloroform
East (m)	North (m)	Well Number	(µg/L)	(µg/L)
567641.6	136663.9	299-W11-3	365	2
567482.3	136492.9	299-W11-6	1500	6
567260.6	136675.2	299-W11-7	1200	8
568099.1	136616.3	299-W11-10	560	6
567641.4	136874.2	299-W11-14	947	3
567182	137162.6	299-W11-18	411	2
566905.3	136801.3	299-W11-23	5	2
566885	136796.6	299-W11-27	5	2
566934.9	136743.7	299-W11-28	900	46
567193.4	136858.9	299-W11-30	333	407
567221.6	137235.3	299-W11-31	695	5
568331.4	137205.9	299-W12-1	5	2
566932.6	136340.7	299-W14-2	422	5
566899.6	136040.1	299-W14-5	121	4
566899.4	136101	299-W14-6	164	2
566905.7	136284.2	299-W14-12	339	2
566094.1	136337.4	299-W15-2	40	2
566820.7	136018.9	299-W15-4	571	36
566801.5	135654.4	299-W15-6	5000	86
566674.6	135920.7	299-W15-7	2100	12
566449	135981.2	299-W15-10	1003	13
566412.4	136001	299-W15-11	1129	16
566699.5	136369	299-W15-12	1500	10
566088.9	135751.9	299-W15-15	1333	4
566307.1	135733.6	299-W15-16	5433	22
566308.9	135562	299-W15-18	1333	20
566189.4	135969	299-W15-19	1066	127
566083.2	135964.5	299-W15-20	190	8
566683.1	136110.9	299-W15-22	1230	26
566084	135858.4	299-W15-23	590	4
566091.4	135606	299-W15-24	118	41
566793.6	135561.1	299-W15-216	4458	579
566768.2	135667.4	299-W15-218	6379	
566733.2	135657.4	299-W15-219	3862	
566838.2	135627.4	299-W15-220	1130	
566380.2	135383.6	299-W18-2	2064	477
566349.7	135453.9	299-W18-5	1655	42
566472.9	135302.1	299-W18-9	210	15
566663.5	136734.8	299-W18-10	1300	
566381.4	134734.7	299-W18-15	120	10
566702.7	135425.2	299-W18-17	1167	22
566590.1	135081.8	299-W18-20	35	13
566098	134979	299-W18-21	297	6
566084.9	135342.6	299-W18-23	550	6

Table I-1. Sumary of 200 West Area Groundwater Concentration Data for Carbon Tetrachloride and Chloroform (1/1/92 - 10/1/93). (sheet 3 of 3)

Lambert Coordinates East (m)	North (m)	Well Number	Carbon Tetrachloride (µg/L)	Chloroform (µg/L)
566370.9	135346.3	299-W18-24	507	17
566721.5	134978.2	299-W18-25	12	2
566091.6	135492	299-W18-26	134	13
566090.5	135226.8	299-W18-27	342	12
566092.9	135107.1	299-W18-28	48	22
566561.2	135028.4	299-W18-29	30	19
566871.1	135194	299-W18-30		2
566515.9	134975.9	299-W18-32	40	10
566493.3	135392.9	299-W18-246	964	270
566503.5	135232	299-W18-247	18	183
566448.2	135437.4	299-W18-252	1130	
566887.2	134925.9	299-W19-1	5	2
567311.4	134989.7	299-W19-3	179	4
567950.2	135351.2	299-W19-4	230	2
567272.7	135012.8	299-W19-9	240	5
567277.3	135002.1	299-W19-11	208	3
566897.4	135059.7	299-W19-12	15	2
567286.7	134895.5	299-W19-13	21	
567254.5	134976.2	299-W19-15	191	4
567271.1	135029.5	299-W19-16	246	4
567360.9	135012.7	299-W19-18	132	3
567827.2	134914.8	299-W19-19	30	5
567874.2	134901.4	299-W19-20	24	5
566953.7	134880.1	299-W19-21	5	2
567771.9	134893.4	299-W19-23	34	5
567771.9	134928.1	299-W19-24	30	6
567874.9	134916.7	299-W19-25	31	5
567845.8	134895	299-W19-26	32	3
567014.9	134931.1	299-W19-27	13	2
567590.1	134991.5	299-W19-28	87	5
567664.2	134999.8	299-W19-29	160	6
567666.1	134924.8	299-W19-30	43	5
566897	135127.5	299-W19-31	115	4
566896.6	135009.3	299-W19-32	5	2
566954.9	134927.1	299-W19-91	5	2
566939.7	134889.2	299-W19-92	5	2
566905.7	134827.2	299-W19-93	5	2
567736.5	134192.4	299-W22-9	160	2
567191.4	134184.8	299-W22-12	5	6
567593.6	133879.7	299-W22-20	7	11
567160.9	134008	299-W22-21	5	2
567617.6	134464.7	299-W22-22	5	2
567587	134445.3	299-W22-23	5	2
566903.9	134213.7	299-W22-39	5	2

Table I-1. Sumary of 200 West Area Groundwater Concentration Data for Carbon Tetrachloride and Chloroform (1/1/92 - 10/1/93). (sheet 4 of 4)

Lambert Coordinates				
East (m)	North (m)	Well Number	Carbon Tetrachloride (µg/L)	Chloroform (µg/L)
567634.6	134510	299-W22-40	5	2
567637.1	134479.5	299-W22-41	5	2
567623.2	134452.2	299-W22-42	5	2
567532.5	134539.2	299-W22-43	5	2
566945.2	134292.5	299-W22-45	5	2
566642.4	134275.1	299-W23-9	5	6
566512.9	134299.2	299-W23-11	5	2
566712.8	134445.9	299-W23-13	5	2
566708.7	134290.2	299-W23-14	5	2
566463	133407.8	299-W26-6	5	2
566325.4	133242.4	299-W26-7	5	2
566645.9	133663.8	299-W26-8	5	2
566492.1	133229.2	299-W26-9	5	2
566683.2	133499.1	299-W26-10	5	2
566901	133689.9	299-W26-12	5	4
567575.1	133750.3	299-W27-1	5	10
571009.6	133215.9	699-32-62	5	6
566416.8	133152.5	699-32-77	5	2
568566.5	133987.6	699-35-70	5	2
571395.1	134557	699-36-61A	5	2
564907.1	134738.9	699-37-82A	5	2
568500.9	135089.2	699-38-70	44	4
565890.9	135411.9	699-39-79	635	14
571164.3	135764.4	699-40-62	5	2
562933.5	136620.9	699-43-88	5	
570390.6	136897.4	699-44-64	5	2
568729.2	137182.5	699-45-69A	5	2
571474.4	137968.7	699-47-60	5	2
568351.6	138045.6	699-48-71	5	2
566415.6	137965.2	699-48-77A	5	2
572536.4	138381	699-49-57B		6
565771.1	138271.1	699-49-79	5	4
572761.4	139115.3	699-52-57		2
572619.4	140029.6	699-54-57		6
572445.4	140119.9	699-55-57		2
571562.9	140267.4	699-55-60A	5	2
566749.8	140227.5	699-55-76	5	2
571830.4	140924.1	699-57-59		2
572273.6	141415	699-59-58		2
571588.6	141763.9	699-60-60	5	2

DATE
FILMED
9/14/94

END