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1100-EM-1 Soil Gas Survey Final Report

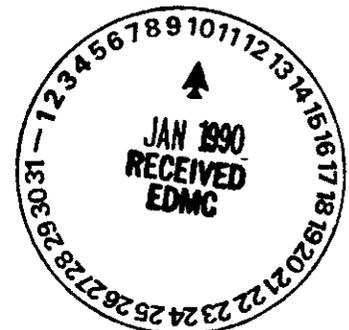
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Prepared for the U.S. Department of Energy
Assistant Secretary for Environment, Safety and Health



Westinghouse
Hanford Company Richland, Washington

Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930



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J. C. Evans
Pacific Northwest Laboratory

Date Published
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EXECUTIVE SUMMARY

A soil gas survey was performed at four sites to be contained within the Hanford 1100 EM-1 operable unit. The soil gas survey was conducted prior to more detailed Remedial Action/Feasibility Study investigations. The survey was intended to provide information concerning potential subsurface concentrations of volatile organic solvents in order to site sampling boreholes and wells in the most representative manner. The four sites surveyed were 1100-1 (battery acid pit), 1100-2 (identified in the work plan as paint and solvent pit), 1100-3 (identified in the work plan as the antifreeze and degreaser pit), and the Horn Rapids Disposal Area (HRD). Soil gas samples were taken through a probe inserted into the soil with a pneumatic hammer to a depth of 4 ft. Samples were analyzed by high-sensitivity gas chromatography employing flame ionization and electron capture detection.

Significant levels of perchlorethylene (PCE) were found at the southwest corner of the 1100-2 site. The concentration gradient was very steep. The location of the maximum concentration is close to the end of the road leading from the maintenance area and is consistent with a logical scenario for waste disposal. No other volatile species were detected at that site. Measurements ranged from a low of $<0.003 \mu\text{g/L}$ to a high of $727 \mu\text{g/L}$. The dynamic range of the measurements thus covered more than 5 orders of magnitude. Low concentrations of PCE were found throughout much of the site, but the dominant source appeared to be very localized.

Evidence for the presence of several chlorinated species including 1,1,2 trichlorethylene (TCE), 1,1,1 trichloroethane (TCA), and PCE was found at the HRD site. Measurable TCE in the soil gas was widespread on the east side of the landfill and in a narrow plume west of the central pit spreading north from the site's southern boundary. Significant concentrations of PCE were also evident; however, the location of the PCE maximum was approximately 500 ft to the east of the TCE maximum. The PCE maximum apparently represents an independent source. A small region of detectable TCA appeared to be coincident with the western TCE plume. No volatile constituents were detectable in soil gas samples collected at the far western side of the site or the northern part of the site. Since only a limited amount of data was available

from the center of the site, it is not possible to make definitive statements about that region. The apparent extent of the soil gas anomalies suggests that volatile compounds may be present in the groundwater.

No detectable volatile organic species were found in the soil gas samples collected at the 1100-3 site. It appears unlikely that any solvent residues are widespread at that site.

No major solvent concentrations were found in soil gas collected from 5 points sampled at the 1100-1 site. Low levels of PCE and TCA were seen in all 5 samples with levels of PCE ranging from 0.004 to 0.013 $\mu\text{g}/\text{L}$ and TCA concentrations ranging from 0.01 to 0.05 $\mu\text{g}/\text{L}$. The data showed no obvious association with the 1100-1 site.

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by volatile organic constituents, particularly chlorinated hydrocarbons, represents one of the most persistent contamination issues under consideration throughout the U.S. (Devitt et al. 1987). Measurable concentrations of volatile organic compounds have already been identified in groundwater samples collected at several locations on the Hanford Site (Evans, Bryce, and Sherwood 1989) and is suspected at others (Stenner et al. 1988). These contaminants are typically identified through groundwater monitoring and surveillance programs. Well sampling techniques, while unquestionably necessary to provide hydrologic data and evidence of regulatory compliance, are nevertheless limited in effectiveness for rapidly diagnosing the extent of plume spread of volatile organic compounds. The soil gas method was developed as an alternative technique for generating relatively dense data grids on a short time scale. The soil gas method can be used effectively as a preliminary screening tool for aiding in the optimal placement of monitoring wells and has been adapted by PNL to the needs of the Hanford Site.

In favorable cases, the soil gas method has been found to correlate well with directly measured concentrations in groundwater. Volatile organic compounds dissolved in water will partition between the water and gas phase in a ratio referred to as the Henry's Law constant. Under ideal conditions, the soil gas concentration of each species present in the groundwater will decrease linearly from the Henry's Law value in the head space above the water table to zero at the soil-air interface. The method has been far less successful with nonchlorinated species, which tend to be consumed by biological activity resulting in a depth distribution in concentration that drops off much more rapidly than linearly. Some of the other factors that influence soil gas profiles include: geologic properties of the vadose zone, soil moisture content, temperature, depth to groundwater and groundwater flow rate, phase separation, soil organic content, temperature and temperature gradients, water table oscillations, lithology of the aquifer, barometric effects, and rainfall. Interpretation of soil gas data may thus be complex and highly site specific. The study described here is highly qualitative in nature and no attempt has been made to account for geologic or other environmental effects in data interpretation.

2.0 SITE DESCRIPTIONS

The operable unit work plan (DOE/RL 88-23) identified four sites suitable for the performance of soil gas surveys: 1100-1, 1100-2, 1100-3, and the Horn Rapids Disposal Area (HRD). A detailed description of these sites and their operational history can be found in the work plan. A portion of that information is reproduced in the following section.

2.1 1100-1

During the approximate period of 1957 to 1977, waste battery acid was disposed of into an unlined pit (i.e., dry sump or French drain) with sand and gravel in the bottom. The pit is located a few feet from a paved area, near the southwest corner of the 1171 Building, which is a vehicle service, maintenance, and repair building. The general location of the site is shown in Figure 2.1.

The battery acid pit is located on a very slight slope toward railroad tracks that are ~50 ft to the west. The exact location and size of the pit is not known, although estimates by motor pool workers range from 5 to 12 ft in diameter and 5 to 10 ft deep. Based on a review of vehicle fleet size and estimated battery requirements by Hanford Site personnel, the maximum quantity of battery acid disposed to the pit over a 23-yr period is estimated to be about 15,000 gal. Depth to the water table is about 50 ft from ground surface. Because of the proximity of the pit to the maintenance shops, it is suspected that other materials such as waste oil, antifreeze, or solvents, may have been disposed of in the pit. While no record of such disposal exists, it was believed that a limited soil gas survey was warranted as a means to further explore that possibility.

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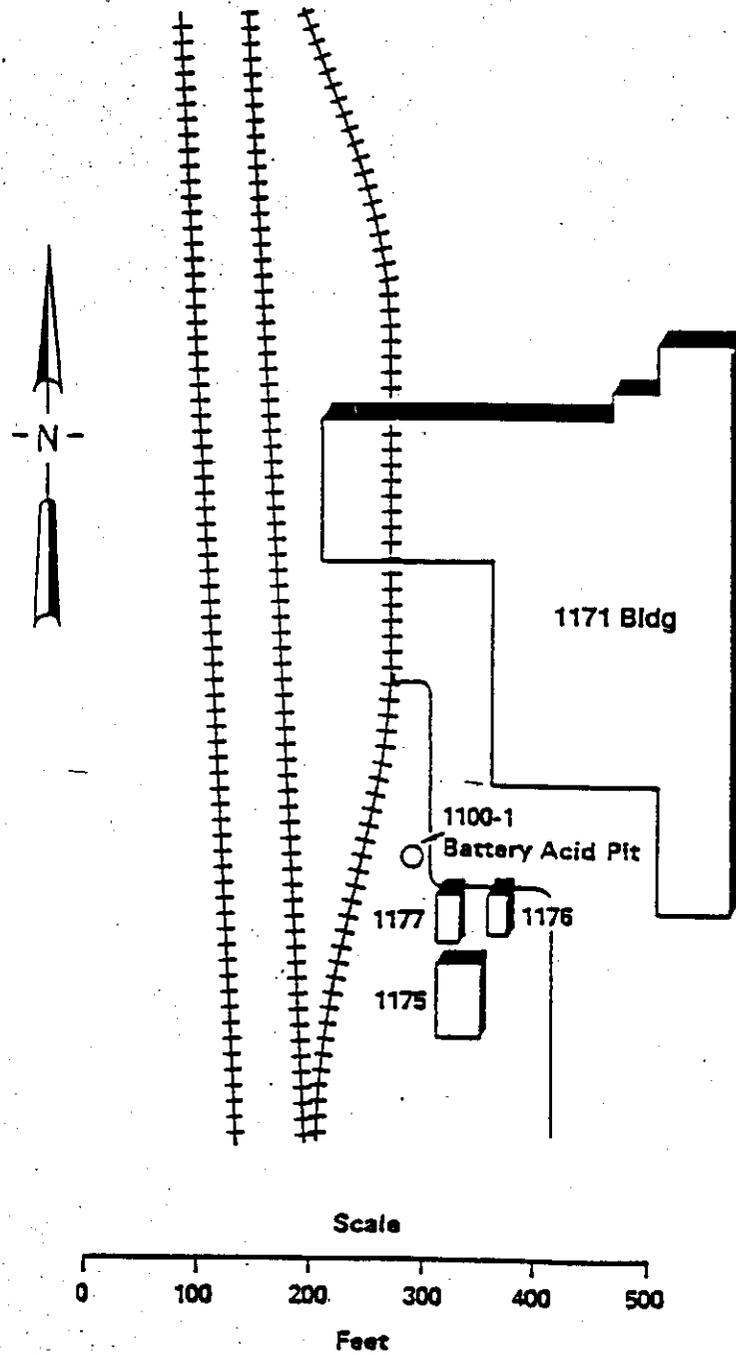


FIGURE 2.1. Location of 1100-1 Site Battery Acid Pit

2.2 1100-2

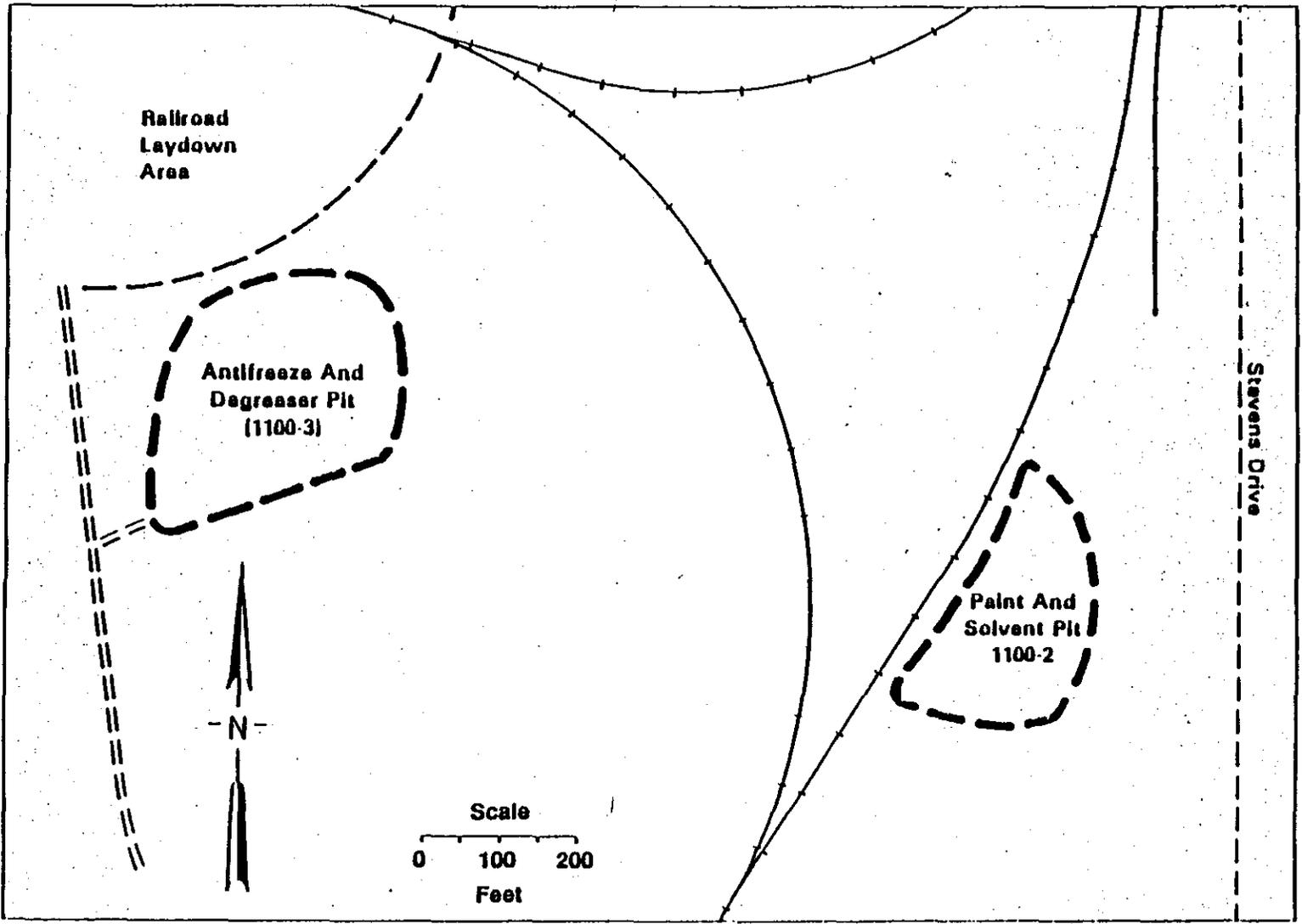
Location 1100-2 was originally developed as a sand and gravel pit. It was used for the disposal of construction debris from 1954 to 1985. The general location of the pit is shown in Figure 2.2. The pit is an elongated depression 4 to 6 ft deep, approximately 250 ft long, and 100 ft wide lying along the eastern side of the railroad tracks. Depth to groundwater is approximately 50 ft from ground surface.

The construction debris is reported to include broken concrete, asphalt, and lumber from construction, maintenance, and demolition activities on the Hanford Site. The pit presently contains 5 ft of backfill material. In addition to the construction waste, the pit is reported to occasionally have received waste solvents, paints, and paint thinner. The maximum volume of disposal is estimated to have been approximately 100 gal/yr. There is no visible evidence of paint, solvent, or discolored soil on the ground surface in the vicinity of the pit. The exact locations of any paint or solvent disposal are unknown. No chemical inventory is available. Analyses of two soil samples collected at the ground surface in March 1988 revealed no evidence of contamination. At present, the only evidence of chemical soil contamination is anecdotal.

2.3 1100-3

Location 1100-3 is a shallow, roughly circular depression ~250 ft in diameter and 6 to 8 ft deep (Figure 2.2). Depth to the water table is about 50 ft from ground surface. The pit is reported to have been an excavation for sand and gravel, with the bottom of the original pit at roughly the present observed depth. The pit was used for disposal of construction debris from 1979 to 1985. Approximately 30 yd³ of used roofing gravel and 1 yd³ of concrete rubble lie in piles dumped in the bottom of the pit. The pit is also reported to have occasionally received waste antifreeze and degreasing solutions from the vehicle cleaning operations at the 1171 Building. The quantity of antifreeze or degreasers disposed of in the pit are unknown, and no specific disposal sites have been identified. There is no visible evidence of such disposal on the ground surface, and analyses of two soil

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FIGURE 2.2. Locations of 1100-2 Site and 1100-3 Site

samples taken from the ground surface in March 1988 revealed no evidence of contamination. As with the 1100-2 site, the only evidence of chemical soil contamination is anecdotal.

2.4 HORN RAPIDS DISPOSAL AREA

The HRD (also referred to as Horn Rapids Landfill; see Figure 2.3) is an inactive disposal site that was intended primarily for office and construction waste from the early 1950s to 1970. This is not to be confused with the City of Richland municipal waste disposal. Discussions with Hanford Site staff involved in the operation of the landfill indicate that other wastes are likely present, including possibly as many as 200 drums of carbon tetrachloride. Mention was made during these discussions of standing water and "springs," which indicate that the bottom of the landfill may be just above or in contact with groundwater. The depth to the water table is estimated to be 30 ft. At present, the HRD is a designated curlew nesting area, and access is restricted.

No detailed waste inventory is available. One cell of the landfill is marked by signs indicating that asbestos is buried there. Nearby are two locations, several yards apart, that have signs with the legend "Burial Site." These apparently mark an earlier trench, but what was buried there is unknown. Used tires occupy an open trench at the northern end of a landfill cell. Another area is surrounded by a low berm and occupied by a dark gray-brown, mud-like substance that exhibits mud cracks. This site appears to have been used for disposal of unknown liquid materials, possibly including sewage sludge and/or fly ash.

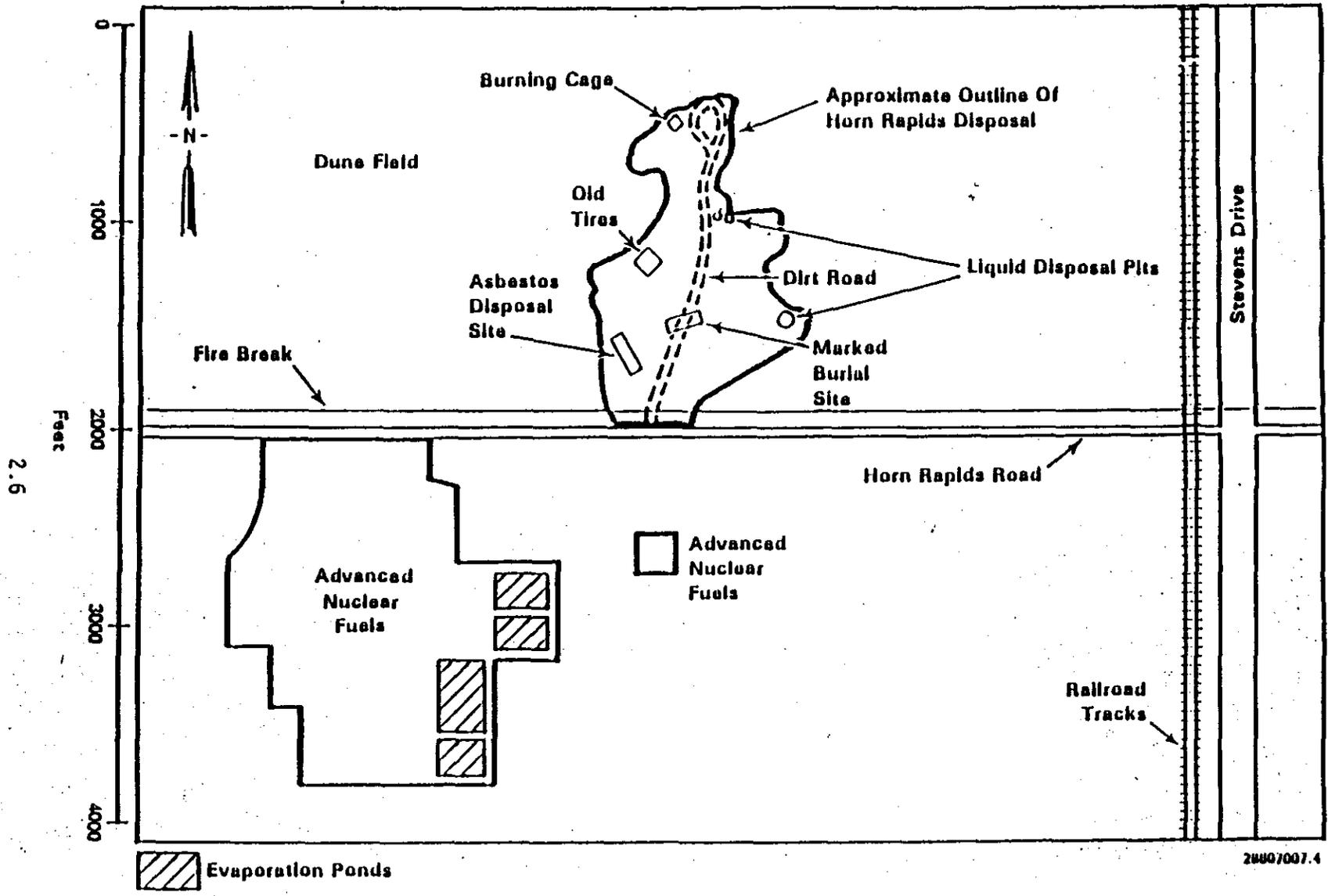


FIGURE 2.3. Location of Horn Rapids Disposal Area

3.0 SOIL GAS SURVEY

Site-specific soil gas survey plans were presented in the work plan (DOE/RL 88-23). The plan was used as general guidance; however, as more complete information became available concerning the accurate dimensions of the sites, some modification and expansion was needed, particularly at HRD.

3.1 GEODETIC SURVEYS

Geodetic surveys were conducted by Kaiser Engineers Hanford prior to commencement of fieldwork. Stakes emplaced by the surveyors were used as reference points for all sampling activities. Soil gas probes were emplaced as close as possible to the stakes. Deviations from those locations that were the result of either penetration refusal problems or authorized changes in the grid size were duly noted in the field records with distance and direction from the nearest survey stake recorded.

3.2 RADIATION SURVEYS

Radiation surveys of all four sites were completed by Westinghouse Hanford prior to commencement of further field activities. No detectable gamma, beta, or alpha radiation was found at any of the sites. Based on those results and the very low probability of radioactive contamination at the 1100-1, 1100-2, and 1100-3 sites, no further radiological protection steps were implemented. The HRD was considered to represent a potential work hazard of unknown nature. Accordingly, a Westinghouse Hanford radiation monitor was assigned full time to monitor field activities. A radiation work permit was filed for the Horn Rapids work. Probes were checked for the presence of radioactive contamination in all cases following removal from the ground at HRD. No evidence of subsurface radioactive contamination was detected.

3.3 GEOPHYSICAL SURVEYS

Geophysical survey work preceded the soil gas work at each site in order to locate potential waste disposal locations. Information obtained

from the geophysical survey could also be used in job safety planning for the soil gas survey to minimize the possibility of accidental penetration of subsurface hazards, such as solvent drums. The work was performed by a PNL group. Instrumentation used for the geophysical survey work included ground-penetrating radar (GPR), electromagnetic induction (EMI), and a metal detector. The findings are briefly discussed in the following subsections.

3.3.1 1100-1 Site

A depression, located by GPR, is believed to be the location of the pit. That location is consistent with the anecdotal information concerning the distance south from the safety shower (see Figure 2.1).

3.3.2 1100-2 Site

Subsurface debris appeared to be similar to that found on the surface consisting of concrete (with rebar) and asphalt construction debris. That evaluation was based on an examination of all available geophysical data including GPR, EMI, and metal detector surveys. No additional evidence of waste disposal activities was apparent within the limitations of the methods.

3.3.3 1100-3 Site

Less debris was visible on the surface than at the 1100-2 site, but the subsurface situation was similar.

3.3.4 Horn Rapids Disposal Area

The geophysics survey located several subsurface features at a wide range of depths. Numerous small targets were found by the GPR survey in the less than 4-ft depth zone. The soil gas survey was required to avoid those areas for safety reasons. Several large targets were also found at depth. The geophysical methods used were not able to resolve whether or not the large targets represented waste disposal containers, such as the 200 drums suggested by anecdotal information. That issue remains inconclusive.

3.4 HEALTH AND SAFETY

All fieldwork was performed in accordance with a job-specific health and safety plan (HASp) prepared by Westinghouse Hanford Industrial Health and

Safety specifically for the PNL soil gas work. The plan was approved prior to initiation of fieldwork. Prejob safety meetings at the 1100-2 and HRD sites to review the plan were held prior to initiation of activities at each site. All field personnel were required to have documented proof of 40-h hazardous material handling training and up-to-date, annual 8-h refresher training. Personal protective equipment included, at a minimum, hardhats, steel-toed boots, safety glasses, leather gloves, coveralls, and hearing protection. Portable photoionization detection equipment was used for early warning of organic vapor hazards. At least one operational two-way radio was available at all times during sampling. Full-time radiation monitoring was provided for all activities conducted at the HRD. Additional protective gear including Level B respiratory protection was available if needed. Chemically resistant gloves were used at the 1100-1 site. Geophysical survey information was reviewed prior to initiation of sampling to minimize risk of penetration of buried hazards; 76 sampling points of a total of 287 were eliminated from the HRD work on that basis. No final resolution of this issue has been reached at the time of this writing and the HRD survey is thus somewhat incomplete as a result of overriding personnel safety considerations.

3.5 FIELD SAMPLING ACTIVITIES

Field investigations were carried out starting with the 1100-2 site and ending with the 1100-1 site. Lessons learned during the fieldwork are described in the following sections.

3.5.1 1100-2 Site

The survey at 1100-2 was laid out on 40-ft centers. The design of the grid is shown in Figure 3.1. Grid points subsequently sampled are shown on the figure as solid squares. Points not sampled are shown as open squares. Work at the 1100-2 site began on February 10, 1989. Because of the very rocky conditions on the site, a hand-held, gasoline-powered 1 1/2-in. solid stem auger was used for initial penetration tests. The auger was unable to penetrate the surface by more than a few inches on six successive attempts. Direct probe penetration with the vibratory hammer was also ineffective.

Attempts to sample were temporarily abandoned pending further study. A hydraulic, 6-in.-diameter solid stem auger was subsequently provided by Westinghouse Hanford Environmental Engineering; sampling was successfully resumed on February 17. Holes were bored to 36-in. depth by the 6-in. auger. The probes were then hammered in an extra foot and the hole backfilled and tamped down. For most of the samples taken at that site, the soil column was allowed to "equilibrate" for a relatively short period of time before sampling. A comparison was made between samples taken promptly with those taken after a 3-day period. The samples taken after a longer period were somewhat higher in perchlorethylene (PCE) concentration but qualitatively identical and within the range of variability seen for long-term repeat sampling at a single point. Samples collected over a 1-month period at a single point (K2, see Figure 3.1) showed a relative standard deviation of 38%. Sampling activities at the site continued until March 15, 1989. On March 15, an alternate probe insertion method was tested. The procedure consisted of using a sharpened, solid steel, 1-in.-diameter bar driven by the pneumatic hammer as a pilot probe. After removal of the solid bar, the sampling probe was then hammered into the same hole. This method worked well even in one area which the auger could not penetrate. One probe was left in the ground to continue the study of long-term variability. In all, 82 usable samples, exclusive of blanks and interlab splits, were collected at 62 sampling points at the 1100-2 site.

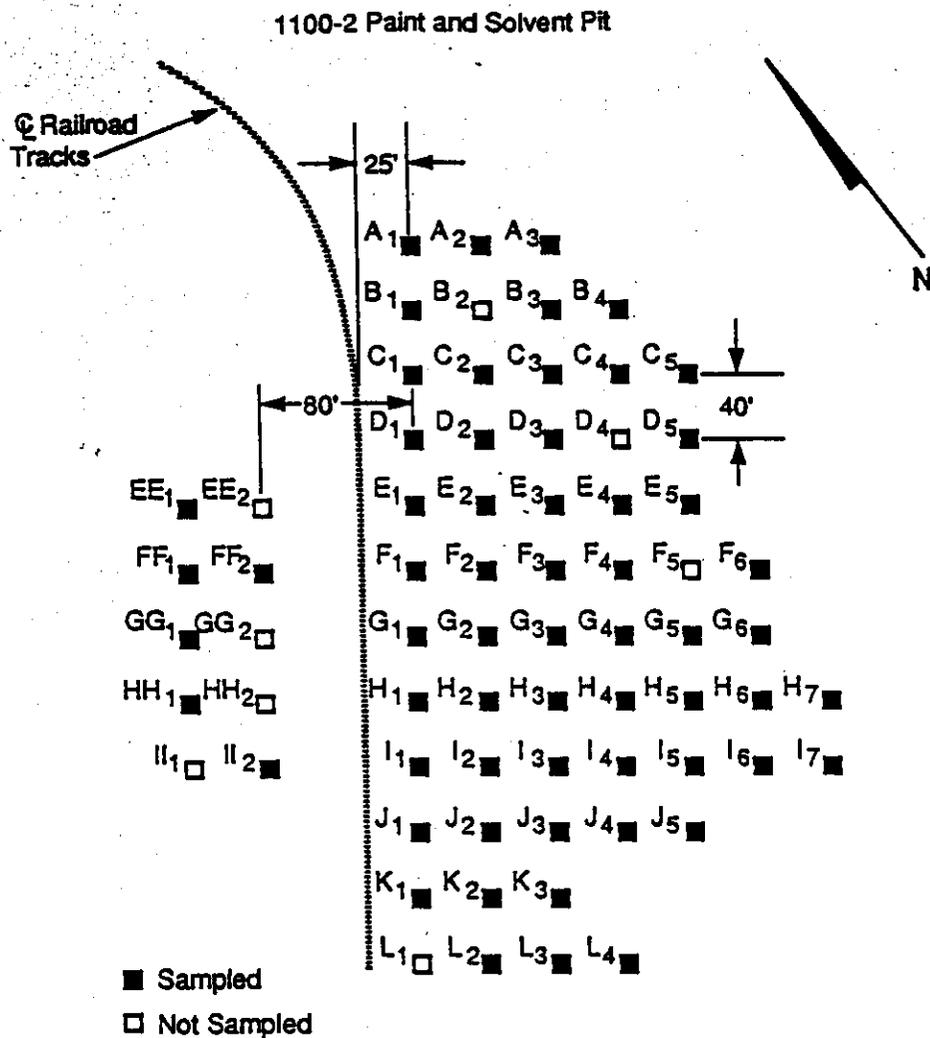


FIGURE 3.1. Soil Gas Survey Grid for 1100-2 Site. Grid was surveyed on 40-ft centers

3.5.2 Horn Rapids Disposal Area

The survey grid at HRD was set on 100-ft centers. This spacing was somewhat larger than desirable for a 50-ft depth to groundwater; however, in view of the large size of the site it was not practical to attempt closer spacing. A diagram of the grid layout is shown in Figure 3.2. Sampling activities began at HRD on March 17, 1989. The pilot probe technique was used at HRD and for all subsequent sampling. In order to minimize concerns about soil column equilibration, the sampling procedure was modified such that in all subsequent work probes were left in the ground overnight prior to

3.5.3 1100-3 Site

The survey grid at the 1100-3 site was surveyed on 40-ft centers, as shown in Figure 3.3. Site 1100-3 proved to be the most difficult of the four sites to sample because of the very rocky conditions. In most parts of the site, the surface was littered with large cobbles. The gravel layer a few feet below the surface proved to be an even more formidable obstacle. The pilot probe system was effective in penetrating the surface, but sampling was difficult at best and some equipment breakage occurred. Work started on May 16, 1989, and concluded on June 2, 1989, with 42 points sampled. No volatile organic compounds were detected and it was concluded that no further sampling was needed. Grid points subsequently sampled are shown on the figure as solid squares. Points not sampled are shown as open squares.

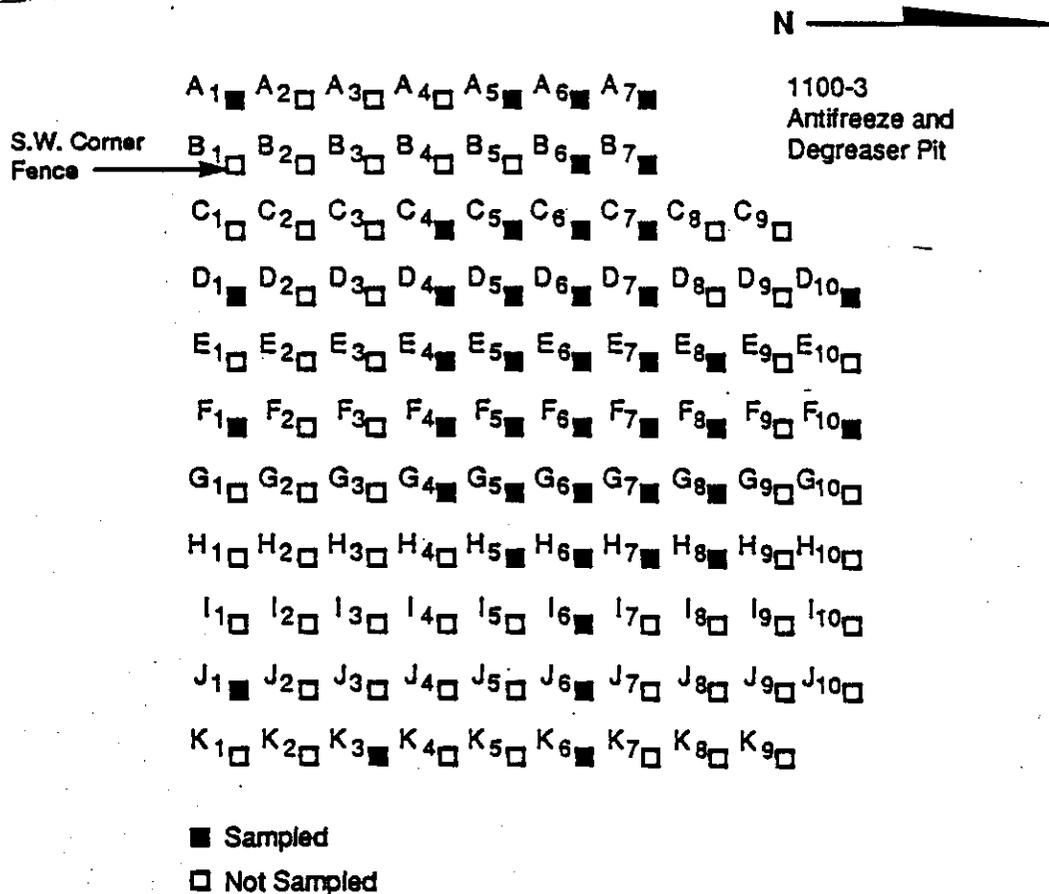


FIGURE 3.3. Soil Gas Survey Grid for 1100-3 Site. Grid was surveyed on 40-ft centers.

3.5.4 1100-1 Site

The survey at the 1100-1 site consisted simply of five points spaced about a central point that is believed to be close to the center of the pit based on a combination of geophysical survey information and measurements from a safety shower still located at the site. A map of the site and associated survey points is shown in Figure 3.4. Figure 3.4 shows a crosshatched area revealed by GPR that is believed to be the location of the pit. Probes were inserted on June 23, 1989; however, because several of the probe tips were plugged, it was necessary to reinsert the probes on June 27, 1989. No significant levels of volatile organic compounds were detected in the five samples and it was concluded that no further sampling was needed.

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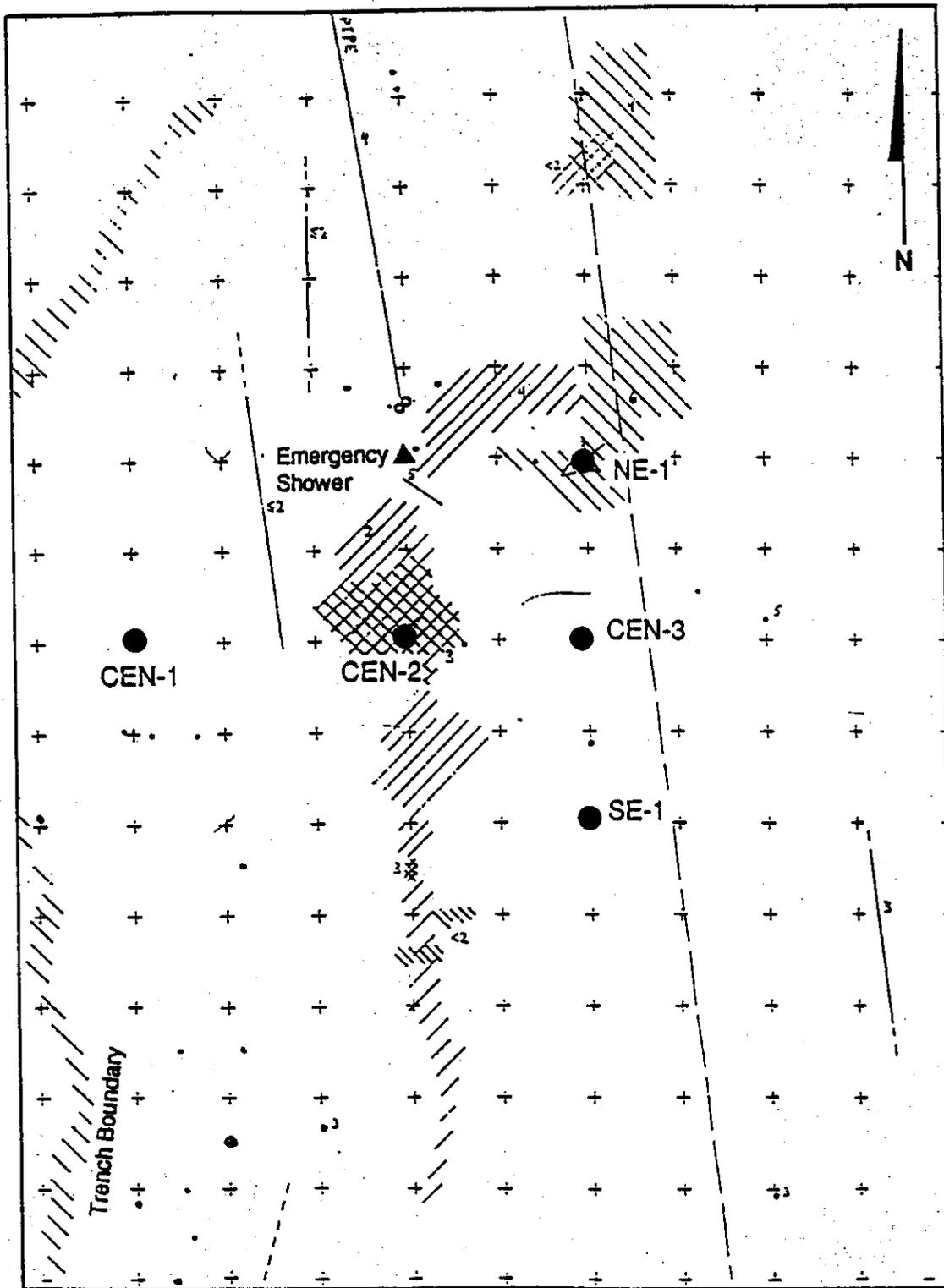


FIGURE 3.4. Soil Gas Survey Points at 1100-1 Site

4.0 EXPERIMENTAL PROCEDURES

Experimental procedures were documented and approved by Westinghouse Hanford prior to the initiation of fieldwork (WHC 1989). Some modification of the procedures was needed during the course of the work as new lessons were learned. The final version of the procedure is described in the following sections.

4.1 DESCRIPTION OF METHOD

At present, no universally or regulatorily accepted method is available for the performance of soil gas surveys. Consequently, considerable latitude is possible for the exact choice of methodology employed. Soil gas probes are typically emplaced 3 to 6 ft below the surface. If possible, all samples should be taken at the same penetration depth to facilitate interpretation. In the PNL procedure that was employed at the 1100 Area sites, a constant depth of 4 ft was employed (whenever possible) for all samples. Probe penetration of less than 36 in. was considered to be penetration refusal and the probe was moved to a new location. Gas samples were drawn through the probe by a low-volume pump. They were collected by a direct sampling method employing flow-through gas sampling bulbs of volumes ranging from 300 to 1000 mL. The samples were later withdrawn from the bulbs with gas-tight syringes of volumes ranging from 0.1 to 5 mL. The use of these sampling bulbs allowed repeat measurements to be made in the laboratory for improved dynamic range and evaluation of precision. Analysis of the drawn sample was performed by gas chromatography (GC) employing detectors with both broad spectrum sensitivity [i.e., flame ionization detector (FID)] and halogen selectivity [i.e., electron capture detector (ECD)]. The ECD in particular is an extremely sensitive device, making it possible to use relatively small sample volumes. The GC system employed by PNL used a split inlet with separate capillary columns connected to ECDs and FIDs. The analytical work itself was performed according to appropriate EPA guidelines for the analysis of volatile organics by GC (EPA 1986). Suitable calibration standards were available to permit identification and quantification of the most commonly detected species. A listing of the compounds for which suitable calibration

standards were available and their respective gas phase method detection limit (MDL) is presented in Table 4.1. The table also includes a notation as to which detection channel provided the most sensitive quantitation for each analyte.

TABLE 4.1. Compounds and Detection Limits

<u>Compound</u>	<u>MDL ($\mu\text{g/L}$)</u>	<u>Detector</u>
1,1,1 trichloroethane (TCA)	0.01	ECD
carbon tetrachloride (CCl ₄)	0.002	ECD
trichloroethylene (TCE)	0.01	ECD
1,2 dichloroethane		
1,1 dichloroethane		
perchloroethylene (PCE)	0.002	ECD
cis dichloroethylene		
trans dichloroethylene		
chloroform		
methylene chloride		
chlorobenzene		
benzene		FID
toluene		FID
ethyl benzene		FID
m+p-xylene		FID
o-xylene		FID
methylethyl ketone (MEK)		FID
methylisobutyl ketone (MIBK)		FID
hexane		FID
heptane		FID
octane		FID

4.2 SAMPLING PROBES

Sample probes were constructed according to detailed hardware descriptions and drawings published in a report by Kerfoot and Barrows (1987). The PNL version of the design was modified somewhat to provide a sacrificial penetrator tip slipped over the end of the probe to prevent clogging of the sampling ports during probe entry. Other design improvements included a larger diameter probe body (1 in.) to provide better durability in rocky soil, the use of Acme threads in place of pipe threads, and Swagelok-type fittings on the interior plumbing to eliminate leak problems associated with vibration. The probes and tips were mass produced in the 300 Area machine shop. The probes were of all steel construction to minimize the potential

for carryover of volatile organics. Probe outer bodies were constructed of carbon steel; all other probe parts were stainless steel.

Following assembly, the probes were pressure leak checked. Probes were cleaned with methylene chloride followed by acetone and methanol to remove machine oil prior to final assembly. They were placed in the ground to a nominal depth of 4 ft by hammering with a pneumatic vibratory hammer. Following penetration to the required depth, the probe was withdrawn 2 in. to allow separation from the sacrificial tip. For work in excessively rocky soil (e.g., 1100-2 site), a powered auger with a 6-in. bit was used to facilitate entry of the probe. The auger drilled a hole to within 12 in. of the required depth. The probe was then placed in the hole and hammered to the required depth. The hole was carefully backfilled with spoil and firmly tamped down. In work performed subsequent to the activities at the 1100-2 site, a sharpened solid steel bar was used to create a channel for probe entry. The probe was simply reinserted in the same hole and hammered to the required depth. That procedure greatly reduced stress on the probes and increased their working lifespan; however, because of the very rocky nature of all of the sites investigated, some equipment damage was inevitable. In either case, the probes were left in the ground for at least 12 h prior to sampling to allow recovery of the soil gas profile following penetration. The probes were removed by reverse hammering or with a mechanical jack if necessary after completion of sampling. In some cases involving exceptionally rocky conditions (i.e., subsurface gravel layers), it was necessary to use a power winch to remove the probes.

4.3 SAMPLE COLLECTION

The sample collection train consisted of a 1/8-in.-diameter stainless steel tube connected to a gas sampling bulb with o-ring sealed high-vacuum fittings. Gas was drawn through a 300 to 1000 mL gas sampling bulb by a battery-powered pump. The pump was used at a flow rate of 1 L/min. The rotameter flow meter on the pump was used to verify the presence of flow through the probe. A very sensitive pressure sensor in the pump shut the pump down automatically if it started to pull vacuum as a result of a plugged probe tip.

To verify that it was leak tight, the sample train was tested by plugging before each use. It was then connected to the probe and flow verified. In the event that the probe tip was found to be plugged with soil, remedial measures were implemented. Initially that simply included lifting the probe a few inches and tapping to clear the tip. If flow was still obstructed, the probe was removed, cleared, and reinserted in, or as close as possible to, the same hole.

To collect a sample, the pump was run for a period of time sufficient to completely purge the dead volume of the system, which is typically dominated by the sample bulb volume. A nominal purge time of at least 7 min before sampling was normally allowed to completely purge the gas sampling bulb. No internal combustion engines were operated in the immediate vicinity during sample collection. A photoionization detector (PID) was connected to the output of the sampling pump during the purge period. The PID reading was recorded on the field records at the end of the purge period. A high PID reading served as a warning to the analyst to use a smaller sample to avoid overloading the GC. The sample bulb was then valved off, labeled, and removed to the laboratory for analysis. Sample location, pump time, and any other pertinent observations including meteorological conditions were recorded on the field record sheets and field notebook. This information was also entered into a computer data base at a later time. The probes were cleaned and moved to new locations while the samples were being analyzed. Prior to reuse in each case, the probe tips were unscrewed from the bodies of the probes, cleaned, and inspected to verify that the fittings were tight.

4.4 MOBILE LABORATORY

Analyses of the samples were performed as soon as possible following receipt of sample. Samples were not held more than 24 h without analysis. All analytical equipment was located in the PNL Environmental Sciences Department Mobile Gas Chromatography Laboratory. This facility is centered around a 30 ft motor home. The facility is fully portable with abundant generator power available; however, since all of the 1100 Area sampling locations were within a 5 min driving time of the PNL Sigma 5 facility (which

is the normal home base for the motor home), all analytical work was thus performed at that central location.

4.5 INSTRUMENTATION

Samples were analyzed with a laboratory GC. The GC was equipped with two identical 30-m X 0.53-mm fused silica capillary columns. The capillary columns were coated with a cross-linked and bonded stationary phase composed of cyanopropyl, phenyl, dimethylsiloxane. The two columns were teed together at the inlet and were routed to separate ECDs and FIDs. Sample introduction was via a purge and trap unit. Samples could be introduced into the purge and trap unit in either gaseous or liquid form through the same inlet fitting thus permitting calibration of the system by water standards. The purge and trap unit contained a sorption trap. Samples were thermally desorbed from the trap and transferred to the columns through a heated transfer line. The purge and trap unit was modified by addition of a pneumatic valve actuator to permit full automation of the purge and trap cycle by the GC run table. The GC was equipped with two separate integrators to simultaneously integrate data from both detectors.

4.6 ANALYTICAL METHODOLOGY

At the present time, there are no standard reference analytical methods for analysis of soil gas samples. Analytical measurements were performed in accordance with the general guidelines set forth in EPA Method 502.2 (1986). There were several significant exceptions to the method as presented. EPA Method 502.2, as written, is a capillary column GC method for analysis of volatile organic compounds in water. The method employs a Hall electrolytic conductivity detector (HECD) for halogen selectivity in series with a PID for detection of a broad range of compounds. The detector used in this work for halogen selectivity was an ECD. The ECD is considerably more sensitive than the HECD for the most common chlorinated solvents and has adequate halogen selectivity to satisfy the goals of the method. The FID, on the other hand, is less selective than the PID, providing maximum assurance of broad spectrum response. Incompatibilities in makeup gas require that the two detectors be run in parallel rather than in series. The use of parallel columns does

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somewhat reduce sensitivity by splitting the sample and requires that retention times be independently determined for each column but does have the advantage that two independent analyses are performed effectively on each sample simultaneously.

The method of sample introduction was modified to accommodate either gas or water samples. The purge and trap cell was filled with 5 mL of boiled deionized water. Gas samples in gas-tight syringes were introduced through the normal sample inlet of the purge and trap unit and bubbled through the water where most of the sample dissolved in the water and a small fraction passed through to the sorption trap. The initial injection was followed by a second volume of ambient air to clear the syringe and sample inlet of any residual analyte. Following injection, the purge and trap unit was then cycled through a complete cycle consisting of a helium purge to strip the sample out of the water and quantitatively transfer it to the trap. The purge step was then followed by thermal desorption from the trap. The purge and trap system was set up and operated according to EPA guidelines and manufacturers' recommendations. Calibration was performed as described in Section 4.7 with water samples; however, the units used for calibration were micrograms of total sample recovered, rather than concentration. Gas concentrations were calculated by dividing by the injected volume.

The quality of soil gas data was assessed through the use of replicate measurements, blanks, standards, and interlaboratory splits as specified in the quality assurance plan of the work plan (DOE/RL 88-23). Replicate samples were taken in the field by sequential collection of samples in separate sampling bulbs. In general, at least 1 replicate measurement and standard were analyzed for every 20 points, blanks were run for every tenth sample or daily at a minimum, whichever was more frequent. Interlaboratory splits were collected for analysis at the Hanford Environmental Health Foundation (HEHF). A number of useful measurements were made at HEHF. In general, agreement was excellent where comparison was possible. All measurements made at HEHF were done according to strict EPA Method 502.2 protocol as implemented for their drinking water protection program under the State of Washington certification.

4.7 CALIBRATION

External calibrations were performed with water samples prepared according to standard methods and introduced into the purge and trap unit according to manufacturers' recommendations. Linearity was verified for five concentration ranges. Working standards were prepared by dilution with boiled, deionized water of stock solution of the analytes of interest dissolved in methanol. High-end calibrations were performed for the following species at the specified concentrations: chloroform (10 ppb), 1,1,1 TCA (6 ppb), PCE (3 ppb), CC14 (3 ppb), and TCE (6 ppb). Two-, five-, ten-, and twenty-fold dilutions with boiled, deionized water were then made to verify linearity. Response factors were computed for both the ECD and FID channels and stored in the integrator memory. Detection limits were calculated by reference to the low-end standard and ambient air blank. Calibration factors were verified once daily before sample analysis with a midrange standard. In addition to the species discussed above, stock solutions were also available for the following analytes: 1,2 dichloroethane, 1,1 dichloroethane, cis and trans dichloroethylene, methylene chloride, chlorobenzene, benzene, toluene, ethyl benzene, m+p-xylene, o-xylene, MEK, MIBK, hexane, heptane, and octane. Dilutions of these analytes were used for accurate determination of retention time; however, these species were not normally quantified unless found in actual soil gas samples.

The validity of the calibration procedure was confirmed by preparation of gas standards. Gas standards for the analytes of interest were prepared by adding 10- μ l samples of stock solution in methanol to a gas sampling bulb of accurately known volume. The volume of the bulb was determined by filling with water and weighing. Evaporation of the methanol sample solution inside the bulb produced a dilute analyte-air mixture of accurately known concentration. Bulbs were heated to 100°C for at least 1 h to promote complete mixing. Samples drawn from the gas sampling bulb were injected into the GC and compared with samples of the same analyte introduced into the purge and trap unit as water solution.

4.8 BLANKS

Two types of blanks were considered: water blanks and gas blanks. At least one set of each type of blank was run before initiation of sample analysis each day. More frequent analyses of blanks were performed if blank contamination was detected or suspected. Water blank analysis was performed on samples of reboiled deionized water produced in the Sigma 5 Building. Ambient air blanks in the laboratory were run daily. Gas blanks consisted of ambient air that was drawn through the entire sampling train set up at least 0.5 m above the ground surface at the sampling site, collected, and treated as a sample. Care was taken in collecting ambient air samples to ensure that the air sample was pristine. A single sampling point at each site was used daily to ensure comparability of blanks.

4.9 SAMPLE ANALYSIS

Samples were analyzed as soon as possible following receipt in the motor home. In the event that some delay in analysis was unavoidable, the sample was stored in the refrigerator until analyzed and returned to room temperature before analysis. Samples were withdrawn from the gas sampling bulb with a gas-tight syringe fitted with a 2-in. sampling needle. In areas with suspected high levels of analyte, an initial sample of 200 μL was taken with a 1-mL syringe to avoid accidental overload of the GC. Based on the result, a scaleup to 5 mL was performed, if necessary. At least 10% of the samples showing positive detection on the 5 mL or smaller sample were run in duplicate to provide data for estimation of precision. Syringes and gas sampling bulbs were vacuum flushed prior to reuse. Bulbs were disassembled and baked before reuse if they had been exposed to analyte levels in excess of 5 ng/mL.

4.10 QUALITY ASSURANCE

Work was performed according to the quality assurance provisions of PNL-MA-70, Quality Assurance Manual. Additional quality assurance guidelines were specified in the quality assurance plan of the work plan.

5.0 RESULTS AND DISCUSSION

5.1 1100-2 SITE

Measurable levels of PCE were found at the southwest corner of the site. The concentration gradient was very steep, peaking at survey point J2, which is close to the end of the road leading from the maintenance area and is consistent with a logical scenario for waste disposal. A complete listing of the PCE data is given in Table A.1 of the Appendix. Only PCE is listed because no other species were detected. All data are listed in micrograms of analyte per liter of gas as collected. Measurements ranged from a low of $<0.003 \mu\text{g/L}$ to a high of $727 \mu\text{g/L}$ at J2. The dynamic range of the measurements thus covered more than five orders of magnitude. Low concentrations of PCE were found throughout much of the site but the dominant source appeared to be very localized.

A contour plot of the data is presented in Figure 5.1. Because of the steep gradient in the data, it was necessary to perform a logarithmic transformation on the data before plotting. The transformed data were then contoured using the SURFER[®](a) code mounted on a microcomputer. The contouring was performed with an inverse squared algorithm for a grid spacing half the size of the physical grid. Duplicate measurements were averaged. Contour intervals were $0.5 \text{ LOG}_{10} (\mu\text{g/L})$ units starting at a minimum of -1.5, which corresponds to $0.03 \mu\text{g/L}$ PCE concentration. Figure 5.1 shows a localized concentration at the southwest portion of the site, which likely represents a shallow, localized concentration of PCE. Some minor PCE concentrations were also found west of the railroad tracks and at the north end of the site, but the levels found were very low. While it is clear that the steep areal gradient of PCE at the southern end of the site is dominated by near-surface effects, the widespread distribution of low-level PCE concentrations suggests that some groundwater impact remains a possibility.

(a) SURFER[®] is the registered trademark of Golden Software Inc. of Golden, Colorado.

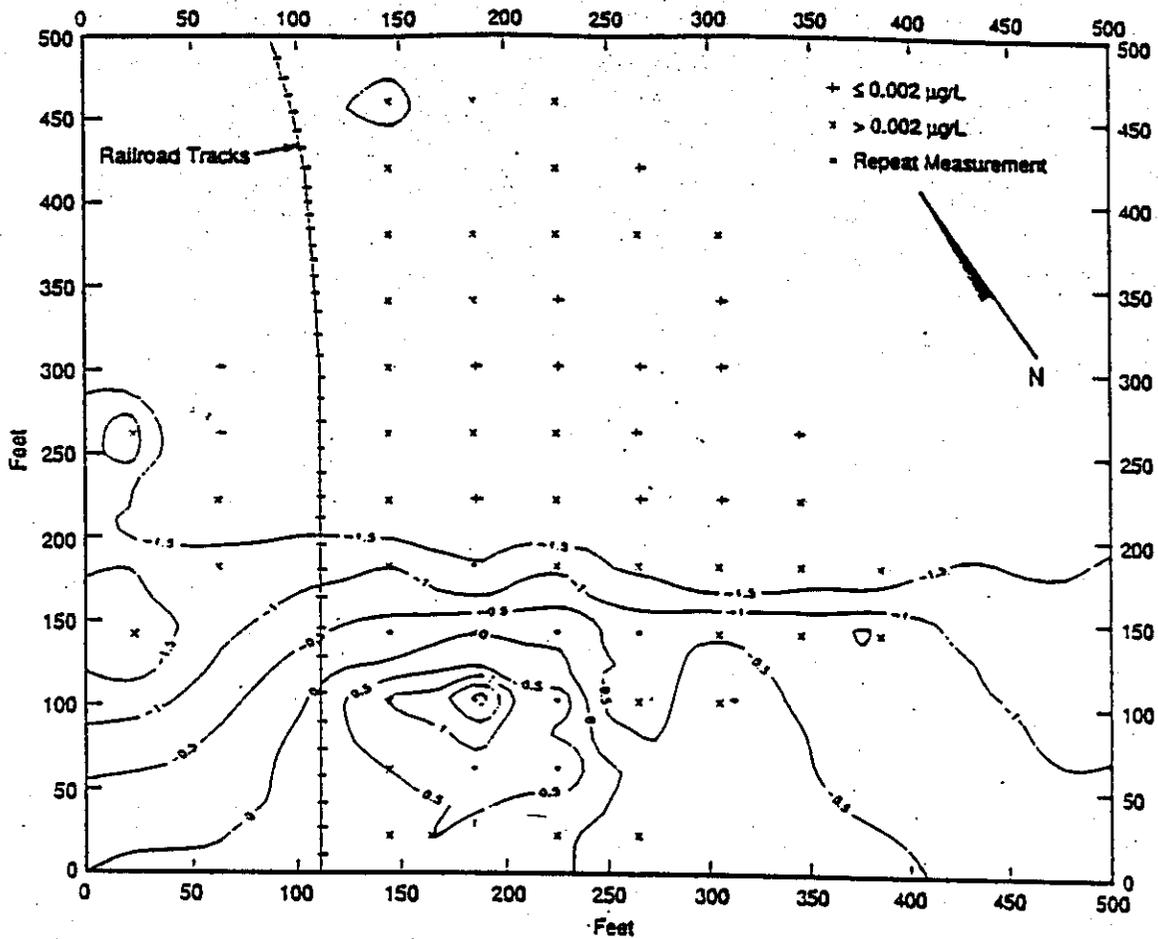


FIGURE 5.1. Logarithmic Contour Plot for PCE Detected in Soil Gas Survey of 1100-2 Site

5.2 HORN RAPIDS DISPOSAL AREA

Several chlorinated species including 1,1,2 TCE, 1,1,1 TCA, and PCE were measurable in soil gas samples collected at the HRD site. A complete listing of the data for the detected species is presented in Table A.2 of the Appendix. No other species were detected.

Measurable TCE concentrations were widespread on the east side of the landfill and in a narrow plume west of the central pit spreading north from the site's southern boundary. The areal distribution of TCE at HRD is shown in Figure 5.2. Data without any transformation were plotted with the SURFER code. Otherwise, the same approach as described for the 1100-2 site was used. Contour intervals are 0.4 $\mu\text{g}/\text{L}$. Figure 5.3 shows the same type of presentation for the PCE data with contour intervals of 0.2 $\mu\text{g}/\text{L}$. Significant levels of PCE are evident; however, the location of the maximum is approximately 500 ft to the east of the TCE maximum. The PCE maximum apparently represents an independent source. Figure 5.4 presents the contour information for TCA. A small region of measurable TCA concentration appears to be coincident with the western TCE plume. A summary of total measurable solvent concentration is presented in Figure 5.5, which is plotted as the sum of all of the data shown in Figures 5.2 through 5.4. No measurable levels of volatile organic compounds were found in samples collected on either the far western side of the site or the northern part of the site. Since only a limited amount of data was available from the center of the site, it is not possible to make definitive statements about that region. The apparent extent of the soil gas anomalies suggests that volatile compounds may be present in the groundwater.

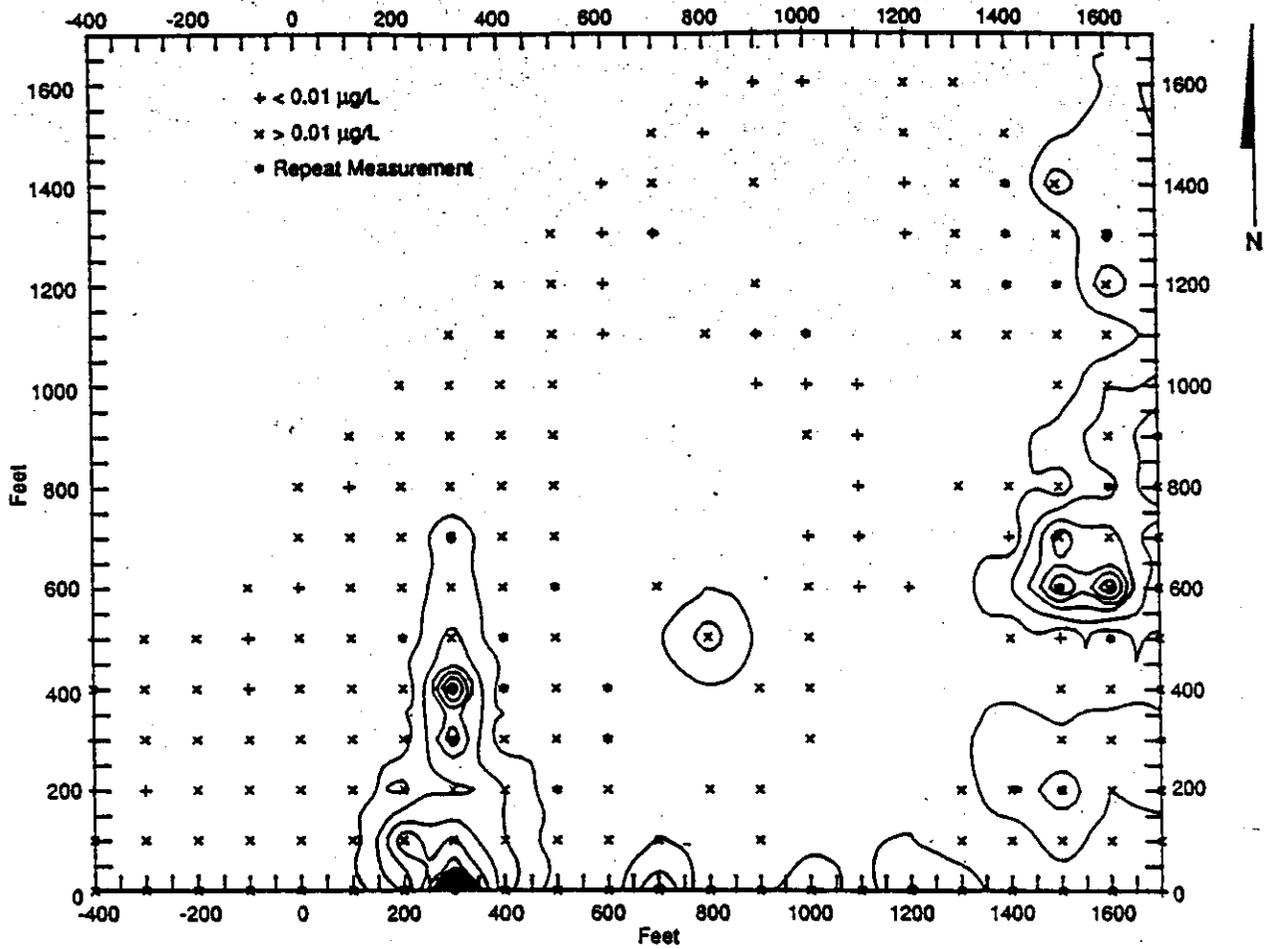


FIGURE 5.2. Distribution of TCE in Soil Gas at Horn Rapids Disposal Area

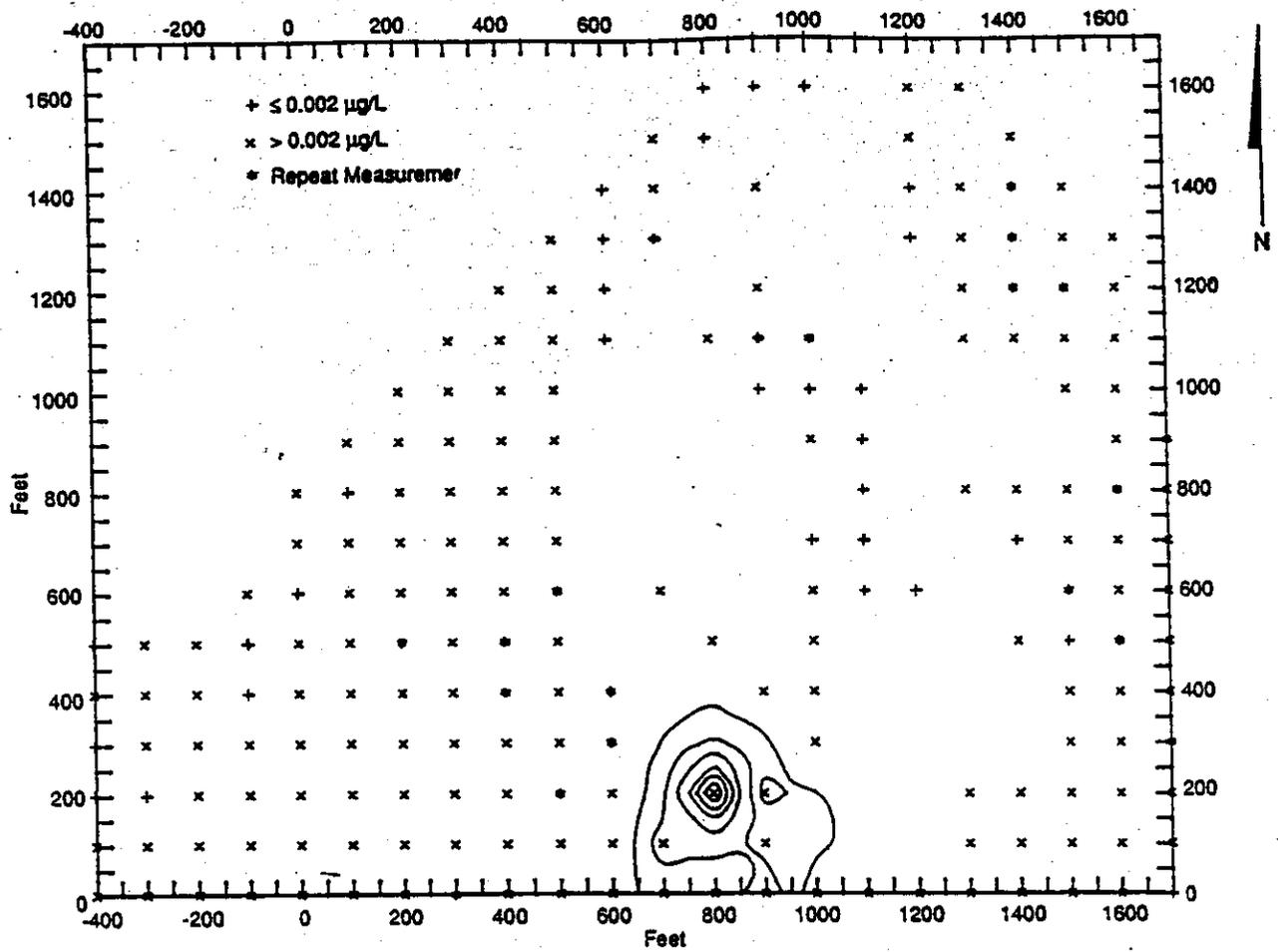


FIGURE 5.3. Distribution of PCE in Soil Gas at Horn Rapids Disposal Area

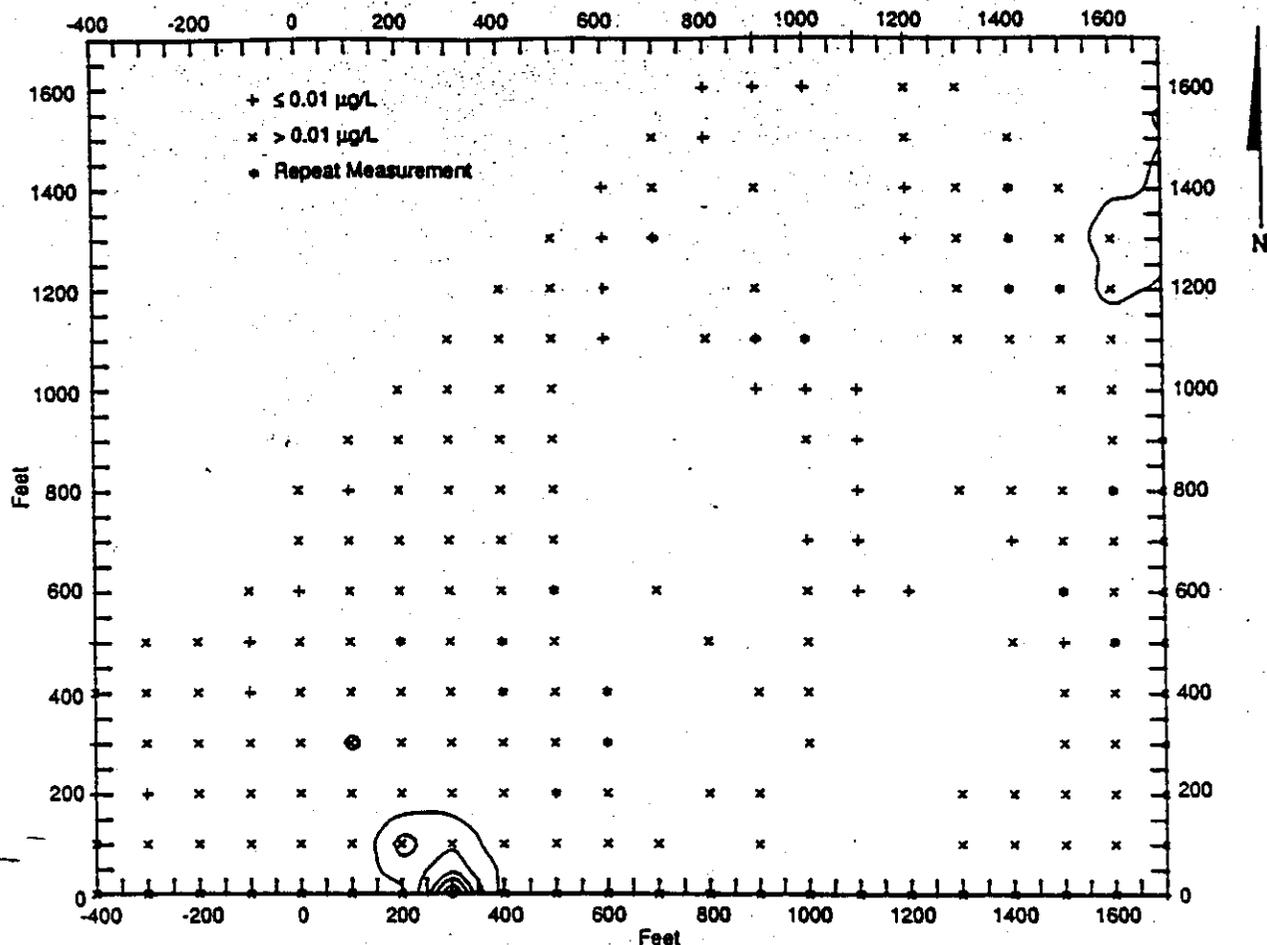


FIGURE 5.4. Distribution of TCA in Soil Gas at Horn Rapids Disposal Area

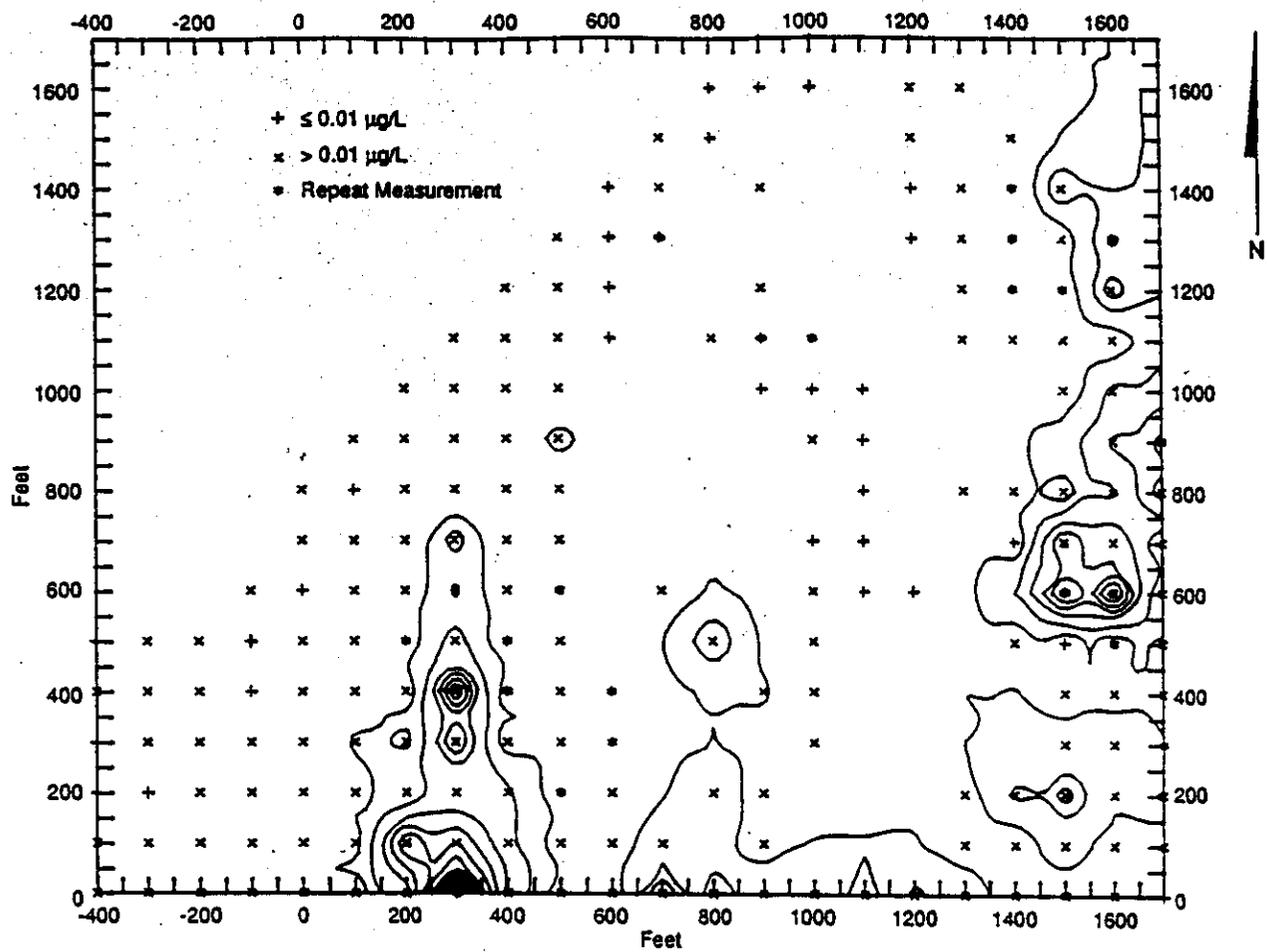


FIGURE 5.5. Distribution of Total Detected Chlorinated Hydrocarbon Contamination (TCE + PCE + TCA) in Soil Gas at Horn Rapids Disposal Area

5.3 1100-3 SITE

No detectable concentrations of volatile organic compounds were found at the 1100-3 site. It appears unlikely that solvent residues are widespread at this site. The fundamental limitations of the method discussed previously should be recognized, however.

5.4 1100-1 SITE

No major solvent concentrations were found in the five points sampled at the 1100-1 site. Low levels of PCE and TCA were seen in all five samples: PCE levels ranged from 0.004 to 0.013 $\mu\text{g}/\text{L}$, and TCA concentrations ranged from 0.01 to 0.05 $\mu\text{g}/\text{L}$. The data show no obvious association with the 1100-1 site. A listing of the data is given in Table A.3.

6.0 CONCLUSIONS

Soil gas surveys were successfully performed at the four sites. The very rocky soil conditions encountered at all four sites resulted in major difficulties in obtaining samples and significant lessons were learned concerning sampling protocols for rocky soil. The combination of a vibratory pneumatic hammer and solid pilot probe were particularly successful and will be used for all future work.

Significant levels of volatile organic compounds were found at two of the four sites sampled. The 1100-2 site showed evidence of the presence of PCE in the near surface at one end of the site. The possibility of limited groundwater impact could not be ruled out. Measurable TCE, PCE, and TCA concentrations were found at several locations in the HRD. No significant levels of volatile organic compounds were found at either the 1100-3 site or the 1100-1 site.

7.0 REFERENCES

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APPENDIX

DATA LISTINGS

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TABLE A.1. 1100-2 Site Soil Gas Data

<u>Site ID</u>	<u>Collection Date</u>	<u>PCE (µg/L)</u>
1100-2-SG-A1A	03/09/89	0.071
1100-2-SG-A2A	03/09/89	0.010
1100-2-SG-A3A	03/10/89	0.003
1100-2-SG-B1A	03/09/89	0.011
1100-2-SG-B3A	03/10/89	0.013
1100-2-SG-B4A	03/10/89	<0.005
1100-2-SG-C1A	03/08/89	0.016
1100-2-SG-C2A	02/21/89	0.004
1100-2-SG-C3A	02/23/89	0.039
1100-2-SG-C4A	03/13/89	0.005
1100-2-SG-C5A	03/13/89	0.013
1100-2-SG-D1A	03/08/89	0.021
1100-2-SG-D2A	02/21/89	0.010
1100-2-SG-D3A	02/22/89	<0.002
1100-2-SG-D5A	03/14/89	<0.002
1100-2-SG-E1A	03/08/89	0.017
1100-2-SG-E2A	02/21/89	<0.002
1100-2-SG-E3A	02/22/89	<0.002
1100-2-SG-E4A	03/14/89	<0.002
1100-2-SG-E5A	03/14/89	<0.002
1100-2-SG-EE1A	03/07/89	<0.002
1100-2-SG-F1A	02/27/89	0.006
1100-2-SG-F2A	02/21/89	<0.002
1100-2-SG-F3A	02/22/89	0.010
1100-2-SG-F4A	03/14/89	<0.002
1100-2-SG-F6A	02/10/89	<0.002
1100-2-SG-FF1A	03/07/89	<0.002
1100-2-SG-FF2A	03/02/89	0.290
1100-2-SG-G1A	02/27/89	0.007
1100-2-SG-G2A	02/17/89	<0.002
1100-2-SG-G2B	02/21/89	<0.002
1100-2-SG-G3A	02/22/89	0.003
1100-2-SG-G4A	02/17/89	0.002
1100-2-SG-G5A	03/14/89	<0.002
1100-2-SG-G6A	03/14/89	0.006
1100-2-SG-GG1A	03/02/89	0.011
1100-2-SG-H1A	02/27/89	0.120
1100-2-SG-H2A	02/17/89	0.020
1100-2-SG-H2B	02/21/89	0.020
1100-2-SG-H3A	02/22/89	0.140
1100-2-SG-H4A	02/17/89	0.020
1100-2-SG-H5A	03/14/89	0.007
1100-2-SG-H6A	03/14/89	0.011
1100-2-SG-H7A	03/14/89	0.014
1100-2-SG-HH1A	03/02/89	0.049
1100-2-SG-I1A	02/23/89	0.440
1100-2-SG-I1B	02/23/89	1.200

TABLE A.1. (contd)

<u>Site ID</u>	<u>Collection Date</u>	<u>PCE ($\mu\text{g/L}$)</u>
1100-2-SG-I1C	02/23/89	0.270
1100-2-SG-I2A	02/17/89	1.200
1100-2-SG-I3A	02/17/89	1.700
1100-2-SG-I3B	02/21/89	2.500
1100-2-SG-I4A	02/17/89	0.220
1100-2-SG-I4B	02/21/89	0.310
1100-2-SG-I5A	03/15/89	0.751
1100-2-SG-I6A	03/14/89	0.570
1100-2-SG-I7A	03/14/89	0.596
1100-2-SG-II2A	03/07/89	0.009
1100-2-SG-J1A	02/23/89	17.000
1100-2-SG-J2A	02/23/89	727.000
1100-2-SG-J2B	02/23/89	521.000
1100-2-SG-J2C	02/23/89	676.000
1100-2-SG-J3A	02/23/89	9.500
1100-2-SG-J3B	02/23/89	5.800
1100-2-SG-J3C	02/23/89	9.600
1100-2-SG-J4A	02/23/89	0.039
1100-2-SG-J5A	03/15/89	2.200
1100-2-SG-K1A	02/28/89	3.300
1100-2-SG-K2A	03/20/89	4.780
1100-2-SG-K2B	03/20/89	5.400
1100-2-SG-K2C	03/23/89	14.000
1100-2-SG-K2D	03/23/89	10.610
1100-2-SG-K2E	03/23/89	11.600
1100-2-SG-K2F	03/23/89	9.800
1100-2-SG-K2G	03/29/89	6.080
1100-2-SG-K2H	03/29/89	6.300
1100-2-SG-K2I	03/29/89	5.920
1100-2-SG-K2J	03/29/89	6.900
1100-2-SG-K3A	03/15/89	17.300
1100-2-SG-K3B	03/16/89	5.070
1100-2-SG-L1A	02/28/89	1.300
1100-2-SG-L2A	03/01/89	3.430
1100-2-SG-L3A	03/01/89	1.200
1100-2-SG-L4A	03/01/89	0.370

TABLE A.2. Horn Rapids Disposal Area Soil Gas Data

<u>Site ID</u>	<u>Collection Date</u>	<u>TCE (µg/L)</u>	<u>TCA (µg/L)</u>	<u>PCE (µg/L)</u>
600-HRD-SG-A1A	03/30/89	0.200	0.110	0.006
600-HRD-SG-A2A	03/30/89	0.040	0.050	0.004
600-HRD-SG-A3A	03/30/89	<0.010	0.010	0.012
600-HRD-SG-A4A	04/03/89	0.010	0.010	<0.002
600-HRD-SG-A5A	04/03/89	0.010	0.050	0.002
600-HRD-SG-A6A	04/03/89	<0.010	0.010	<0.002
600-HRD-SG-A7A	04/03/89	<0.010	<0.010	<0.002
600-HRD-SG-A8A	04/03/89	0.022	0.023	0.017
600-HRD-SG-A9A	04/03/89	<0.010	0.020	0.012
600-HRD-SG-AA1A	03/30/89	0.030	0.080	0.006
600-HRD-SG-AA2A	03/30/89	<0.010	0.020	0.003
600-HRD-SG-AA3A	03/30/89	0.030	0.120	0.147
600-HRD-SG-AA4A	03/30/89	<0.010	0.030	0.002
600-HRD-SG-AA6A	03/29/89	<0.010	<0.010	<0.002
600-HRD-SG-AA6C	03/29/89	<0.010	<0.010	<0.002
600-HRD-SG-AA7A	03/29/89	<0.010	0.010	<0.002
600-HRD-SG-B1A	04/04/89	0.070	0.010	<0.002
600-HRD-SG-B2A	04/04/89	0.190	0.060	0.002
600-HRD-SG-B3A	04/04/89	0.030	0.030	<0.002
600-HRD-SG-B4A	04/04/89	0.200	0.240	0.010
600-HRD-SG-B5A	04/04/89	0.030	0.030	0.004
600-HRD-SG-B6A	04/04/89	0.030	<0.010	<0.002
600-HRD-SG-B7A	04/03/89	0.010	0.020	0.004
600-HRD-SG-B8A	04/03/89	0.020	0.030	0.004
600-HRD-SG-B9A	04/03/89	<0.010	<0.010	<0.002
600-HRD-SG-B10A	04/03/89	<0.010	<0.010	0.002
600-HRD-SG-BB1A	03/30/89	<0.010	0.050	0.009
600-HRD-SG-BB2A	03/29/89	<0.010	0.050	0.007
600-HRD-SG-BB3A	03/29/89	0.010	0.060	0.013
600-HRD-SG-BB4A	03/29/89	0.010	0.010	<0.002
600-HRD-SG-BB5A	03/29/89	<0.010	0.040	0.010
600-HRD-SG-BB6A	03/30/89	<0.010	<0.010	<0.002
600-HRD-SG-C1A	04/04/89	0.820	0.160	0.007
600-HRD-SG-C2A	04/04/89	1.940	0.500	0.025
600-HRD-SG-C3A	04/04/89	0.340	0.070	0.003
600-HRD-SG-C4A	04/05/89	0.220	0.080	0.004
600-HRD-SG-C5A	04/05/89	0.022	0.050	0.004
600-HRD-SG-C6A	04/05/89	0.090	0.060	0.004
600-HRD-SG-C6B	04/05/89	0.090	0.050	0.004
600-HRD-SG-C7A	04/05/89	0.070	0.050	0.005
600-HRD-SG-C8A	04/05/89	0.105	0.060	0.006
600-HRD-SG-C9A	04/05/89	0.030	0.020	0.002
600-HRD-SG-C10A	04/05/89	0.120	0.040	0.003
600-HRD-SG-C11A	04/05/89	0.030	<0.010	<0.002
600-HRD-SG-CC1A	03/30/89	0.010	0.090	0.015
600-HRD-SG-CC2A	03/29/89	<0.010	0.020	0.002

TABLE A.2. (contd)

<u>Site ID</u>	<u>Collection Date</u>	<u>TCE</u> <u>($\mu\text{g/L}$)</u>	<u>TCA</u> <u>($\mu\text{g/L}$)</u>	<u>PCE</u> <u>($\mu\text{g/L}$)</u>
600-HRD-SG-CC3A	03/28/89	<0.010	<0.010	<0.002
600-HRD-SG-CC4A	03/28/89	<0.010	0.060	0.003
600-HRD-SG-CC5A	03/28/89	<0.010	0.020	0.004
600-HRD-SG-CC6A	03/28/89	<0.010	0.020	0.002
600-HRD-SG-D1A	04/06/89	4.740	1.190	0.035
600-HRD-SG-D1B	04/06/89	4.700	1.400	0.045
600-HRD-SG-D2A	04/06/89	1.670	0.360	0.009
600-HRD-SG-D3A	04/06/89	0.730	0.100	0.004
600-HRD-SG-D4A	04/06/89	1.860	0.200	0.011
600-HRD-SG-D5A	04/06/89	2.760	0.100	0.012
600-HRD-SG-D6A	04/06/89	0.960	0.024	0.004
600-HRD-SG-D7A	04/10/89	0.780	0.070	0.006
600-HRD-SG-D8A	04/06/89	0.890	0.110	0.016
600-HRD-SG-D9A	04/06/89	0.100	0.020	0.004
600-HRD-SG-D10A	04/06/89	0.080	0.010	0.003
600-HRD-SG-D11A	04/05/89	0.150	0.060	0.004
600-HRD-SG-D12A	04/05/89	0.040	0.016	<0.002
600-HRD-SG-DD1A	03/28/89	<0.010	0.020	0.004
600-HRD-SG-DD2A	03/28/89	<0.010	0.010	<0.002
600-HRD-SG-DD3A	03/28/89	<0.010	<0.010	<0.002
600-HRD-SG-DD4A	03/28/89	<0.010	<0.010	<0.002
600-HRD-SG-DD5A	03/29/89	0.010	0.010	0.003
600-HRD-SG-DD6A	03/28/89	<0.010	<0.010	<0.002
600-HRD-SG-E1A	04/11/89	0.870	0.060	0.003
600-HRD-SG-E2A	04/11/89	0.810	0.060	0.007
600-HRD-SG-E3A	04/11/89	0.800	0.040	0.003
600-HRD-SG-E4A	04/12/89	0.120	0.010	0.005
600-HRD-SG-E5A	04/11/89	0.160	0.010	<0.002
600-HRD-SG-E5B	04/11/89	0.120	<0.010	<0.002
600-HRD-SG-E6A	04/10/89	0.020	<0.010	<0.002
600-HRD-SG-E6B	04/10/89	0.020	<0.010	<0.002
600-HRD-SG-E7A	04/10/89	0.110	<0.010	<0.002
600-HRD-SG-E8A	04/12/89	0.120	0.010	0.004
600-HRD-SG-E9A	04/10/89	0.160	0.020	0.004
600-HRD-SG-E10A	04/10/89	0.100	0.030	0.003
600-HRD-SG-E11A	04/10/89	0.010	<0.010	<0.002
600-HRD-SG-E12A	04/10/89	0.040	0.010	0.002
600-HRD-SG-E13A	04/10/89	0.050	0.010	0.002
600-HRD-SG-F1A	04/29/89	0.050	<0.010	<0.002
600-HRD-SG-F2A	04/20/89	0.010	<0.010	<0.002
600-HRD-SG-F3A	04/13/89	0.050	<0.010	<0.002
600-HRD-SG-F3B	04/13/89	0.040	<0.010	<0.002
600-HRD-SG-F4A	04/14/89	0.020	<0.010	<0.002
600-HRD-SG-F5A	04/13/89	0.020	<0.010	<0.002
600-HRD-SG-F6A	04/13/89	0.020	<0.010	<0.002
600-HRD-SG-F7A	04/14/89	0.090	0.010	<0.002

TABLE A.2. (contd)

<u>Site ID</u>	<u>Collection Date</u>	<u>TCE (µg/L)</u>	<u>TCA (µg/L)</u>	<u>PCE (µg/L)</u>
600-HRD-SG-F7B	04/14/89	0.100	<0.010	<0.002
600-HRD-SG-F8A	04/13/89	0.050	0.010	0.002
600-HRD-SG-F9A	04/13/89	0.140	0.040	0.007
600-HRD-SG-F10A	04/13/89	0.400	0.110	0.026
600-HRD-SG-F11A	04/13/89	0.010	<0.010	<0.002
600-HRD-SG-F12A	04/13/89	0.010	<0.010	<0.002
600-HRD-SG-F13A	04/13/89	0.020	<0.010	0.002
600-HRD-SG-F14A	04/13/89	0.010	<0.010	<0.002
600-HRD-SG-G1A	04/17/89	0.170	<0.010	0.002
600-HRD-SG-G2A	04/17/89	0.110	<0.010	<0.002
600-HRD-SG-G3A	04/17/89	0.020	<0.010	<0.002
600-HRD-SG-G4A	04/17/89	0.020	0.010	<0.002
600-HRD-SG-G4B	04/17/89	0.020	<0.010	<0.002
600-HRD-SG-G5A	04/18/89	0.040	<0.010	0.003
600-HRD-SG-G5B	04/18/89	0.150	0.020	0.005
600-HRD-SG-G12A	04/17/89	<0.010	<0.010	<0.002
600-HRD-SG-G13A	04/14/89	<0.010	<0.010	<0.002
600-HRD-SG-G14A	04/14/89	<0.010	<0.010	<0.002
600-HRD-SG-G15A	04/14/89	<0.010	<0.010	<0.002
600-HRD-SG-H1A	04/17/89	1.400	0.040	0.199
600-HRD-SG-H2A	04/18/89	0.420	0.020	0.270
600-HRD-SG-H7A	04/17/89	0.150	0.020	0.019
600-HRD-SG-H14A	05/10/89	0.010	<0.010	<0.002
600-HRD-SG-H15A	05/10/89	0.010	<0.010	<0.002
600-HRD-SG-H16A	05/10/89	0.010	<0.010	<0.002
600-HRD-SG-J1A	04/17/89	0.030	0.010	0.117
600-HRD-SG-J3A	04/18/89	0.090	<0.010	0.714
600-HRD-SG-J6A	04/18/89	0.980	0.040	0.040
600-HRD-SG-J12A	04/20/89	<0.010	<0.010	0.009
600-HRD-SG-J16A	05/10/89	<0.010	<0.010	<0.002
600-HRD-SG-J17A	05/10/89	<0.010	<0.010	<0.002
600-HRD-SG-K1A	04/18/89	0.330	<0.010	0.280
600-HRD-SG-K2A	04/18/89	0.060	<0.010	0.180
600-HRD-SG-K3A	04/18/89	0.080	<0.010	0.053
600-HRD-SG-K5A	04/18/89	0.380	0.020	0.046
600-HRD-SG-K11A	04/19/89	<0.010	<0.010	<0.002
600-HRD-SG-K12A	04/19/89	<0.010	<0.010	0.002
600-HRD-SG-K13A	04/20/89	0.007	<0.010	<0.002
600-HRD-SG-K13A	05/10/89	0.010	0.010	<0.002
600-HRD-SG-K15A	04/20/89	<0.010	<0.010	0.009
600-HRD-SG-K17A	05/10/89	<0.010	<0.010	<0.002
600-HRD-SG-K18A	05/10/89	<0.010	<0.010	<0.002
600-HRD-SG-L1A	04/18/89	0.710	<0.010	0.021
600-HRD-SG-L4A	04/19/89	0.020	<0.010	<0.002
600-HRD-SG-L5A	04/19/89	0.070	<0.010	0.008
600-HRD-SG-L6A	04/19/89	0.070	<0.010	0.002

TABLE A.2. (contd)

<u>Site ID</u>	<u>Collection Date</u>	<u>TCE (µg/L)</u>	<u>TCA (µg/L)</u>	<u>PCE (µg/L)</u>
600-HRD-SG-L7A	04/19/89	0.060	<0.010	<0.002
600-HRD-SG-L10A	04/19/89	0.030	<0.010	<0.002
600-HRD-SG-L11A	04/19/89	<0.010	<0.010	<0.002
600-HRD-SG-L12A	04/19/89	<0.010	<0.010	0.009
600-HRD-SG-L12B	04/19/89	<0.010	<0.010	0.008
600-HRD-SG-L17A	05/10/78	<0.010	<0.010	<0.002
600-HRD-SG-L17B	05/10/89	<0.010	<0.010	<0.002
600-HRD-SG-L18A	05/10/89	<0.010	<0.010	<0.002
600-HRD-SG-M1A	04/20/89	0.202	<0.010	0.005
600-HRD-SG-M7A	05/05/89	<0.010	<0.010	<0.002
600-HRD-SG-M8A	05/05/89	0.010	<0.010	<0.002
600-HRD-SG-M9A	05/05/89	<0.010	<0.010	<0.002
600-HRD-SG-M10A	05/05/89	<0.010	<0.010	<0.002
600-HRD-SG-M11A	05/05/89	<0.010	<0.010	<0.002
600-HRD-SG-M18A	05/04/89	<0.010	<0.010	<0.002
600-HRD-SG-N1A	05/05/89	0.860	0.020	0.006
600-HRD-SG-N7A	05/05/89	<0.010	<0.010	<0.002
600-HRD-SG-N14A	05/02/89	<0.010	<0.010	<0.002
600-HRD-SG-N15A	05/04/89	<0.010	<0.010	<0.002
600-HRD-SG-N16A	05/04/89	<0.010	<0.010	0.041
600-HRD-SG-N17A	05/04/89	<0.010	<0.010	0.032
600-HRD-SG-N18A	05/04/89	<0.010	<0.010	<0.002
600-HRD-SG-P1A	05/03/89	0.740	0.030	0.005
600-HRD-SG-P2A	05/03/89	0.080	<0.010	0.002
600-HRD-SG-P3A	05/03/89	0.230	0.010	0.007
600-HRD-SG-P9A	05/01/89	0.020	<0.010	<0.002
600-HRD-SG-P12A	05/01/89	<0.010	0.020	<0.002
600-HRD-SG-P13A	05/01/89	<0.010	0.010	0.023
600-HRD-SG-P14A	05/01/89	<0.010	<0.010	0.004
600-HRD-SG-P15A	05/04/89	0.010	<0.010	<0.002
600-HRD-SG-P17A	05/04/89	<0.010	<0.010	0.026
600-HRD-SG-R1A	05/03/89	0.060	<0.010	<0.002
600-HRD-SG-R2A	05/03/89	0.040	0.010	<0.002
600-HRD-SG-R3A	05/03/89	0.830	0.040	0.010
600-HRD-SG-R6A	05/03/89	0.050	<0.010	<0.002
600-HRD-SG-R8A	05/05/89	<0.010	<0.010	<0.002
600-HRD-SG-R9A	05/01/89	0.010	<0.010	<0.002
600-HRD-SG-R12A	05/02/89	0.050	0.040	0.005
600-HRD-SG-R13A	05/01/89	0.040	0.050	0.004
600-HRD-SG-R13B	05/01/89	0.020	0.030	0.003
600-HRD-SG-R14A	05/04/89	0.020	0.020	0.012
600-HRD-SG-R14B	05/04/89	0.010	0.010	0.007
600-HRD-SG-R15A	05/03/89	<0.010	<0.010	0.009
600-HRD-SG-R15B	05/03/89	<0.010	0.010	0.013
600-HRD-SG-R16A	03/27/89	0.010	0.010	0.013
600-HRD-SG-S1A	03/23/89	0.130	0.010	<0.002

TABLE A.2. (contd)

Site ID	Collection Date	TCE ($\mu\text{g/L}$)	TCA ($\mu\text{g/L}$)	PCE ($\mu\text{g/L}$)
600-HRD-SG-S2A	03/23/89	0.670	0.040	0.004
600-HRD-SG-S3A	03/23/89	1.290	0.100	0.014
600-HRD-SG-S4A	03/23/89	0.450	0.060	0.005
600-HRD-SG-S5A	03/23/89	0.010	<0.010	0.024
600-HRD-SG-S6A	03/27/89	<0.010	<0.010	<0.002
600-HRD-SG-S7A	03/28/89	2.470	0.080	0.021
600-HRD-SG-S7B	03/28/89	2.440	0.080	0.022
600-HRD-SG-S8A	03/27/89	1.880	0.130	0.054
600-HRD-SG-S9A	03/27/89	0.090	0.010	0.003
600-HRD-SG-S11A	03/27/89	0.010	<0.010	<0.002
600-HRD-SG-S12A	03/27/89	0.030	0.010	0.002
600-HRD-SG-S13A	03/27/89	0.110	0.020	0.006
600-HRD-SG-S13B	03/27/89	0.100	0.020	0.007
600-HRD-SG-S14A	03/27/89	0.100	0.040	0.018
600-HRD-SG-S15A	03/27/89	1.060	0.080	0.043
600-HRD-SG-T1A	03/23/89	0.012	<0.010	0.002
600-HRD-SG-T2A	03/23/89	0.070	<0.010	0.003
600-HRD-SG-T3A	03/23/89	0.395	0.045	0.005
600-HRD-SG-T4A	03/21/89	0.704	0.064	0.021
600-HRD-SG-T5A	03/21/89	0.193	<0.010	0.002
600-HRD-SG-T6A	03/23/89	0.058	<0.010	<0.002
600-HRD-SG-T6B	03/23/89	0.053	<0.010	<0.002
600-HRD-SG-T6C	03/23/89	0.041	<0.010	<0.002
600-HRD-SG-T7A	03/21/89	2.820	0.133	0.760
600-HRD-SG-T8A	03/21/89	1.340	0.122	0.027
600-HRD-SG-T9A	03/21/89	0.674	0.066	0.018
600-HRD-SG-T9B	03/21/89	0.604	0.060	0.046
600-HRD-SG-T10A	03/23/89	1.160	0.086	0.024
600-HRD-SG-T11A	03/23/89	0.793	0.081	0.016
600-HRD-SG-T12A	03/21/89	0.049	0.049	0.009
600-HRD-SG-T13A	03/20/89	1.100	0.298	0.041
600-HRD-SG-T14A	03/20/89	0.834	0.398	0.035
600-HRD-SG-U1A	03/17/89	<0.010	<0.010	<0.002
600-HRD-SG-U2A	03/17/89	0.029	<0.010	<0.002
600-HRD-SG-U3A	03/17/89	0.689	0.167	0.006
600-HRD-SG-U4A	03/20/89	0.720	0.053	0.006
600-HRD-SG-U5A	03/20/89	0.140	<0.010	<0.002
600-HRD-SG-U6A	03/20/89	0.320	<0.010	<0.002
600-HRD-SG-U7A	03/20/89	0.360	<0.010	<0.002
600-HRD-SG-U8A	03/20/89	0.340	0.031	0.012
600-HRD-SG-U9A	03/20/89	1.670	0.118	0.019
600-HRD-SG-U10A	03/20/89	1.690	0.108	0.022
600-HRD-SG-U10B	03/20/89	1.560	0.081	0.021

TABLE A.3. 1100-1 Site Soil Gas Data

<u>Site ID</u>	<u>Collection Date</u>	<u>TCA ($\mu\text{g/L}$)</u>	<u>PCE ($\mu\text{g/L}$)</u>
1100-1-SG-CEN-1A	6/26/89	0.01	0.005
1100-1-SG-CEN-2A	6/30/89	0.05	0.006
1100-1-SG-CEN-3A	6/26/89	0.04	0.012
1100-1-SG-NE-1A	6/30/89	0.03	0.013
1100-1-SG-SE-1A	6/30/89	0.02	0.004

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