Site Reg. 8/96

HARTCROWSER

Earth and Environmental Technologies

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J-4422-07

August 12, 1996

Ms. Louise Bardy
Washington State Department of Ecology
Northwest Regional Office
3190 - 160th Avenue SE
Bellevue, Washington 98008-5452

Re: Proposed Modifications to Cleanup Action
Former Tux Shop Site
5409 15th Avenue Northwest
Seattle, Washington

Dear Ms. Bardy:

On behalf of our client, The Tux Shops, we are submitting this update regarding recent site characterization results and proposed modifications to the independent cleanup action at the former Tux Shop site in Seattle. Please consider this letter an addendum to our original notification of the proposed cleanup action to the Washington State Department of Ecology (Ecology), addressed to Mr. Mike Gallagher on December 12, 1995, and our response to Ecology comments, addressed to Ms. Louise Bardy on January 4, 1996.

SUMMARY

As you will recall, our proposed cleanup action consists of an air sparging/soil vapor extraction system to remediate groundwater impacted by tetrachloroethene (PCE). Originally, the system would have had two components: a source area system located near the former sump; and an optional downgradient system at the downgradient boundary of the site. The source area system would be installed beneath a planned Walgreens drug store building at the site. The primary reason for conducting the recent site characterization activities was to confirm the need for and optimum location of the optional downgradient system.

The recent site characterization results are generally consistent with our previous assessment of the site. However, groundwater flow measurements and groundwater quality data indicate that peak on-site PCE concentrations downgradient from the source area are actually at the south boundary of the site rather than at the east boundary as indicated by previous data. In fact the maximum PCE concentration at the east boundary decreased from 0.21 mg/L in September 1994 to 0.051 in April 1996. The highest downgradient PCE concentration at the south boundary is only 20 feet away from the proposed Walgreens building, which is significantly less than the 70 feet between the building and the east boundary. Therefore, we propose to increase the areal extent of the source area sparging/extraction system under the building and eliminate the optional downgradient sparging/extraction system. The expanded source area sparging/extraction system will address essentially all of the on-site groundwater contaminant plume.

Since the maximum observed concentration at the southern boundary of the site (23 mg/L) was higher than the previously observed maximum concentration at the western boundary of the site (0.21 mg/L), we conducted a preliminary risk screening to assess potential risk to downgradient receptors. Based on conservative groundwater and soil vapor modeling and risk screening, we believe the potential risk associated with the off-site migration of PCE-impacted groundwater to be very small. Furthermore, the expected cleanup of the on-site PCE groundwater plume within the next 3 years will reduce any long-term impacts from off-site migration of PCE.

Site development activities by Walgreens are currently underway, and we anticipate field mobilization for installation of the air sparging/soil vapor extraction system in early September.

The remainder of this letter consists of the following sections, providing background information and a summary of recent activities at the site.

- **BACKGROUND**;
- **ADDITIONAL SITE CHARACTERIZATION DATA**;
- **PRELIMINARY RISK SCREENING**; and
- **MODIFICATIONS TO CLEANUP ACTION**.

Supporting documentation is reported in Appendices A through D as follows.

- Appendix A - Monitoring Well Logs
- Appendix B - Soil Vapor Migration Calculations
- Appendix C - Groundwater Migration Calculations
- Appendix D - Risk Screening Calculations

BACKGROUND

The Tux Shop site is located on the corner of Northwest Market Street and 15th Avenue NW in the Ballard section of Seattle, Washington. The eastern portion of the site formerly contained a Unocal service station, which was decommissioned in 1993. A dry cleaning facility operated on the western portion of the site from the early 1950s until 1993 when the facility was shut down because of a fire. All of the structures that were formerly present on both portions of the site have been demolished.

The Unocal portion of the property has been cleaned up through excavation and removal of approximately 4,400 cubic yards of petroleum-containing soil. During site characterization activities conducted by Unocal in 1990, tetrachloroethene (PCE) and several other chlorinated solvents were detected in shallow groundwater beneath the property. The presence of chlorinated solvents at the site appears to be associated primarily with dry cleaning operations that were formerly conducted on the western portion of the property. The highest PCE concentrations in soil and groundwater occur in the vicinity of a sump (sewer drain) located immediately south of the former Tux Shop building (located immediately north of KMW-5 on Figure 1).

Trichloroethene (TCE), 1,2-dichloroethene (1,2-DCE), and vinyl chloride (VC) were observed in groundwater at the site at much lower concentrations than PCE and appear to be biotransformation products resulting from a release of PCE. However, groundwater at the site is generally aerobic, so that the reductive biotransformation of PCE to TCE, DCE, and VC will generally not occur. Regardless, the planned cleanup action for the site would effectively remove these other chlorinated solvents along with the PCE.

An independent cleanup action has been initiated by The Tux Shops and the FN&F Investment Company at the former Tux Shop facility located in the Ballard area of Seattle. At this time, our client has not decided whether it will seek a No Further Action (NFA) Letter under the Independent Remedial Action Program (IRAP). The site has been leased to Walgreens for construction of a retail drug store. These redevelopment activities will coincide with implementation of the cleanup action. This is consistent with our understanding of the State Legislature's intent when they revised the MTCA statute last year to encourage "brownfield" development.

On December 12, 1995, we submitted a letter on behalf of The Tux Shops to Mr. Mike Gallagher of Ecology presenting available site information and our basis for selecting air sparging/soil vapor extraction to remediate groundwater impacted by PCE at the site. The purpose of our letter to Ecology was to obtain an informal opinion as to whether our approach would be consistent with the MTCA. On January 2, 1995, we received verbal comments from Ecology regarding our December 12 letter, and we submitted our response to the comments to Ms. Louise Bardy on January 4, 1996.

Please refer to our December 12, 1995, letter for additional details concerning the historical site characterization data and the remedial strategy for the site.

ADDITIONAL SITE CHARACTERIZATION DATA

Additional site characterization work in 1996 included explorations for groundwater sampling and for soil vapor sampling. The Strataprobe drilling method (direct-push technology) was used to collect the following data:

- Groundwater samples along the property boundary (SP-1A, SP-1B, SP-2A, SP-2B, and SP-3 through SP-7).
- Soil vapor samples along the property boundary (SP-V1, SP-V2, SP-V3, and SP-V4).

In addition, three new monitoring wells (HC-3, HC-4, and HC-5) were installed, developed, and sampled just south of the property boundary. Boring logs for the new wells are presented in Appendix A. The site and exploration location plan is presented on Figure 1.

Groundwater Monitoring Results

A summary of the available groundwater quality data is presented in Table 1 and in plan view on Figure 2. Additional groundwater sampling data collected in 1996 for site characterization include Strataprobe samples SP-1A, SP-1B, SP-2A, SP-2B, and SP-3 through SP-7; new monitoring wells HC-3 through HC-5; and a complete set of samples from existing on-site wells. The groundwater samples collected in 1996 were analyzed for volatiles by EPA Method 8260. Groundwater levels were also measured. These data were used to develop the groundwater elevation contour map presented on Figure 3.

Figures 4 and 5 present subsurface cross sections through the property. Cross Section A-A' (Figure 4) cuts through the site in the direction of groundwater flow on the eastern half of the site, toward the southeast. Cross Section B-B' (Figure 5) runs through the site in a generally north to south direction, corresponding with the direction of groundwater flow on the western half of the site as illustrated on Figure 3. Cross Section B-B' cuts through the former sump area (in the vicinity of HC-1W and HC-1D) in the direction of groundwater flow. An approximated groundwater flow net is shown on Cross Section B-B'. The flow net illustrates a vertically downward component to groundwater flow. Available groundwater chemistry for PCE is also shown on the cross sections. These data suggest a vertical boundary to the PCE plume with off-site migration to the south.

Soil Gas Monitoring Results

To assess the potential for off-site migration of PCE in the vapor phase, four soil vapor samples were collected (located as shown on Figure 6). Vapor samples SP-V1 through SP-V3 were collected at a depth of 5 feet using the Strataprobe rig. Two on-site samples (SP-V1 and SP-V2) were collected near locations where groundwater samples SP-2B and SP-4 had been collected, providing data for a comparison of dissolved phase and vapor phase concentrations. One off-site sample (SP-V3) was collected within the backfill of a storm sewer line just south of the property, and another (SP-V4) was collected directly from a storm sewer manhole near the southwest corner of the property. Vapor samples were collected in 1-liter SUMMA canisters and analyzed for PCE by EPA Method TO-14. The analytical results for the soil vapor samples are presented on Figure 6 and are summarized below:

Location	PCE in Soil Vapor in ppm
SP-V1	1.0
SP-V2	5.8
SP-V3	4.3
SP-V4	0.092

The soil vapor results were used in the soil vapor migration calculations presented in Appendix B.

Soil Organic Matter Test Results

Three soil samples were analyzed for Total Organic Carbon, and the results are as follows:

Sample Number	Total Organic Carbon in Percent
HC-4/S-3	0.067
HC-4/S-7	0.35
HC-5/S-5	0.052

These results were used in the groundwater migration caclulations presented in Appendix C.

PRELIMINARY RISK SCREENING

The additional groundwater data collected in 1996 indicated that PCE-impacted groundwater is migrating off site. To evaluate whether this impacted groundwater would have any health effect on the surrounding community, potential exposure pathways were evaluated. The following risk screening does not take into account the reduction in groundwater concentrations expected from the remedial action currently being implemented.

Potential exposure pathways include:

- Migration of soil vapors in the ambient air;
- Migration of soil vapors into buildings;
- Drinking water; and
- Surface water.

Migration of soil vapor into buildings is expected to create a greater risk than migration in the outdoor ambient air because a building allows accumulation of vapors and has a small ventilation rate compared to the outdoors. Therefore, we modeled the potential indoor air PCE concentration in a hypothetical building located just outside the proposed soil vapor extraction treatment area as a worse case scenario. A summary of the approach and results are presented below. Details of the modeling are presented in Appendix B.

We requested Ecology water well and water right records to assess the potential risk to downgradient groundwater receptors. The search was conducted within a one-mile radius of the site, except where the one-mile radius extends beyond the Lake Washington Ship Canal. There were no water wells or water rights found in the Ecology records that would be affected by groundwater migration from the former Tux Shop site.

Since there are no known drinking water supply wells downgradient of the site, the impacted groundwater does not currently pose a risk via a drinking water exposure. Furthermore, the groundwater is not a potential future source of drinking water since on-site pump test data indicate that the sustainable groundwater yield would be below the minimum criteria of 0.5 gallon per minute used under MTCA (WAC 173-340-720) to define potential drinking water.

Groundwater in the shallow water-bearing zone beneath the site flows toward the south, and we assume it ultimately discharges to the Ship Canal located approximately 1/2 mile south of the site. Therefore, we completed contaminant transport modeling to evaluate PCE concentrations potentially discharging to the Ship Canal under a conservative set of assumptions. A summary of the approach and results are presented below. Details of the groundwater modeling are presented in Appendix C.

Soil Vapor Migration to Adjacent Structures

For this exposure assessment, the analytical-solution, one-dimensional spreadsheet model by Johnson and Ettinger (see Appendix B) was used to predict the influx of subsurface contaminant vapors into buildings through cracks and seams in the building foundation. This model is based largely on predictive equations that were developed by other researchers to address influx of gaseous radon into residential dwellings. The general approach for the model is to assume that influx of vapors from a nearby contaminant source is governed by the following mechanisms:

- Vapors migrate upward from the contaminant source toward the region adjacent to the building foundation primarily by Fickian diffusion through the soil.

- After the vapors diffuse to the region adjacent to the foundation, they are then carried from the soil into the building by advective flow through foundation cracks.

- The model assumes that the influx of VOCs from the outdoor ambient air is negligible compared to the influx from the soil vapor under the building foundation.

As a worse case scenario, we assumed that the hypothetical building modeled would be located above SP-V2, on the former Tux Shop property.

For the parameters selected, the modeled indoor air concentration is 0.159 $\mu g/m^3$. In the scenario considered, this indoor concentration varies proportionally to the source concentration, the depressurization of the building, and the soil permeability, but is relatively insensitive to the percentage of cracks or seams in the floor, the soil porosity, moisture content, or density.

Groundwater Migration to Downgradient Receptors

To assess the potential risk at the Ship Canal, we completed contaminant transport modeling using EPA's Exposure Assessment Multimedia Model, Multimed (Salhotra et al., 1990), to evaluate PCE concentrations potentially discharging to the Ship Canal. The model simulates uniform one-dimensional groundwater flow with numerical dispersion in three dimensions. Sorption to the aquifer matrix was also considered in our evaluation. Conservative parameter assumptions were used in all cases where site-specific data were not available.

Detailed groundwater contaminant transport modeling methods and results are presented in Appendix C. Parameter assumptions were based on a combination of site-specific data where available, local hydrogeologic and meteorologic information, and selected literature values as presented in Appendix C. Assuming a starting PCE concentration of 100 mg/L at the source, the simulated maximum PCE concentration at the point of groundwater discharge to the Ship Canal was 0.004 mg/L (4 µg/L). This represents a concentration reduction of about 25,000 from the source area to the Ship Canal.

Given the conservatism in individual parameter assumptions used in this evaluation, the modeling is considered to be a conservative representation of actual transport conditions. Actual groundwater flow paths can be expected to be considerably more tortuous than represented with this one-dimensional model, which would create greater dispersion, dilution from recharge, and capacity for sorption, and, in turn, greater concentration reductions than predicted by the model.

Summary of Risk Screening

The risk from inhalation of PCE in adjacent off-site buildings was assessed by comparing modeled PCE concentrations in indoor air with MTCA Method B ambient air cleanup levels for PCE in accordance with MTCA (WAC 173-340-750). The calculated PCE ambient air cleanup levels are: for non-carcinogenic risks, 16 $\mu g/m^3$, and for carcinogenic risks is 0.172 $\mu g/m^3$ (see Appendix D). The modeled indoor PCE concentration is below both these cleanup levels. Therefore, no acute or chronic toxic effects are expected from inhalation of PCE in buildings adjacent to this site.

The maximum modeled concentration of PCE in groundwater discharging to the Ship Canal was below the Federal Ambient Water Quality Criteria for Consumption of Aquatic Organisms and the MTCA Method B cleanup level for Surface Water for Carcinogenic and

Non-carcinogenic risks (see Appendix D). Furthermore, although groundwater cleanup under MTCA does not allow use of surface water dilution to demonstrate compliance with surface water cleanup levels (WAC 173-340-720), in reality it is unlikely that any organisms inhabiting the Ship Canal would be exposed to the maximum modeled concentration of PCE in groundwater because of the dilution of the entering groundwater by the receiving water.

In conclusion, we believe the potential risk associated with the off-site migration of PCE-impacted groundwater to be very small. Furthermore, the expected cleanup of the on-site PCE groundwater plume within the next 3 years will reduce any long-term impacts from off-site migration of PCE.

MODIFICATIONS TO CLEANUP ACTION

The proposed cleanup action presented in our original notification addressed to Mr. Mike Gallagher of Ecology on December 12, 1995, consisted of an air sparging/soil vapor extraction system to remediate groundwater impacted by PCE. Originally, the system could have had two components: a source area system located near the former sump; and an optional downgradient system at the downgradient boundary of the site. The source area system would be installed beneath a planned Walgreens drug store building at the site. The optional downgradient system would be installed to address the migrating PCE plume as it migrated across the site boundary.

The recent site characterization results are generally consistent with our previous assessment of the site. However, groundwater flow measurements and groundwater quality data indicate that peak on-site PCE concentrations downgradient from the source area are actually at the south boundary of the site rather than at the east boundary as indicated by previous data. In fact the maximum PCE concentration at the east boundary decreased from 0.21 mg/L in September 1994 to 0.051 in April 1996. The highest downgradient PCE concentration at the south boundary is only 20 feet away from the proposed Walgreens building, which is significantly less than the 70 feet between the building and the east boundary. Therefore, we propose to increase the areal extent of the source area sparging/extraction system under the building and eliminate the optional downgradient sparging/extraction system. The expanded source area sparging/extraction system will address essentially all of the on-site groundwater contaminant plume.

The final plan and profile for the Air Sparging/Soil Vapor Extraction System are shown on Figure 7. Relative to our original plan, the number of sparge wells would be increased from 15 to 30 and the number of chimney vents from 8 to 12. We would also increase the sparging depth of the wells by 5 feet, to extend the sparging zone from 20 to 25 feet below the water table. These changes would ensure that the future sparging zone effectively addresses the on-site PCE plume. As originally proposed, ongoing monitoring will document the effectiveness of the cleanup action following startup of the system.

An additional modification to the cleanup action is the source control currently underway at the site as part of site development. We expect approximately 5,000 cubic yards to be excavated, of which about half will probably contain PCE. Based on stockpile testing results collected to date, site development excavation will probably remove about 50 pounds of PCE from the site, centered around the former sump (source) area. Soil designation for disposal is being conducted with Ecology oversight.

CLOSING STATEMENT

Site development activities at the site by Walgreens are currently underway, and we anticipate field mobilization for installation of the air sparging/soil vapor extraction system, beginning with installation of the sparge wells, in early September. We request that Ecology review and respond to this addendum with any comments you might have. We understand that your opinions are in no way binding and do not represent a settlement under MTCA. We would appreciate your response by August 23, 1996, so that this does not conflict with our aggressive cleanup schedule at the site.

If you have any questions, please call the undersigned.

Sincerely,

HART CROWSER, INC.

BARRY L. KELLEMS, P.E.
Associate

WILLIAM B. ABERCROMBIE
Principal

BLK/WBA:sca
L-072696.doc

cc: Martin Nudelman - The Tux Shops
Lynn Manolopoulus - Davis Wright Tremaine

Attachments:

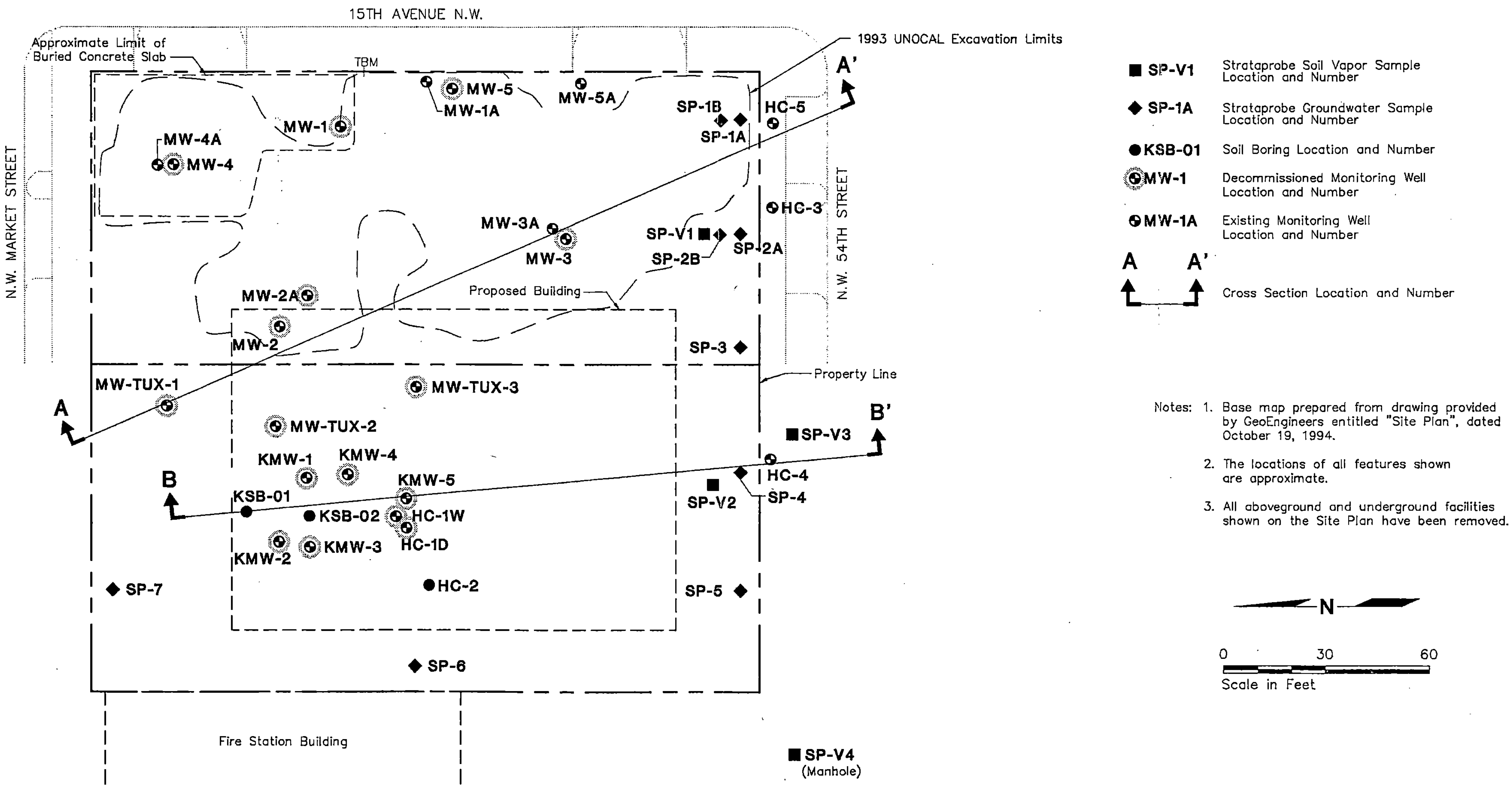
Table 1 - Summary of Tux Shop Ballard Groundwater Quality Data
Figure 1 - Site and Exploration Plan
Figure 2 - Summary of Tetrachloroethene Concentrations in Groundwater
Figure 3 - Groundwater Elevation Contour Map
Figure 4 - Generalized Subsurface Cross Section A-A'
Figure 5 - Generalized Subsurface Cross Section B-B'
Figure 6 - Tetrachloroethene Concentrations in Soil Vapor
Figure 7 - Final Plan and Profile of Air Sparging/Soil Vapor Extraction System
Appendix A - Boring Log and Construction Data for Monitoring Wells
Appendix B - Soil Vapor Migration Calculations
Appendix C - Groundwater Migration Calculations
Appendix D - Risk Screening Calculations

Table 1 - Summary of Tux Shop Ballard Groundwater Quality Data

Well ID	Screen Interval in ft.	Sample Date	Concentration in mg/L (ppm) PCE	TCE	1,2-DCE	1,1-DCE	CTet	VC
MW-Tux-1	6.5 - 18	Mar-91	0.0014	ND	ND	ND	ND	ND
		May-91	0.00071	ND	ND	ND	ND	ND
		Sep-94	0.081	ND	ND	ND	ND	ND
MW-Tux-2	8 - 13.5	Mar-91	32	0.052	0.026	ND	ND	ND
		May-91	DRY	DRY	DRY	DRY	DRY	DRY
		Sep-94	DRY	DRY	DRY	DRY	DRY	DRY
MW-Tux-3	6 - 16	Mar-91	17	ND	ND	ND	ND	ND
		May-91	30	ND	ND	ND	ND	ND
		Sep-94	7.6	0.16	ND	ND	ND	ND
KMW-1	10 - 20	Feb-94	1.2	0.01	ND	ND	ND	ND
		Sep-94	1.2	ND	ND	ND	ND	ND
KMW-2	10 - 20	Mar-94	0.69	0.001	ND	ND	ND	ND
		Sep-94	0.31	ND	ND	ND	ND	ND
KMW-3	10 - 20	Mar-94	1.8	0.003	ND	ND	0.005	ND
		Sep-94	13	ND	ND	ND	ND	ND
KMW-4	10 - 20	Mar-94	41	0.028	ND	ND	0.004	ND
		Sep-94	20	ND	ND	ND	ND	ND
KMW-5	10 - 20	Mar-94	62	0.18	ND	ND	ND	ND
		Sep-94	100	1.1	ND	ND	ND	ND
MW-1A	8 - 18	Sep-94	0.21	0.077	0.15	ND	ND	0.058
		Apr-96	0.0041	ND	ND	ND	ND	ND
MW-2A	8 - 18	Sep-94	0.88	0.0044	0.016	ND	ND	ND
		Apr-96	0.38	ND	0.024	ND	ND	ND
MW-3A	8 - 18	Sep-94	0.37	0.079	0.18	ND	ND	ND
		Apr-96	0.03	ND	ND	ND	ND	ND
MW-4A	8 - 18	Sep-94	ND	ND	ND	ND	ND	ND
		Apr-96	ND	ND	ND	ND	ND	ND
MW-5A	8 - 18	Sep-94	0.012	0.0047	0.056	ND	ND	ND
		Apr-96	0.051	0.018	0.11	ND	ND	ND
HC-1W	38 - 43	Dec-94	21	0.1	0.004	ND	ND	ND
		Jun-95	13	1	0.053	0.0034	ND	ND
		Jul-95	20	0.49	ND	ND	ND	ND
		Apr-96	26	0.42	0.033	ND	ND	ND
HC-1D	86.5 - 91.5	Jul-95	0.034	ND	ND	ND	ND	ND
		Apr-96	0.017	ND	ND	ND	ND	ND
	Blind Duplicate	Apr-96	0.022	ND	ND	ND	ND	ND
HC-3	6-16	May-96	0.25	0.0052	0.0095	ND	ND	ND
HC-4	15-25	Apr-96	23	ND	ND	ND	ND	ND
		May-96	21	ND	ND	ND	ND	ND
HC-5	15-25	Jun-96	1.8	ND	ND	ND	ND	ND
	Duplicate	Jun-96	2.1	ND	ND	ND	ND	ND
SP-1A	8 - 15	Mar-96	0.0087	0.0011	0.0033	ND	ND	ND
SP-1B	7 - 9	Mar-96	0.0031	ND	ND	ND	ND	ND
SP-2B	8 - 12	Mar-96	0.16	0.0063	0.01	ND	ND	ND
SP-3	7 - 10	Apr-96	0.048	ND	ND	ND	ND	ND
SP-4	8 - 10	Apr-96	0.074	0.0011	ND	ND	ND	ND
SP-5	8 - 10	Apr-96	0.059	ND	ND	ND	ND	ND
SP-6	12 - 15	Apr-96	8.9	0.0088	0.0045	ND	ND	ND
SP-7	13 - 15	Apr-96	ND	ND	ND	ND	ND	ND

Notes:
Samples analyzed using EPA Method 8010/8240.
PCE - Tetrachloroethylene
TCE - Trichloroethylene
DCE - Dichloroethylene
CTet - Carbon Tetrachloride
VC - Vinyl Chloride
ND - Not Detected

Site and Exploration Plan



Notes:
1. Base map prepared from drawing provided by GeoEngineers entitled "Site Plan", dated October 19, 1994.
2. The locations of all features shown are approximate.
3. All aboveground and underground facilities shown on the Site Plan have been removed.

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Figure 1

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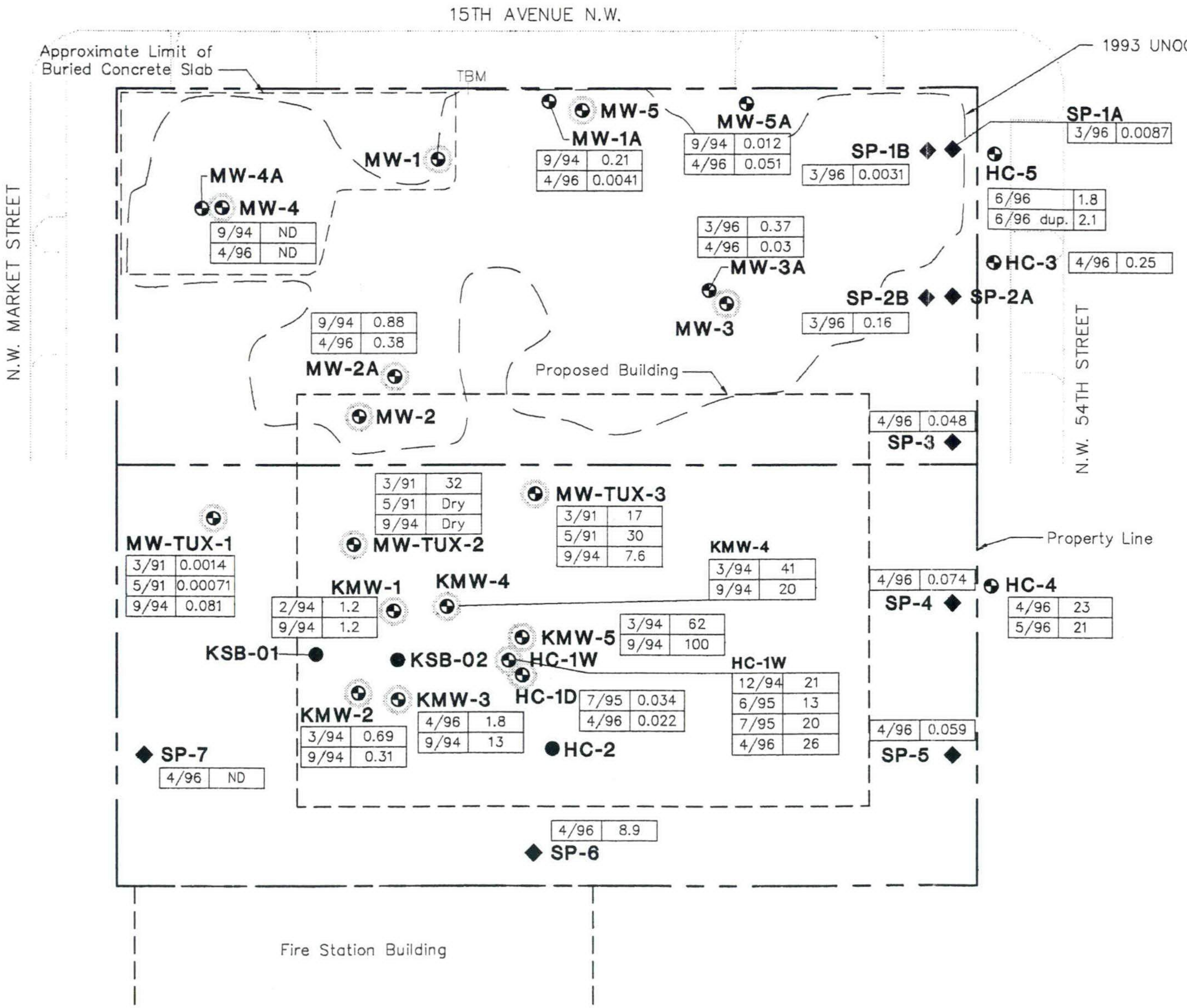
Summary of Tetrachloroethene Concentrations in Groundwater
Through June 1996



◆ SP-1A — Strataprobe Groundwater Sample Location and Number

● KSB-01 — Soil Boring Location and Number

MW-1 — Decommissioned Monitoring Well Location and Number

MW-1A — Existing Monitoring Well Location and Number

3/96 | 0.0031 — Month/Year; Concentration in mg/L

ND — Not Detected

Notes:
1. Base map prepared from drawing provided by GeoEngineers entitled "Site Plan", dated October 19, 1994.
2. The locations of all features shown are approximate.
3. All aboveground and underground facilities shown on the Site Plan have been removed.

N

0 30 60
Scale in Feet

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Figure 2

CVD 7/31/96 1=30 HC.pcp
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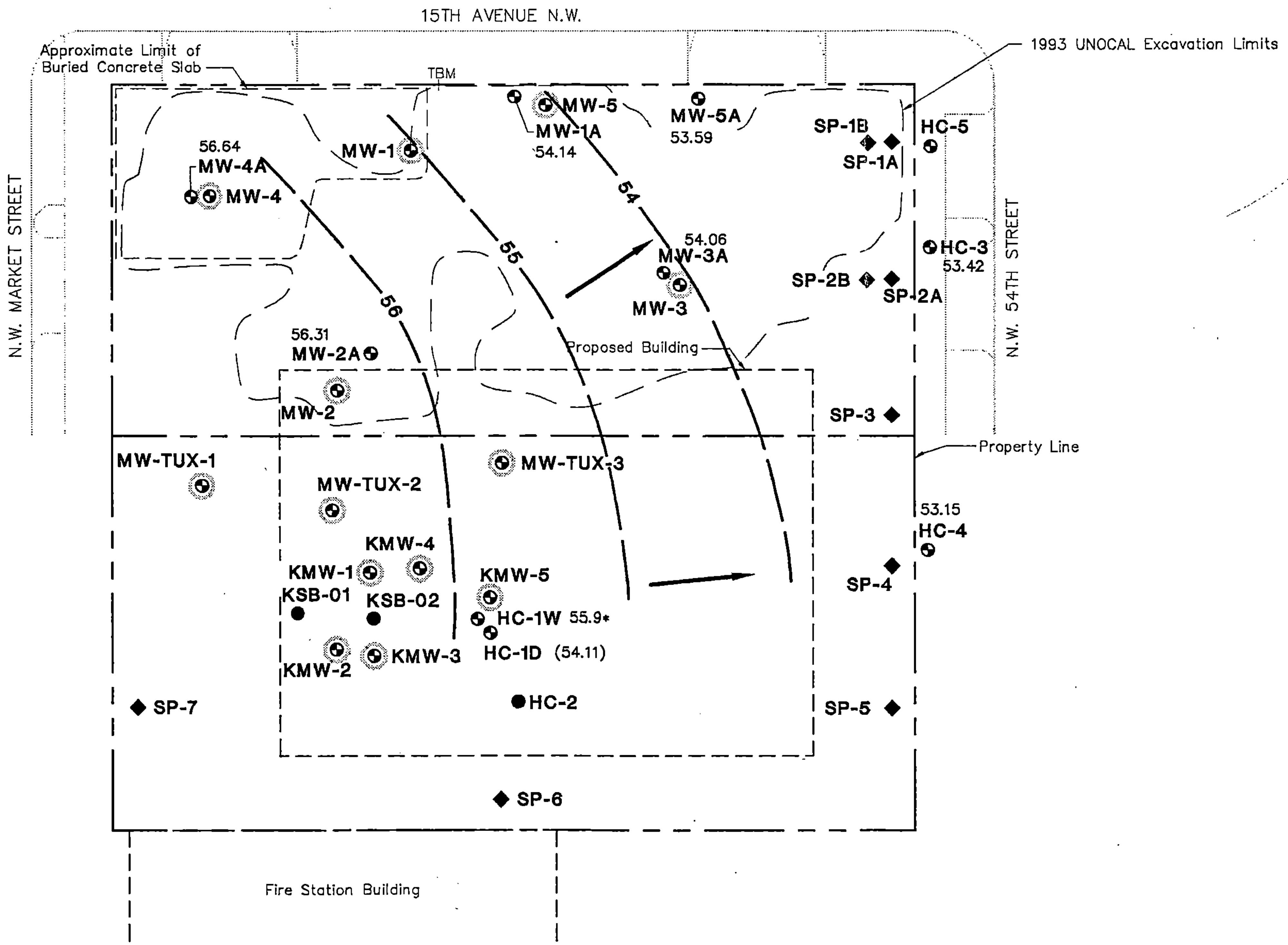
Groundwater Elevation Contour Map
May 15, 1996



◆ SP-1A	Strataprobe Groundwater Sample Location and Number
● KSB-01	Soil Boring Location and Number
MW-1	Decommissioned Monitoring Well Location and Number
MW-1A	Existing Monitoring Well Location and Number
56.31	Groundwater Elevation in Feet
(54.11)	Groundwater Elevation in Feet (not used in contouring)
—54—	Groundwater Elevation Contour in Feet
——→	Generalized Groundwater Flow Direction
*	Groundwater elevation estimated to be about 55.9 at a depth of 25', based on the vertical gradient between HC-1W and HC-1D.

Notes:
1. Base map prepared from drawing provided by GeoEngineers entitled "Site Plan", dated October 19, 1994.
2. The locations of all features shown are approximate.
3. All aboveground and underground facilities shown on the Site Plan have been removed.

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Figure 3

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Generalized Subsurface Cross Section A-A'

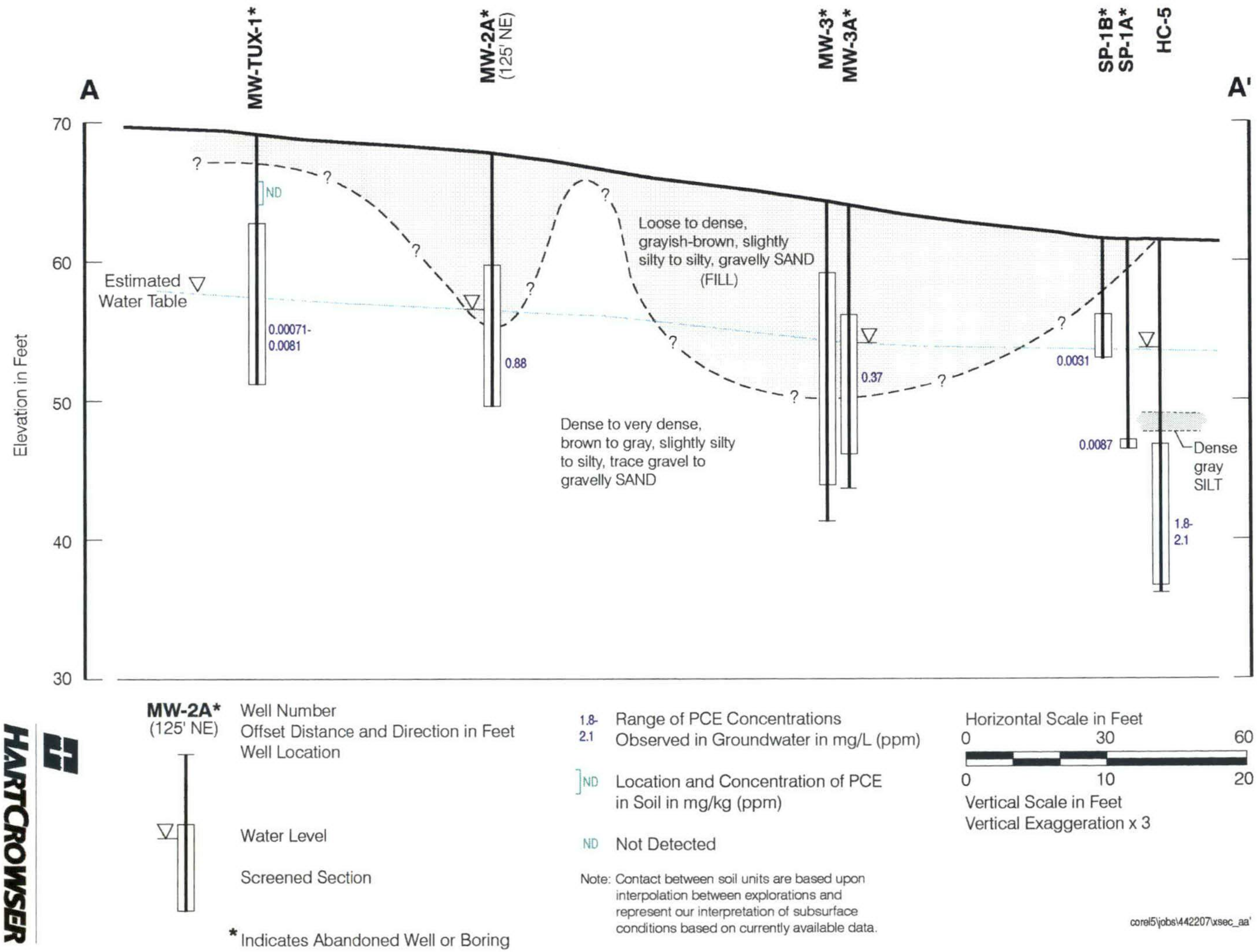

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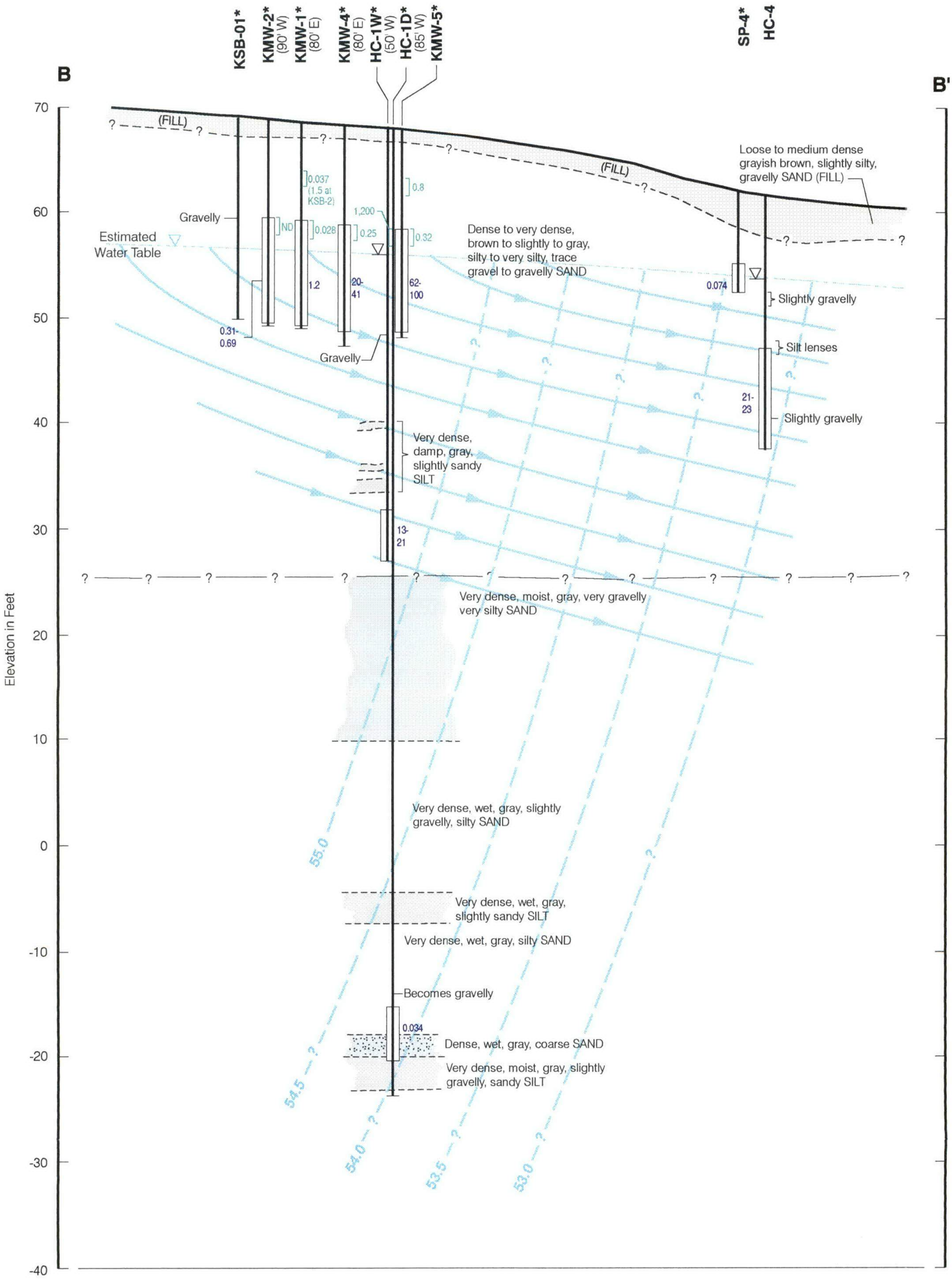
Figure 4

Generalized Subsurface Cross Section B-B'



KMW-2* (90' W) — Exploration Number; Offset Distance and Direction in Feet; Exploration Location

Water Level

Screened Section

*Indicates abandoned well or boring

13-21 — Range of PCE Concentrations Observed in Groundwater in mg/L(ppm)

]0.8 — Location and Concentration of PCE in Soil in mg/kg(ppm)

ND — Not Detected

Estimated flow Net (Based on groundwater elevations on May 15, 1996)

Horizontal Scale in Feet: 0 30 60

Vertical Scale in Feet: 0 10 20

Vertical Exaggeration x 3

Note: Contact between soil units are based upon interpolation between explorations and represent our interpretation of subsurface conditions based on currently available data.

core5\jobs\442207\xsec_bb'

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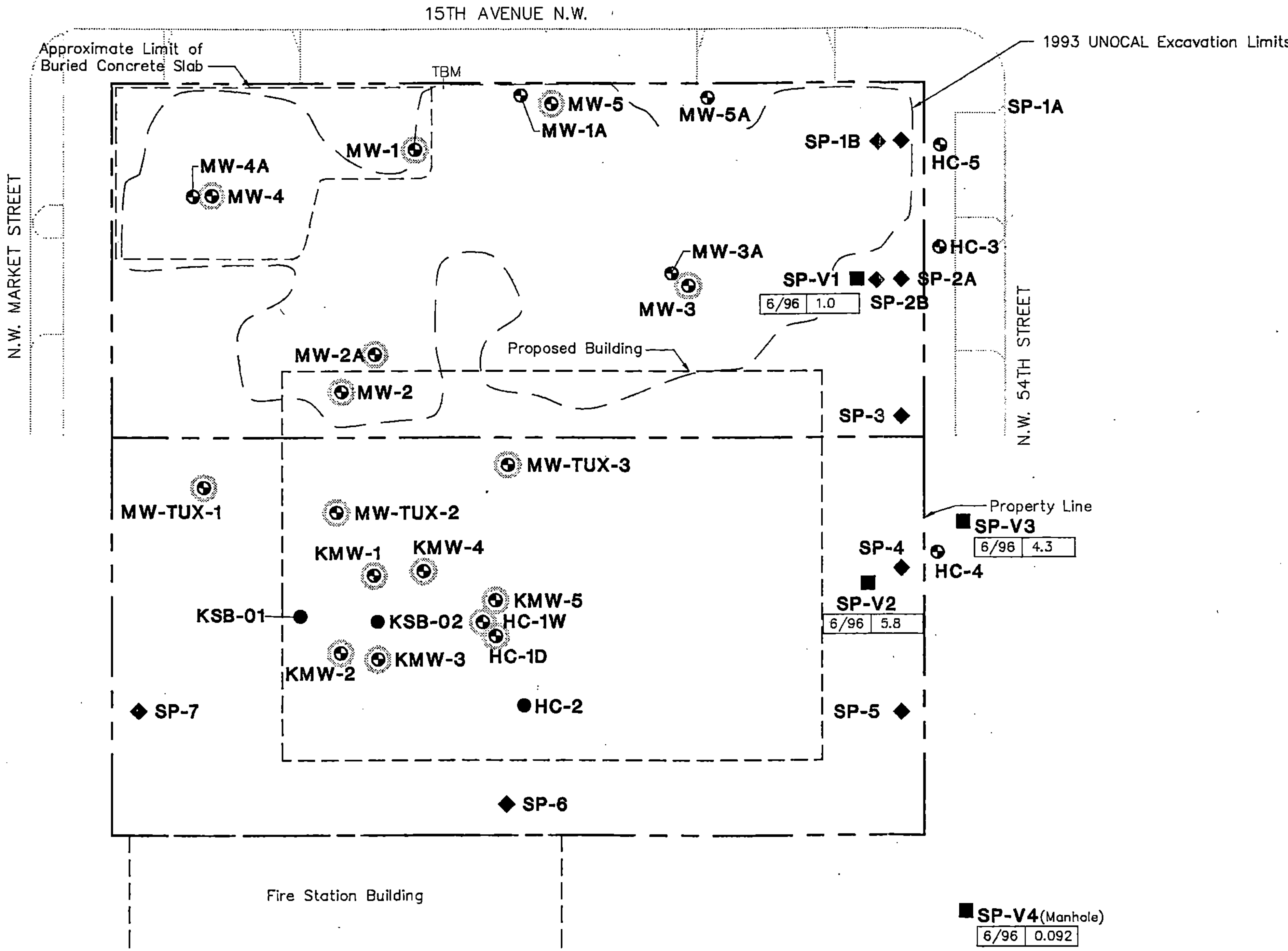
Figure 5

Tetrachloroethene Concentrations in Soil Vapor

June 1996



- ■ **SP-V1** Strataprobe Soil Vapor Sample Location and Number
- ◆ **SP-1A** Strataprobe Groundwater Sample Location and Number
- ● **KSB-01** Soil Boring Location and Number
- **MW-1** Decommissioned Monitoring Well Location and Number
- **MW-1A** Existing Monitoring Well Location and Number

6/96	1.0

Month/Year — Concentration in ppm

Notes:
1. Base map prepared from drawing provided by GeoEngineers entitled "Site Plan", dated October 19, 1994.
2. The locations of all features shown are approximate.
3. All aboveground and underground facilities shown on the Site Plan have been removed.
4. To convert concentrations from ppm to mg/m^3, multiply by 6.89.

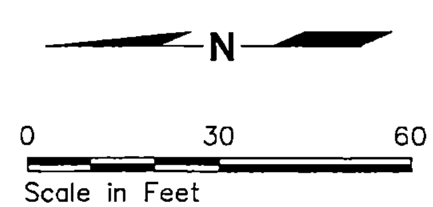


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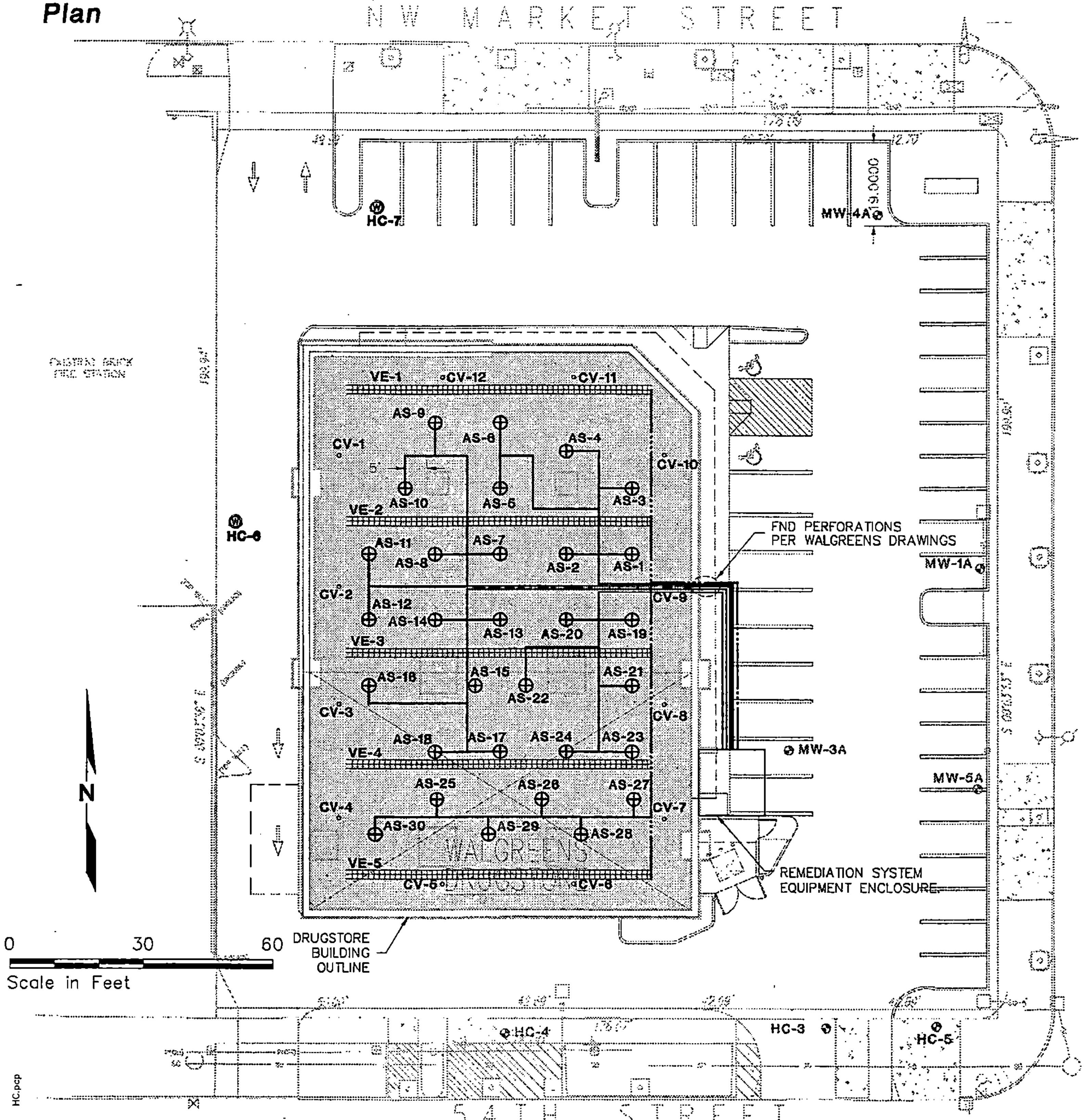
Figure 6

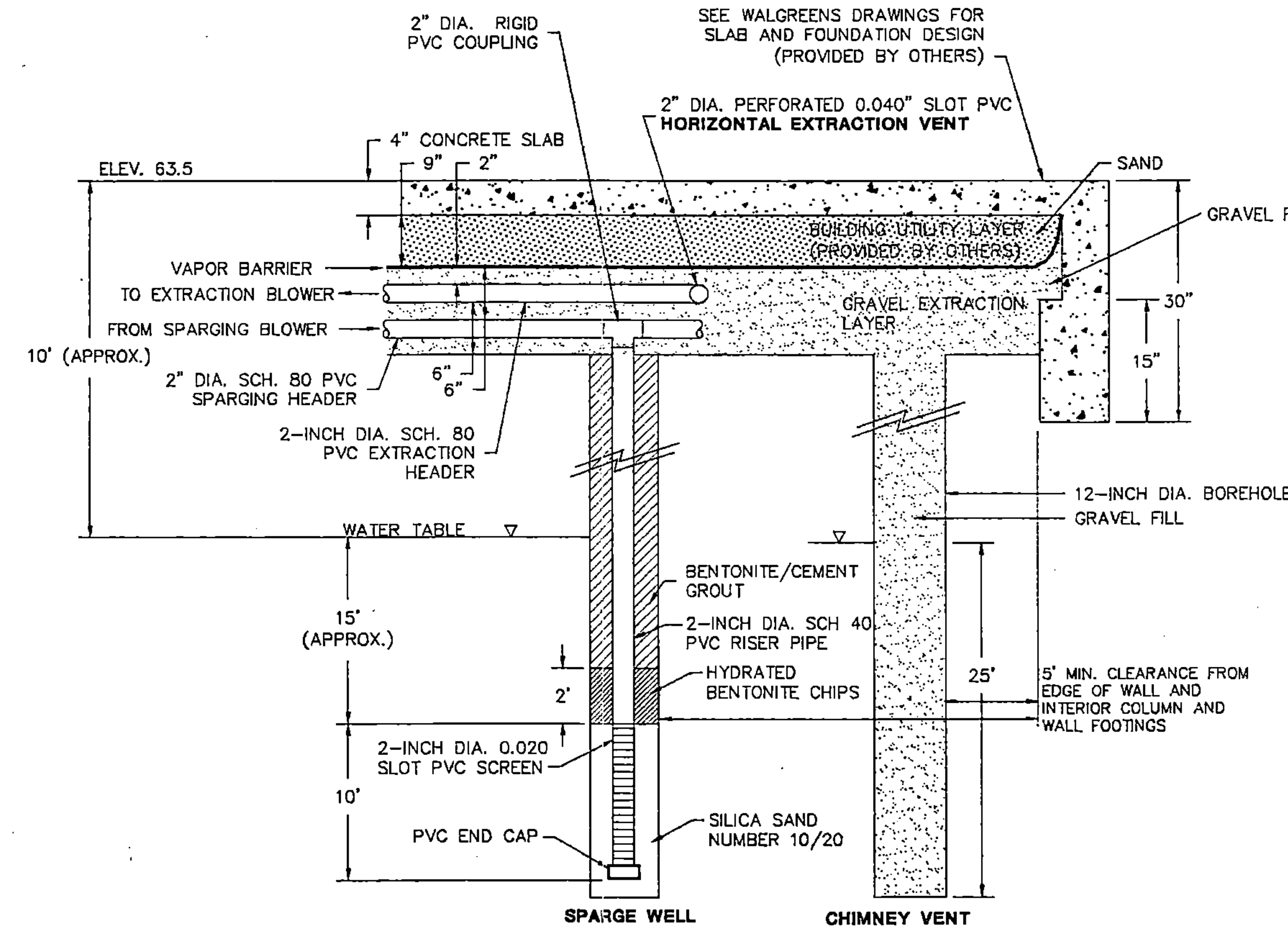
CVD 7/31/96 1=30 HC.pcp
44220703

Final Plan and Profile of Air Sparging/Soil Vapor Extraction System

Plan



Profile



NOT TO SCALE

Symbols

———	SPARGE HEADER	AS-1 THROUGH AS-30 ⊕	SPARGE WELL (30)
—··—··—	EXTRACTION HEADER	CV-1 THROUGH CV-12 °	CHIMNEY VENT (12)
VE1 THROUGH VE-5	HORIZONTAL EXTRACTION VENT	HC-6 AND HC-7	NEW MONITORING WELL (2)

- GRAVEL EXTRACTION LAYER
- MW-4A — EXISTING MONITORING WELL TO BE SAVED
- FOUNDATION FOOTING PER WALGREENS DRAWINGS

SWP 8/8/96 4422070 1=30 HC.pcp

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J-4422-07 8/96

Figure 7

APPENDIX A
BORING LOG AND CONSTRUCTION DATA FOR MONITORING WELLS

Key to Exploration Logs

Sample Description

Classification of soils in this report is based on visual field and laboratory observations which include density/consistency, moisture condition, grain size, and plasticity estimates and should not be construed to imply field nor laboratory testing unless presented herein. Visual-manual classification methods of ASTM D 2488 were used as an identification guide.

Soil descriptions consist of the following:
Density/consistency, moisture, color, minor constituents, MAJOR CONSTITUENT, additional remarks.

Density/Consistency

Soil density/consistency in borings is related primarily to the Standard Penetration Resistance.
Soil density/consistency in test pits is estimated based on visual observation and is presented parenthetically on the test pit logs.

SAND or GRAVEL Density	Standard Penetration Resistance (N) in Blows/Foot	SILT or CLAY Consistency	Standard Penetration Resistance (N) in Blows/Foot	Approximate Shear Strength in TSF
Very loose	0 – 4	Very soft	0 – 2	<0.125
Loose	4 – 10	Soft	2 – 4	0.125 – 0.25
Medium dense	10 – 30	Medium stiff	4 – 8	0.25 – 0.5
Dense	30 – 50	Stiff	8 – 15	0.5 – 1.0
Very dense	>50	Very stiff	15 – 30	1.0 – 2.0
		Hard	>30	>2.0

Moisture

Dry	Little perceptable moisture
Damp	Some perceptable moisture, probably below optimum
Moist	Probably near optimum moisture content
Wet	Much perceptable moisture, probably above optimum

Minor Constituents

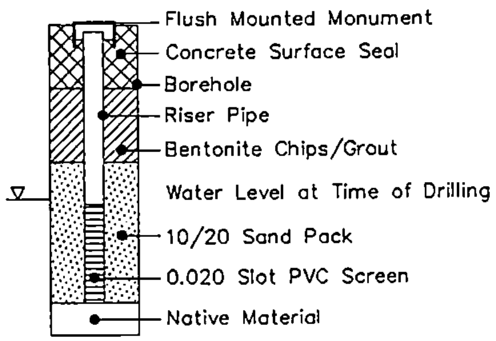
	Estimated Percentage
Not identified in description	0 – 5
Slightly (clayey, silty, etc.)	5 – 12
Clayey, silty, sandy, gravelly	12 – 30
Very (clayey, silty, etc.)	30 – 50

Legends

Sampling Test Symbols

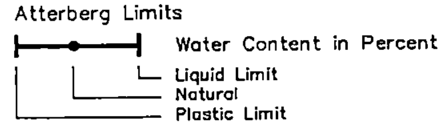
BORING SAMPLES	TEST PIT SAMPLES
⊠ Split Spoon	⊠ Grab (Jar)
Shelby Tube	Shelby Tube
Cuttings	Bag
Core Run	
* No Sample Recovery	
P Tube Pushed, Not Driven	

Groundwater Observations



Test Symbols

GS	Grain Size Classification
CN	Consolidation
TUU	Triaxial Unconsolidated Undrained
TCU	Triaxial Consolidated Undrained
TCD	Triaxial Consolidated Drained
QU	Unconfined Compression
DS	Direct Shear
K	Permeabilty
PP	Pocket Penetrometer Approximate Compressive Strength in TSF
TV	Torvane Approximate Shear Strength in TSF
CBR	California Bearing Ratio
MD	Moisture Density Relationship
AL	Atterberg Limits
PID	Photoionization Reading
CA	Chemical Analysis



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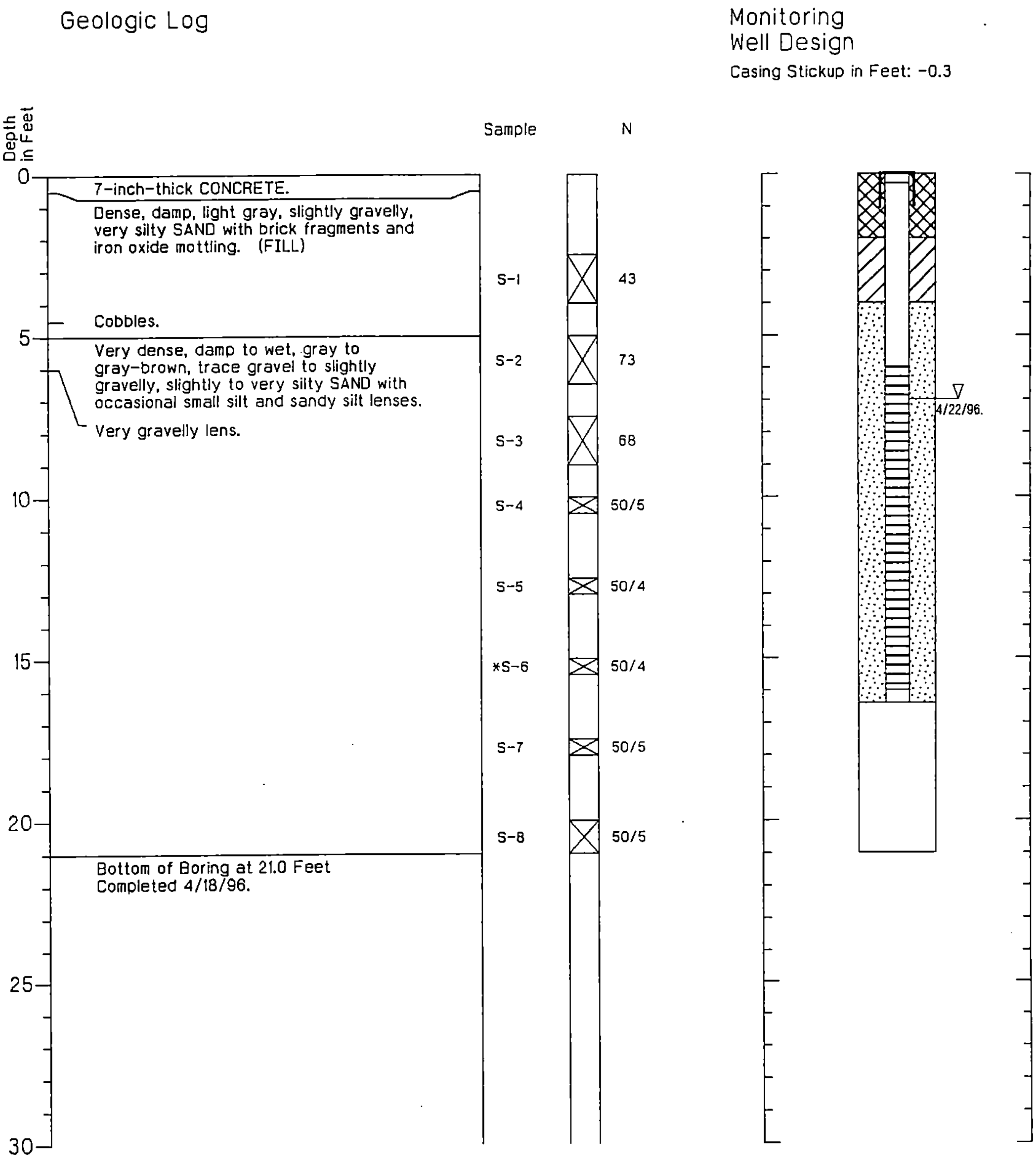
J-4422-07 8/96

Figure A-1

a-1 key 6 1=1 hc.pcp

Boring Log and Construction Data for Monitoring Well HC-3



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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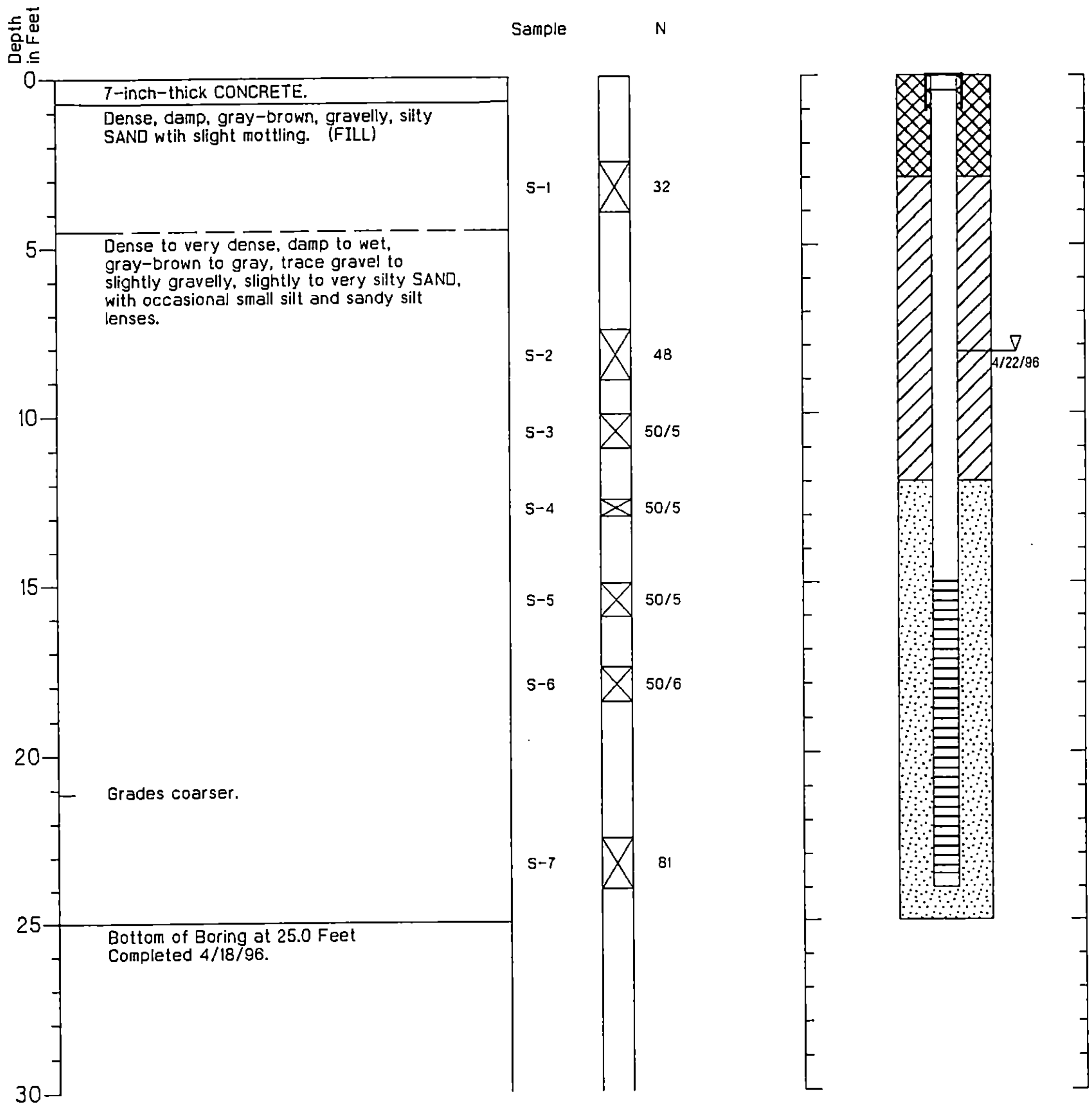
J-4422-07 5/96
Figure A-2

Boring Log and Construction Data for Monitoring Well HC-4

Geologic Log

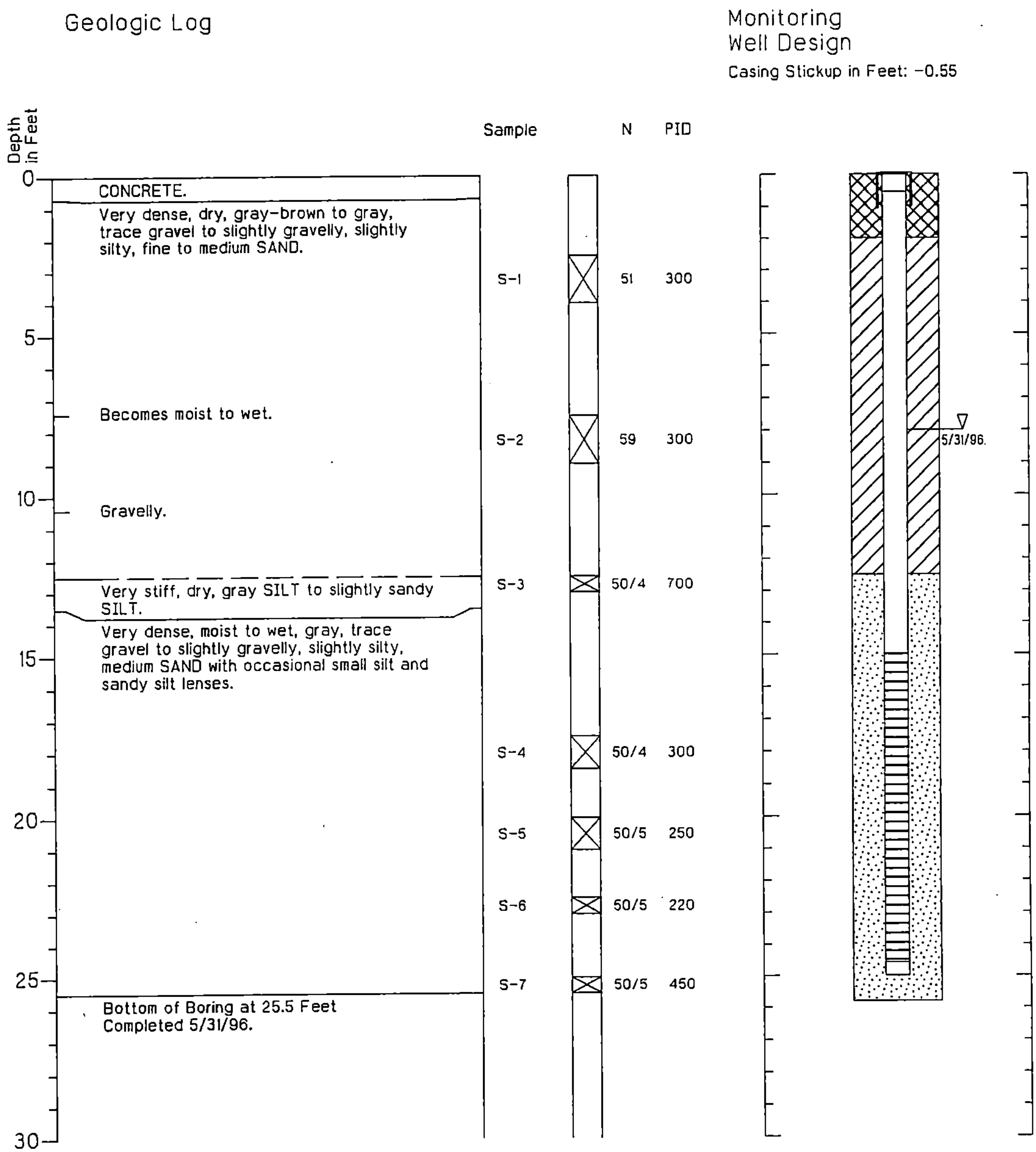
Monitoring
Well Design
Casing Stickup in Feet: -.44



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER
J-4422-07 5/96
Figure A-3

Boring Log and Construction Data for Monitoring Well HC-5



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

HARTCROWSER

J-4422-07 5/96

Figure A-4

APPENDIX B
SOIL VAPOR MIGRATION CALCULATIONS

APPENDIX B
SOIL VAPOR MIGRATION CALCULATIONS

The concentrations of VOC vapors that could potentially accumulate in off-site buildings were modeled by assuming that subsurface vapors enter the building through cracks and seams in the foundation. The methods used to model the indoor concentrations are described in the following sections.

Basis of Model

For the former Tux Shop site exposure assessment, the analytical-solution, one-dimensional spreadsheet model by Johnson and Ettinger (1991) was used to predict the influx of subsurface contaminant vapors into buildings through cracks and seams in the building foundation. This model is based largely on predictive equations that were developed by other researchers to address influx of gaseous radon into residential dwellings. The general approach for the model is to assume that influx of vapors from a nearby contaminant source is governed by the following mechanisms:

- Vapors migrate upward from the contaminant source toward the region adjacent to the building foundation primarily by Fickian diffusion through the soil. The diffusive flux is limited by the vapor diffusivity of the VOC and by the tortuosity of the soil through which the VOC diffuses. The tortuosity is incorporated into the model based on the soil bulk density, the total porosity, and the soil moisture content, using the method of Millington and Quirk (Bruell and Hoag, 1986). This upward diffusion process is the rate-limiting step.

- After the vapors diffuse to the region adjacent to the foundation, they are then carried from the soil into the building by advective flow through foundation cracks. The advective flow rate is governed by the percentage area of the foundation that is open because of cracks or seams, the soil permeability, and the relative pressure difference between the soil vapor and the indoor air (referred to as the "building underpressurization"). The advective flow is generally much faster than the Fickian diffusion step. In that case, all of the vapor that diffuses to the base of the foundation will eventually be carried by advective flow into the building.

- The model assumes that the influx of VOCs from the outdoor ambient air is negligible compared to the influx from the soil vapor under the building foundation.

Nazaroff et al. (1985) measured the time-variant concentration profiles of radon gas in a residential house with a basement. They concluded that the influx of radon into the basement was governed by both diffusive flow and advective flow from the soil. The advective flow rate was dependent on the building underpressurization. Nazaroff et al. (1987) measured the influx of tracer gases into a residential basement and correlated the influx to the building underpressurization. They presented simplified equations derived from ASHRAE (1985) for prediction of the building underpressurization.

Nazaroff (1988) utilized a simplified analytical expression for advective flow through an infinite-length crack in the foundation, to estimate the rate of accumulation of radon gas in buildings. The predicted advective flow is governed by the soil permeability and the relative building underpressurization, which can be estimated from ASHRAE (1985). As a simplification, it is assumed that the cracks are filled with soil that has the same permeability as the vadose zone soil under the building. A description of the estimated modeled building underpressurization is given below.

Hodgson et al. (1988) measured the indoor air concentrations of toxic VOCs in a residential dwelling that was exposed to subsurface vapors from a nearby landfill. They then injected tracer gases into the soil surrounding the house and measured the influx of the tracer gases into the house during periods of induced building underpressurization. They concluded that, during periods of strong underpressurization, advective flow is the predominant transport mechanism. However, during periods with weak underpressurization, the influx into the building was limited by diffusive flow and was low enough to be of no significant concern.

Modeled Building Underpressurization

The ASHRAE (1985) equations are used in the heating, ventilation, and air conditioning industry to estimate building underpressurization, to assess the leakage of ambient air into buildings for design of heating systems. Building underpressurization can be caused by two meteorological effects:

- Wind blowing across a building creates a small hydrostatic pressure (or vacuum) on the downwind side of the building. For the Tux Shop assessment, it was assumed that the annual-average wind speed (at a 10-meter anemometer height) is 5.2 knots, based on National Weather Service data for Sea-Tac airport.

- If the average temperature inside the building is higher than the outdoor temperature, then a "chimney effect" can result inside the building.

Warm air in the building rises and leaks out at the roof, with the net effect of causing a relative vacuum at the building floor. The vacuum can cause outdoor air and soil vapor to enter the building through openings in the foundation. For this assessment, it was assumed that the annual-average indoor and outdoor temperatures are 70° F and 51° F, respectively. The mean outdoor temperature was derived from National Weather Service data for Sea-Tac airport.

For this assessment, we modeled a residential building with basement, that is 10 meters by 10 meters in size, with a 6.5-meter height. The predicted building underpressurizations by wind effect (P_W) and temperature effect (P_T) are as follows:

$$P_W = \frac{1}{2} C_F \varrho_a V_W^2$$

where:

C_F = 0.30 coefficient for typical buildings
ϱ_a = air density = 1.2 kg/m^3
V_W = wind speed = 1.92 m/sec

$$P_W = \frac{1}{2} (0.30)(1.2)(1.92)^2 = 0.66 \textit{ Pascals}$$

$$P_T = C_F P_a (\tfrac{1}{2} H) \left[\frac{1}{T_0} - \frac{1}{T_1} \right]$$

where:

C_F = 0.52 proportionality constant
P_a = ambient pressure = 14.7 psi
H = building height = 21.4 feet
T_0 = outside temperature = 51° F = 511° R
T_1 = inside temperature = 70° F = 530° R

$$P_T = (0.52)(14.7)(\tfrac{1}{2})(21.4) \left[\frac{1}{511} - \frac{1}{530} \right] = 0.0057 \textit{ inch } H_2O = 1.41 \textit{ Pascals}$$

Total Building Underpressurization = $P_W + P_T$
= 0.66 + 1.41
= 2.07 Pascals
= 0.008 inch H_2O

Estimates of Subsurface/Indoor Dilution Ratios

The influx of subsurface vapors through foundation cracks was predicted using a spreadsheet model based on the equations from Johnson and Ettinger (1991). The output of the model is the Indoor Dilution Ratio, which is the ratio of the diluted indoor air concentration to the subsurface vapor concentration at the contaminant source.

The model requires the user to input many parameters for the building properties and soil properties. Table B-1 summarizes the parameters that were assumed. The assumptions used for the parameters are as follows:

- The air exchange rate represents an "average" value for 134 houses in the Pacific Northwest, measured during a heating season (ASHRAE, 1993). This is a conservative assumption as increased ventilation, associated with open windows in the summer, will reduce indoor contaminant concentrations.
- The mean wind speed and outdoor temperature used to calculate the building underpressurization were based on National Weather Service data for Sea-Tac airport.
- The vapor diffusivities were taken from the IRIS database.
- The bulk soil density assumption of 1.8 gm/cc is an estimate based on engineering judgement and observation of soil samples from the site.
- The soil moisture range was based on measured values for stockpiled soil excavated during construction at the site.
- The assumed percentage of cracks and seams in the basement was based on the average of two values measured by Nazaroff et al. (1987) in buildings with a full basement with poured concrete floor and walls.
- The assumed vertical soil permeability was based on engineering judgment and is consistent with data provided by Johnson and Ettinger (1991).
- As a worse case estimate, the building was assumed to be located over boring SP-2, on the former Tux Shop property as shown on Figure 6 in the main text. The PCE soil vapor concentration measured in boring SP-2 was used in the model as source concentration located at a depth of 5 feet (1.52 meter). This is a very conservative estimate since no building other than the Walgreens drugstore is planned on the site. In

addition, the remediation system installed under the Walgreens drugstore will reduce soil vapor PCE concentrations in the vicinity.

Table B-1 present the calculated dilution ratio for PCE.

Results of Indoor Air Exposure Calculations

Table B-1 shows the modeled indoor air PCE concentrations in the hypothetical basement located over boring SP-2. For the parameters selected, this indoor air concentration varies proportionally to the source concentration, the depressurization of the building, and the soil permeability, but is relatively insensitive to the percentage of cracks or seams in the basement, the soil porosity, moisture content, or density. In this scenario, the modeled indoor air PCE concentration is below the MTCA Method B cleanup level as shown in Appendix D.

References for Appendix B

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Table B-1
Hypothetical Indoor Air PCE Concentration

Based on "Heuristic Model for Predicting the Intrusion Rate of Contaminant Vapors Into Buildings", P.C. Johnson and R.A. Ettinger, Env. Sci and Technology, Vol 25, 1991.

FOUNDATION PARAMETERS

Length of Foundation	10.0	m
Width of Foundation	10.0	m
Depth of Foundation	1.50	m
Building Height	6.5	m
Thickness of Foundation	0.15	m
Percentage of Foundation That is Cracks	0.04	%
Building Ventilation Flow Rate	0.07	m^3/sec
Air Exchange Rate	0.40	per hour
Characteristic Indoor-Outdoor Pressure Difference	2.07	Pa
Distance Between Source and Foundation	0.02	m

CONTAMINANT PARAMETERS — Perchloroethylene

Vapor Concentration at the Source	30	mg/m^3
Molecular Diffusivity in Water	1.00E-05	cm^2/s
Molecular Diffusivity in Air	0.087	cm^2/s
Vapor Viscosity	1.80E-04	g/cm^s

SOIL PARAMETERS

Moisture Content of Soil	10.1	%
Bulk Soil Density	1.8	Mg/m^3
Total Soil Porosity	35	%
Soil Permeability to Vapor Flow	1.0E-13	m^2

CALCULATED BUILDING AIR CONCENTRATIONS

Building Concentration =	1.59E-04	mg/m^3
OSHA PEL (8-hr Weighted Average) =	170	mg/m^3
10^-6 Cancer Risk Acceptable Concentration =	1.72E-04	mg/m^3
Indoor Air Dilution Ratio (alpha) =	5.35E-06	

APPENDIX C
GROUNDWATER MIGRATION CALCULATIONS

APPENDIX C
GROUNDWATER MIGRATION CALCULATIONS

There are no known drinking water supply wells downgradient of the site, indicating that site groundwater poses no risk via a drinking water exposure. Groundwater in the shallow water-bearing zone beneath the site flows toward the south, and we assume it ultimately discharges to the Ship Canal located approximately 1/2 mile south of the site. We completed contaminant transport modeling to evaluate PCE concentrations potentially discharging to the Ship Canal under a conservative set of assumptions. The simulated maximum concentration discharging to the Ship Canal provides a highly conservative assessment of potential risk to surface water in the Ship Canal, as discussed in Appendix D of this report. The modeling approach, input assumptions, and results are described below.

Modeling Approach and Assumptions

EPA's Exposure Assessment Multimedia Model, Multimed (Salhotra et al., 1990), was used for this evaluation. Multimed is a repackaged version of the analytical contaminant transport model used by EPA to calculate dilution/attenuation factors (DAFs) in development of the TCLP regulations (FR 55 11816). The DAF is equivalent to the concentration reduction occurring in groundwater between the site and a downgradient location, in this case the Ship Canal. Only the saturated zone module of the model was used for this evaluation. The model simulates uniform one-dimensional groundwater flow with numerical dispersion in three dimensions. Sorption to the soil matrix was also considered in this evaluation.

Parameter assumptions were based on a combination of site-specific data where available, local hydrogeologic and meteorologic information, and selected literature values. Table C-1 provides a listing of the parameter values (note that parameters with values of -999 were not used in the model). The parameter assumptions are summarized below.

Chemical-Specific Parameters

- No decay, biodegradation, hydrolysis, or diffusion to air was considered in the model. Experiments indicate that PCE undergoes hydrolysis with a half life of about 9 months (Montgomery, 1996). Considering that transport times to the Ship Canal will be on the order of decades, exclusion of hydrolysis from this evaluation is a conservative assumption.

- The partition (distribution) coefficient for PCE with respect to organic carbon (K_{oc}) was assumed to be 350 L/kg based on literature values. This value is an average of eight values reported in Cohen and Mercer (1993), Fetter (1993), Jeng et al. (1992), and Montgomery (1996).

Source-Specific Parameters

- The source area was assumed to be 100 m^2 (roughly 30 by 30 feet) based on the distribution of the highest PCE concentrations in site groundwater and assuming the former sump is the most likely source.

- The concentration of leachate (the source) entering the saturated zone was set at 102 mg/L, such that the resulting concentration in the saturated zone at the source was 100 mg/L. The rate and duration of leachate infiltration to the saturated zone was conservatively assumed to be 1 m/yr continuously for 15 years.

- Recharge downgradient of the source area was assumed to be 0.1 m/yr (4 in./yr). Average annual precipitation is 38.5 in./yr at Sand Point in Seattle (NOAA, 1995). Assuming that 75 percent of precipitation runs off in commercial/industrial areas (van der Leeden et al., 1990) like that downgradient of the site, and that 57 percent of the residual water is lost to evapotranspiration (Washington State University, 1968), indicates that approximately 11 percent of precipitation (or 4 in./yr) is available for groundwater recharge.

Aquifer-Specific Parameters

- Hydraulic conductivity (K) was assumed to be 1 x 10^{-4} cm/sec (32 m/yr), based on available data. A recovery test conducted in site monitoring well HC-1W provided an estimated K of 1 x 10^{-5} cm/sec. A pumping test conducted at a site four blocks away (Leary and Market streets) provided an estimated K of 8 x 10^{-4} cm/sec. A K of 1 x 10^{-4} cm/sec is the approximate geometric mean of the available estimates and was chosen as a reasonable conservative value for this simulation.

- Hydraulic gradient was assumed to be 0.04 ft/ft, based on water table elevation contour maps from the site at four different times (August 1990, March 1992, September 1994, and May 1996).

- Effective porosity and bulk density for the saturated zone were assumed to be 0.2 (dimensionless) and 1.6 g/cm^3, based on literature values (e.g., Freeze and Cherry, 1979; Sharp-Hansen et al., 1990).

- Thickness of the saturated zone was assumed to be 75 feet (23 m), based on geologic conditions encountered beneath the site.

- Longitudinal, transverse, and vertical dispersion were derived by the model using the model's default method (empirically derived relationships based on distance from the source to the Ship Canal; refer to Salhotra et al, 1990).

- Organic carbon content (f_{oc}) of the saturated zone was assumed to be 0.0016, which was the average of the values measured from three samples of soil from the shallow saturated zone beneath the site. Table C-2 lists the three site-specific f_{oc} measurements.

- Distance to the Ship Canal was set as 800 m (2,600 ft), and concentrations were evaluated at the water table directly downgradient of the source (most conservative). Concentrations below the water table and/or not directly in line along the groundwater flow direction would be lower than the reported model results.

All other model parameters were derived by the model using its default assumptions (Table C-1).

Modeling Results

The simulated maximum PCE concentration at the point of groundwater discharge to the Ship Canal was 0.0039 mg/L (3.9 μg/L). This represents a concentration reduction (a DAF) of about approxiamtely 25,000 from the source area to the Ship Canal.

The modeling is considered to be a conservative representation of actual transport conditions. Actual groundwater flow paths can be expected to be considerably more tortuous than represented with this one-dimensional model, which would create greater dispersion, dilution from recharge, and capacity for sorption, and, in turn, greater concentration reductions than predicted here.

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Table C-1 - Multimed Input Parameters and Result

U.S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.01, June 1991)

1

Run options

--- -------

Simulation of PCE Transport to the Ship Canal
Tux Shop
Chemical simulated is PCE

Option Chosen Saturated zone model
Run was DETERMIN
Infiltration input by user
Run was transient
Reject runs if Y coordinate outside plume
Do not reject runs if Z coordinate outside plume
Gaussian source used in saturated zone model

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Solid phase decay coefficient	1/yr	DERIVED	-999	-999	0.00E+00	1.00E+10
Dissolved phase decay coefficient	1/yr	DERIVED	-999	-999	0.00E+00	1.00E+10
Overall chemical decay coefficient	1/yr	DERIVED	-999	-999	0.00E+00	1.00E+10
Acid catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.00E+00	-999	0.00E+00	-999
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.00E+00	-999	0.00E+00	-999
Base catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.00E+00	-999	0.00E+00	-999
Reference temperature	C	CONSTANT	25	-999	0.00E+00	100
Normalized distribution coefficient	ml/g	CONSTANT	350	-999	0.00E+00	-999
Distribution coefficient	--	DERIVED	-999	-999	0.00E+00	1.00E+10
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.00E+00	-999	0.00E+00	-999
Air diffusion coefficient	cm2/s	CONSTANT	0.00E+00	-999	0.00E+00	10
Reference temperature for air diffusion	C	CONSTANT	25	-999	0.00E+00	100
Molecular weight	g/M	CONSTANT	0.00E+00	-999	0.00E+00	-999
Mole fraction of solute	--	CONSTANT	0.00E+00	-999	1.00E-09	1
Vapor pressure of solute	mm Hg	CONSTANT	0.00E+00	-999	0.00E+00	100
Henry`s law constant	atm	CONSTANT	0.00E+00	-999	1.00E-10	1
Overall 1st order decay sat. zone	1/yr	DERIVED	0.00E+00	0.00E+00	0.00E+00	1
Not currently used		CONSTANT	-999	-999	0.00E+00	1
Not currently used		CONSTANT	-999	-999	0.00E+00	1

Table C-1 - Multimed Input Parameters and Result

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Infiltration rate	m/yr	CONSTANT	1	-999	1.00E-10	1.00E+10
Area of waste disposal unit	m^2	CONSTANT	100	-999	1.00E-02	-999
Duration of pulse	yr	CONSTANT	15	-999	1.00E-09	-999
Spread of contaminant source	m	DERIVED	-999	-999	1.00E-09	1.00E+10
Recharge rate	m/yr	CONSTANT	0.1	-999	0.00E+00	1.00E+10
Source decay constant	1/yr	CONSTANT	0.00E+00	-999	0.00E+00	-999
Initial concentration at landfill	mg/l	CONSTANT	102	-999	0.00E+00	-999
Length scale of facility	m	CONSTANT	10	-999	1.00E-09	1.00E+10
Width scale of facility	m	CONSTANT	10	-999	1.00E-09	1.00E+10
Near field dilution		DERIVED	1	0.00E+00	0.00E+00	1

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Particle diameter	cm	CONSTANT	-999	-999	1.00E-09	100
Aquifer porosity	--	CONSTANT	0.2	-999	1.00E-09	0.99
Bulk density	g/cc	CONSTANT	1.6	-999	1.00E-02	5
Aquifer thickness	m	CONSTANT	23	-999	1.00E-09	1.00E+05
Source thickness (mixing zone depth)	m	DERIVED	-999	-999	1.00E-09	1.00E+05
Conductivity (hydraulic)	m/yr	CONSTANT	32	-999	1.00E-07	1.00E+08
Gradient (hydraulic)		CONSTANT	4.00E-02	-999	1.00E-08	-999
Groundwater seepage velocity	m/yr	DERIVED	-999	-999	1.00E-10	1.00E+08
Retardation coefficient	--	DERIVED	-999	-999	1	1.00E+08
Longitudinal dispersivity	m	FUNCTION OF X	-999	-999	-999	-999
Transverse dispersivity	m	FUNCTION OF X	-999	-999	-999	-999
Vertical dispersivity	m	FUNCTION OF X	-999	-999	-999	-999
Temperature of aquifer	C	CONSTANT	-999	-999	0.00E+00	100
pH	--	CONSTANT	-999	-999	0.3	14
Organic carbon content (fraction)		CONSTANT	1.60E-03	-999	1.00E-06	1
Well distance from site	m	CONSTANT	800	-999	1	-999
Angle off center	degree	CONSTANT	0.00E+00	-999	0.00E+00	360
Well vertical distance	m	CONSTANT	0.00E+00	-999	0.00E+00	1

CONCENTRATION AFTER SATURATED ZONE MODEL 0.3886E-02

Notes:
All concentrations are in mg/L.
Parameters with -999 listed for mean and standard deviation are not used by the model in this simulation.
Limits (min and max) are model-defined parameter limits. -999 listed for a max indicates there is no maximum limit.

Table C-2 - Site-Specific Organic Carbon Data

Sample No.	Fractional organic carbon content (f_{oc})
HC-4, S-3	0.00067
HC-4, S-7	0.0035
HC-5, S-5	0.00052

APPENDIX D
RISK SCREENING CALCULATIONS

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RISK SCREENING CALCULATIONS

Preliminary Risk Evaluation

The potential exposure pathways were considered for this site and the two pathways with the potential for maximum exposure were selected for risk evaluation. These pathways are: soil vapor migration to adjacent structures; and groundwater migration to downgradient receptors.

Soil Vapor Migration to Adjacent Structures

The risk from inhalation of PCE in adjacent off-site buildings was assessed by comparing modeled PCE concentrations in indoor air with MTCA Method B ambient air cleanup levels for PCE in accordance with MTCA (WAC 173-340-750).

Non-Carcinogenic Risk. For PCE, the ambient air cleanup level for non-carcinogenic risks was calculated using Equation 1 below. This level is an exposure concentration which is estimated to result in no acute or chronic toxic effects on human health. The modeled air concentration of PCE was well below the ambient air cleanup level based on non-carcinogenic effects.

$$\text{Ambient air cleanup level } (\mu g/m^3) = \frac{RFD \times ABW \times UCF \times HQ}{BR \times ABS} \qquad \text{(Eq. 1)}$$

MTCA Level B ambient air cleanup level = 16 $\mu g/m^3$
Modeled off-site indoor building concentration = 0.159 $\mu g/m^3$

Where:
RFD = Reference Dose as specified in WAC 173-340-708(7)
(0.0100 mg/kg-day) MTCA CLARC II 2/96
BW = Body Weight (16 kg)
UCF = Units Conversion Factor (1,000 $\mu g/mg$)
BR = Breathing Rate (10 m^3/day)
ABS = Absorption percentage (1.0)
HQ = Hazard Quotient (1)

Carcinogenic Risk. For PCE, the ambient air cleanup level for carcinogenic risks was calculated using Equation 2 below. This level is an exposure concentration for which the upper-bound on the estimated excess cancer risk is less than or equal to 1 in 1,000,000 and is determined using the equation and standard assumptions presented below. The modeled air concentration for PCE was below the ambient air cleanup level based on carcinogenic effects.

$$\text{Ambient air cleanup level } (\mu g/m^3) = \frac{\text{RISK x BW x LIFE x UCF}}{\text{CPF x BR x ABS x DU}} \qquad \text{(Eq. 2)}$$

MTCA Level B ambient air cleanup level = 0.172 $\mu g/m^3$
Modeled off-site indoor building concentration = 0.159 $\mu g/m^3$

Where:
RISK = Acceptable cancer risk level (1 in 1,000,000)
BW = Body Weight (70 kg)
LIFE = Lifetime (75 years)
UCF = Units Conversion Factor (1,000 $\mu g/mg$)
CPF = Carcinogenic potency factor as specified in WAC 173-340-708(8) (0.0510 kg-day/mg) MTCA CLARC II 2/96
BR = Breathing Rate (20 m^3/day)
ABS = Absorption percentage (1.0)
DUR = Duration of exposure (30 years)

Groundwater Migration to Downgradient Receptors

The risk to human and environmental health from exposure to surface water and ingestion of aquatic organisms was evaluated by comparing modeled concentrations of PCE in groundwater discharging to the Ship Canal over time to available state and federal water quality criteria and screening levels. The Ship Canal is located approximately 0.5 mile downgradient to the south of the site.

	Concentration in $\mu g/L$			
	Modeled Maximum PCE Concentration in Groundwater Discharging to Surface Water	Federal Human Health AWQC Consumption of Organisms (10^{-6} risk)	MTCA Method B (WAC 173-340-730)	MTCA Method C (WAC 173-340-730)
Carcinogenic Risk	4	8.85	4.15	104
Non-carcinogenic Risk	4	N.A.	847	2120

The maximum concentration of PCE discharging to the Ship Canal was estimated to be 4 ug/L. This concentration is below the federal AWQC for the consumption of organisms at an excess cancer risk of $1x10^{-6}$ and the

MTCA Method B Surface Water Cleanup Standards for carcinogenic and non-carcinogenic risks and MTCA Method C Surface Water Cleanup Standards for carcinogenic and non-carcinogenic risks. Although MTCA Method C may be inappropriate to apply to this site, it is provided here for reference purposes.

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