

FID 246 009170 ERR/ER

**PHASE III WORKPLAN TO
EVALUATE THE EXTENT OF CHLORINATED VOCs
IN GROUNDWATER
AND TO INVESTIGATE POTENTIAL
ON-SITE SOURCE AREAS
AT THE
TECUMSEH PRODUCTS COMPANY
GRAFTON, WISCONSIN, FACILITY**

**PREPARED FOR
TECUMSEH PRODUCTS COMPANY
GRAFTON, WISCONSIN**

MAY 1995

May 9, 1995

Ms. Pam Mylotta
Hydrogeologist, Environmental Repair Program
Wisconsin Department of Natural Resources
4041 North Richards Street
Milwaukee, WI 53212

RE: Tecumseh Products Company
Grafton, Wisconsin

Dear Pam:

On behalf of Tecumseh Products Company, we are submitting two copies of the Phase III workplan, which outlines our approach to evaluating the extent of chlorinated VOCs in groundwater and to investigating potential on-site source areas at the Grafton Plant. This workplan provides additional information about the field procedures and laboratory methods for implementing the recommendations that were outlined in the second interim status report for this site, and that were discussed with you during the meeting on February 8, 1995. The methods and procedures are generally the same as were used during the second phase of investigation.

The objectives of the third phase of investigation are as follows:

- To determine whether the VOCs in the groundwater at the plant are the result of off-site sources to the north and/or northwest of the plant
- To continue to delineate the areal extent of VOCs in groundwater migrating from the plant within the area potentially influenced by Village water supply wells #3 and #7
- To characterize the nature and extent of contamination in the potential on-site source areas and to characterize key parameters for the evaluation of remedial technologies for these areas

As I discussed with you by telephone in April, the field investigation may take 8 to 10 weeks to complete if all six bedrock monitoring wells are needed to define the extent of the off-site VOC plume. In order to ensure that critical field/office decisions regarding the bedrock well locations and screened intervals do not need to be made while Bernd Rehm is out on vacation in July, we plan to begin the fieldwork on July 24, as soon as he returns. We would appreciate receiving your comments or approval of the workplan by June 19 to allow time to address any questions or concerns you may have.



RMT, INC. — MADISON, WI
744 HEARTLAND TRAIL — 53717-1934
P.O. Box 8923 — 53708-8923
608/831-4444 — 608/831-3334 FAX

Ms. Pam Mylotta
May 9, 1995
Page 2

Pursuant to our discussions, we understand this project is proceeding under NR 700, Wisconsin Administrative Code. If this understanding is incorrect in any respect, please call me immediately. Kerry DeKeyser (414-898-5711) and I are available to answer any questions you may have about this project.

Sincerely,

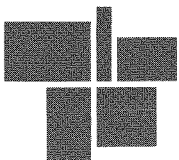
Linda Hicken

Linda E. Hicken, P.E.
Senior Project Manager

amt

Enclosure

cc: Kerry DeKeyser, Tecumseh Products



copy 2 of 2

FID 246 009170 ERR/ERP

**PHASE III WORKPLAN TO
EVALUATE THE EXTENT OF CHLORINATED VOCs
IN GROUNDWATER
AND TO INVESTIGATE POTENTIAL
ON-SITE SOURCE AREAS
AT THE
TECUMSEH PRODUCTS COMPANY
GRAFTON, WISCONSIN, FACILITY**

**PREPARED FOR
TECUMSEH PRODUCTS COMPANY
GRAFTON, WISCONSIN**

MAY 1995



Lisa S. Drzewiecki
Project Hydrogeologist



Bernd W. Rehm
Senior Consulting Hydrogeologist



Linda E. Hicken, P.E.
Senior Project Manager



RMT, INC. — MADISON, WI
744 HEARTLAND TRAIL = 53717-1934
P.O. Box 8923 = 53708-8923
608/831-4444 = 608/831-3334 FAX

TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
1. INTRODUCTION	1
1.1 Background	1
1.2 Objectives	3
1.3 Purpose and Scope	5
2. SITE INVESTIGATION	6
2.1 Upgradient Property Line Source Area Investigation	6
2.2 Downgradient Groundwater VOC Extent Investigation	15
2.3 Potential On-Site Source Investigations	18
2.4 Third Interim Status Report Preparation	28
3. SCHEDULE	29
4. REFERENCES CITED	31

List of Tables

Table 1	Proposed Drilling Program	8
Table 2	Summary of Soil Analytical Program	13
Table 3	Summary of Groundwater Analytical Program	19
Table 4	Proposed Groundwater Analytical Parameters and Detection Limits	21
Table B-1	Detection Limits for Selected Chlorinated VOCs and Xylenes Analyzed by Portable GC	B-2
Table B-2	Portable GC Field Equipment Checklist	B-6
Table B-3	Example of a Commercially Prepared Standard	B-8

List of Figures

Figure 1	Site Locator Map	2
Figure 2	Locations of On-Site Borings and Monitoring Wells	4
Figure 3	Preliminary Locations for Off-Site Upgradient Borings	7
Figure 4	Locations of Proposed Bedrock Wells	16
Figure 5	West Dock Area	22
Figure 6	TCA Filling Area	24
Figure 7	Southeast Degreaser Area and Recycling Docks Area	26
Figure 8	Project Schedule	30
Figure A-1	Water Table Well Construction Detail (Stick-Up Surface Casing)	A-5
Figure A-2	Water Table Well Construction Detail (Flush-Up Cover)	A-6
Figure A-3	Soil Vapor Extraction, Air Sparging, and Associated Monitoring Wells	A-8
Figure A-4	Bedrock Well Construction Detail	A-9



**TABLE OF CONTENTS
(CONTINUED)**

Section

List of Appendices

- Appendix A Field Methods
Appendix B RMT Standard Operating Procedures for Portable GC Analysis of Groundwater
 Samples

List of Attachments

- Photovac® Technical Bulletin #27

Section 1

INTRODUCTION

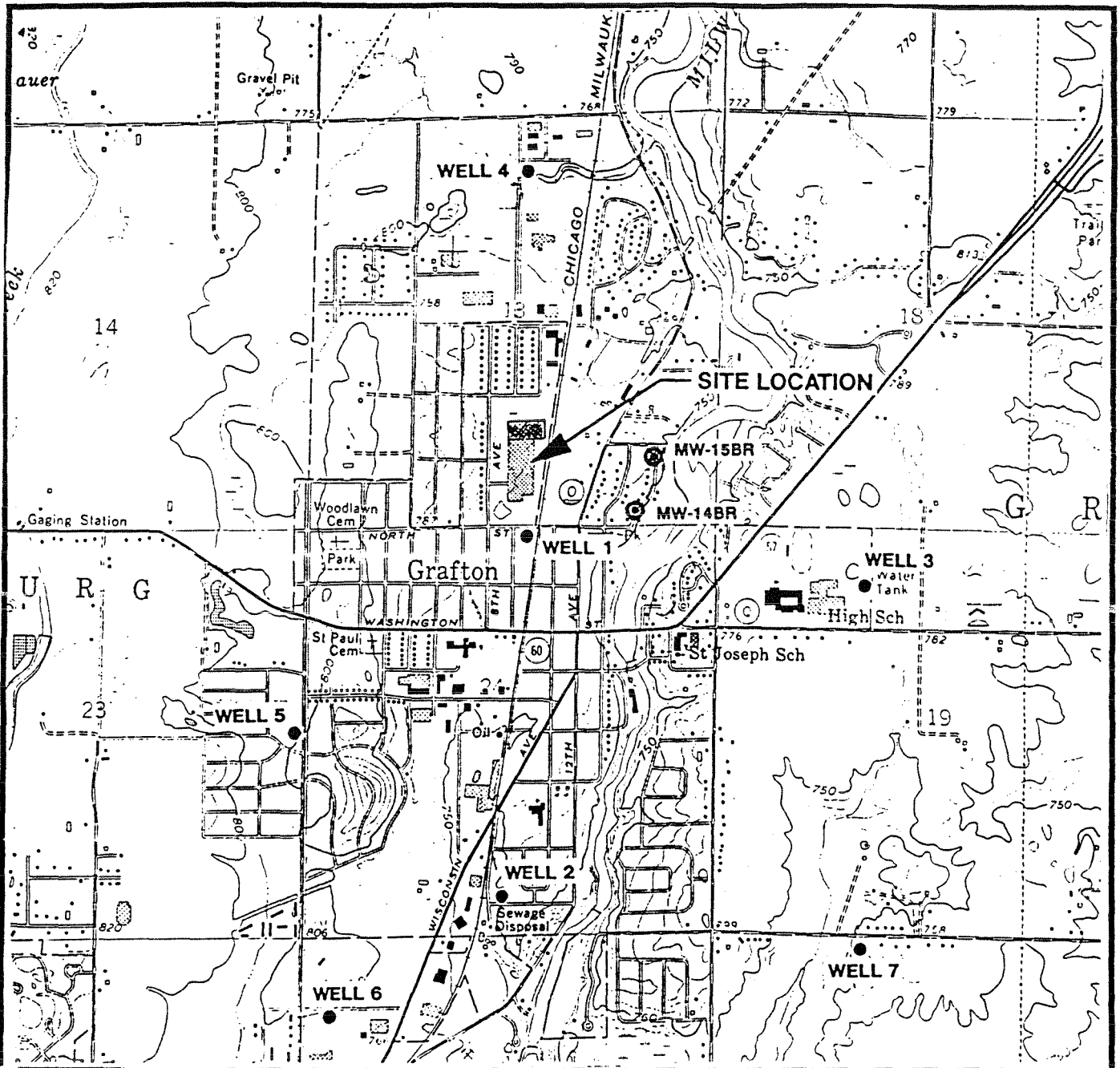
1.1 Background

The Tecumseh Products Company operates a manufacturing facility located at 900 North Street in Grafton, Wisconsin (see Figure 1). During the 1960s, 1970s, and 1980s, the Grafton facility machined and assembled two-cycle gasoline engines. Vapor degreasing of parts and engines and painting of assembled engines were part of the manufacturing process. The process equipment associated with the engine assembly operations included underground storage tanks for the gasoline used in engine testing.

During the period of December 1988 through June 1992, eight underground storage tanks (USTs) were removed at the site. These tanks contained gasoline (leaded and unleaded), kerosene, Stoddard solvent, and motor oil. During the course of investigating the extent of the release associated with the Stoddard solvent tank, chlorinated volatile organic compounds (VOCs) were detected in the soil and groundwater.

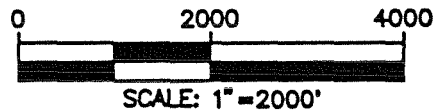
RMT, Inc. (RMT), was hired to conduct additional investigative activities at the Grafton facility to better define hydrogeologic conditions beneath the facility, to evaluate the direction of groundwater flow, and to define the extent of chlorinated solvents identified in groundwater during the previous investigations. The first phase of this investigation was conducted in August 1994 and included the installation of eight soil borings, as outlined in a workplan submitted to the WDNR in August 1994 (RMT, Inc., 1994a). Two of the soil borings were converted to water table wells, and three of the soil borings were converted to piezometers. The findings and conclusions of this initial phase of the investigation are summarized in an interim status report that was submitted to the WDNR on October 10, 1994 (RMT, Inc., 1994b).

The second phase of the investigation was conducted in November and December 1994, and included the installation of nine shallow soil borings, two water table wells in the unconsolidated soil, and five monitoring wells in the bedrock, as outlined in a workplan that was submitted to the WDNR in October 1994 (RMT, Inc., 1994c). Two of the shallow soil borings and two of the bedrock monitoring wells were installed off-site within Village right-of-



LEGEND

- GRAFTON WATER SUPPLY WELLS
- ⊙ BEDROCK MONITORING WELL



STATE LOCATION

**SITE LOCATOR MAP
TECUMSEH PRODUCTS COMPANY
GRAFTON, WISCONSIN**



DWN. BY: SPS
APPROVED BY:
DATE: DECEMBER 1994
PROJ. # 3084.07
FILE # 30840702

SOURCE: BASE MAP FROM CEDARBURG WI. 7.5 MINUTE USGS QUADRANGLE.

\$\$\$DWG\$\$
\$\$\$PRF\$\$\$
\$\$\$SCALE\$\$\$

ways to assess the horizontal extent of VOCs in groundwater in the soil and bedrock to the east of the facility. The locations of the soil borings and monitoring wells are shown on Figures 1 and 2.

The second phase of the investigation also included in-plant observations and interviews with Tecumseh Products employees to identify potential source areas and to evaluate the accessibility of these areas for subsequent investigations. Potential sources of VOCs to the groundwater were identified as the West Dock Area, the Southeast Degreaser Area, the Recycling Docks Area, and the TCA Filling Area. The locations of the potential source areas are shown on Figure 2. All four areas are accessible to some degree for further investigation as described in Section 2 of this Workplan.

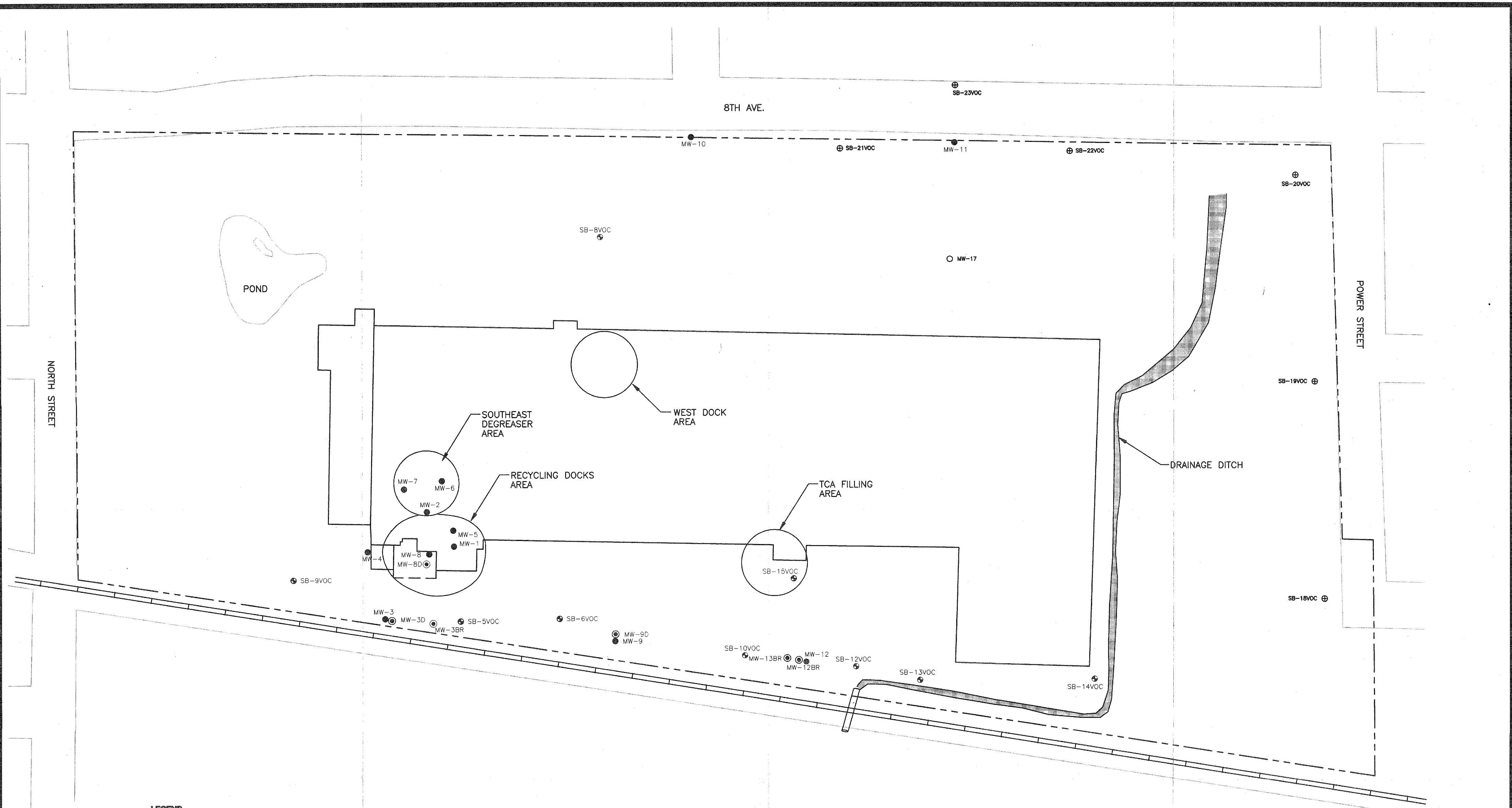
Two rounds of groundwater samples were collected from six residential wells located downgradient (east) of the Tecumseh facility in the Town of Grafton in December 1994. The VOCs that were detected in the residential wells were present at concentrations at or below their respective preventive action limits (PALs), except for TCE which was detected at concentrations above the PAL but below the Enforcement Standard (ES) in two of the residential wells (PW-30 and PW-38). No ESs were exceeded in any of the wells sampled.

The findings and conclusions of the second phase of the investigation were summarized in an interim status report that was submitted to the WDNR in January 1995 (RMT, Inc., 1995). The interim status report also contained recommendations for a third phase of investigation, which would include an upgradient property line source area investigation, a downgradient groundwater VOC extent investigation, and potential on-site source investigations. A meeting among representatives of the WDNR, Tecumseh Products, and RMT was held on February 8, 1995, to discuss the contents of the interim status report. The WDNR representatives generally concurred with the recommendations outlined in the interim status report, but their approval is contingent upon reviewing the details presented in the following workplan.

1.2 Objectives

The objectives of the third phase of the investigation at the Tecumseh Products Grafton facility are as follows:

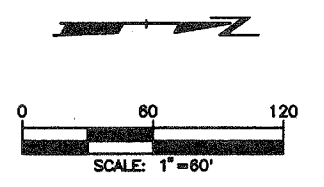
Drawing File = H:\3084_14\30841403
 Plot File = P:\30841403.PRF
 SCALE = 6000000.000000
 Plot Date = Mon Apr 24 13:57:26 1995



LEGEND

● MW-10	WATER TABLE WELL
⊙ MW-3BR	PIEZOMETER
⊕ SB-8VOC	SOIL BORING
○ MW-17	PROPOSED WATER TABLE WELL
⊕ SB-19VOC	PROPOSED SOIL BORING
====	RAILROAD
- - - -	PROPERTY LINE

- NOTES**
- FACILITY LAYOUT ADAPTED FROM DRAWINGS PROVIDED BY TECUMSEH PRODUCTS COMPANY.
 - MONITORING WELL LOCATIONS AND ELEVATIONS WERE SURVEYED BY RMT INC. ON 12/5/94.
 - BORING SB-11VOC IS LOCATED NEAR MONITORING WELL MW-12BR.



3.				
2.				
1.				
NO.	BY	DATE	REVISION	APP'D.
PROJECT: TECUMSEH PRODUCTS COMPANY GRAFTON, WISCONSIN				
SHEET TITLE: LOCATIONS OF ON-SITE BORINGS AND MONITORING WELLS				
DRAWN BY: RBN	SCALE: 1"=60'	PROJ. NO. 3084.14		
CHECKED BY: <i>RBH</i>	DATE PRINTED: APR 24 1995	FILE NO. 30841403		
APPROVED BY: <i>RBH</i>	DATE: APRIL 1995	FIGURE 2		
		744 Heartland Trail Madison, WI 53717-1934 P.O. Box 8923 Madison, WI 53708-8923 Phone: 608/831-4444		

- To determine whether the VOCs in the groundwater at the Grafton Plant are the result of off-site sources to the north and/or northwest of the plant
- To continue to delineate the areal extent of VOCs in groundwater migrating from the plant within the area potentially influenced by Village water supply wells #3 and #7
- To characterize the nature and extent of contamination in the potential on-site source areas identified during the second phase of the investigation and to characterize key parameters for the evaluation of remedial technologies for these areas

1.3 Purpose and Scope

The purpose of this workplan is to describe the field activities and laboratory analyses that will be performed during the third phase of the investigation.

The scope of the investigation includes installing additional shallow soil borings, water table wells in the unconsolidated soil, and monitoring wells with multiple sampling ports in the bedrock. The details of the planned investigative activities are presented in Section 2. The field methods and portable GC analytical procedures are presented in Appendices A and B, respectively, and are the same methods and procedures that were used during the second phase of investigation at this facility.

Section 2 SITE INVESTIGATION

2.1 Upgradient Property Line Source Area Investigation

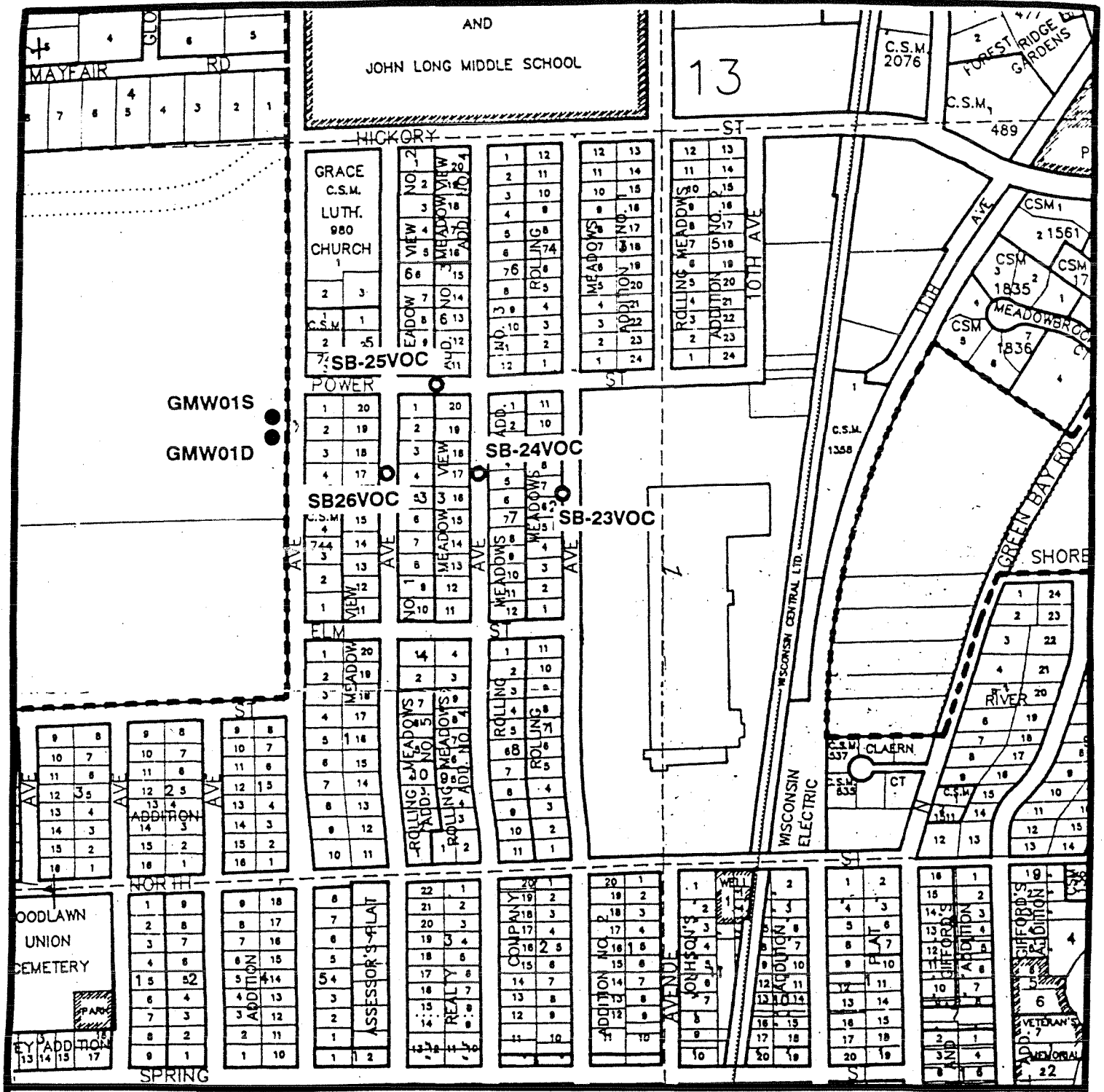
The objective of the upgradient property line source area investigation is to determine whether the VOCs in the groundwater at the Grafton Plant are the result of off-site sources to the north and/or northwest of the plant. The approximate locations of the planned soil borings and monitoring wells are shown on Figures 2 and 3. The drilling program is summarized in Table 1. The field methods and the portable GC operating procedures are contained in Appendices A and B, respectively.

The work will include the following tasks:

- Install up to seven soil borings to the west of the Grafton Plant to delineate the extent of contamination in the vicinity of MW-11. Complete these borings to the bottom of the sand layer, estimated to be at approximately 30 feet below ground surface, as described in Table 1. Three of the borings will be installed on-site—one each to the north, south, and east of MW-11. Soil boring SB-23VOC will be installed upgradient of MW-11 in the Village right-of-way on the western side of 8th Avenue. On the basis of the chemical data from these four initial borings, up to three additional borings will be installed (the soil and groundwater sampling and analysis plans are described in later bullet items).

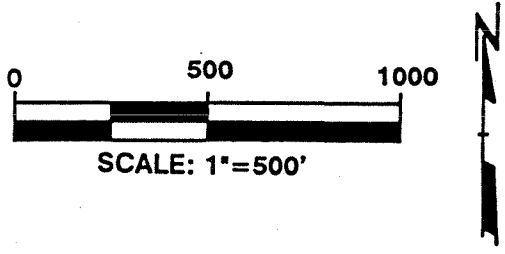
If VOCs are detected in the upgradient boring installed on 8th Avenue, the three additional borings will be installed in the Village right-of-ways west of the plant. The preliminary locations are shown on Figure 3. These locations may be modified on the basis of water level measurements in the monitoring well nests that were installed by the WDNR (IT Corporation, 1989) if these wells are still functional (e.g., GMW01S and D, Figure 3).

If VOCs are not detected in the upgradient boring installed on 8th Avenue, the three additional borings may be installed on-site to better delineate the extent of contamination in the vicinity of MW-11. The need for and the locations of the additional borings will be determined on the basis of chemical data from the initial on-site borings.
- Install water table well MW-17 in the boring installed to the east (downgradient) of MW-11 (Figure 2), in accordance with Chapter NR 141, Wisconsin Administrative Code. Complete the well with a stick-up casing (if appropriate) and locking cover.
- Install shallow soil borings SB-18VOC, SB-19VOC, and SB-20VOC, along the northern plant property line (Figure 2). Complete these borings to the top of bedrock, estimated to be approximately 40 feet below ground surface, using a hollow-stemmed auger.



LEGEND

- PROPOSED BORING AND/OR MONITORING WELL
- EXISTING MONITORING WELL



**PRELIMINARY LOCATIONS FOR
OFF-SITE UPGRADIENT BORINGS
TECUMSEH PRODUCTS COMPANY
GRAFTON, WISCONSIN**

SOURCE: BASE MAP FROM VILLAGE OF
GRAFTON 8-19-94

TABLE 1

PROPOSED DRILLING PROGRAM
TECUMSEH PRODUCTS COMPANY

Investigative Area	Proposed Boring(s)	Type of Boring or Monitoring Well	Estimated Depth (feet)	Primary Objective of Sample Point/Well
Upgradient property line VOC source investigation	SB-18VOC SB-19VOC SB-20VOC	Soil borings	40	To assess the potential for neighboring VOC sources upgradient and to the north of the Tecumseh facility.
	MW-16 ¹	Water table well	30	To monitor shallow groundwater quality and water table elevation along the north Tecumseh property line should VOCs be detected in any of the borings noted above.
	SB-21VOC SB-22VOC	Soil borings	30	To clarify the source and extent of the TCE observed in MW-11 (on-site borings).
	MW-17	Soil boring/water table well	30	To clarify the extent of the VOCs between MW-11 and the Tecumseh plant (on-site borings).
	SB-23VOC	Soil boring	30	To determine whether the source of TCE in MW-11 is upgradient of the Tecumseh facility.
	SB-24VOC ² SB-25VOC ² SB-26VOC ²	Soil borings	30	To identify the source of the TCE in MW-11 if VOCs are detected in boring SB-23VOC.
West Dock Area	SB-1WD through SB-4WD	Soil borings	40	To determine whether the West Dock Area is a source of VOCs in the groundwater.
	SB-5WD through SB-8WD ³	Soil borings	40	As necessary, to evaluate the nature and extent of contamination beneath the West Dock Area.

TABLE 1 (CONTINUED)

**PROPOSED DRILLING PROGRAM
TECUMSEH PRODUCTS COMPANY**

Investigative Area	Proposed Boring(s)	Type of Boring or Monitoring Well	Estimated Depth (feet)	Primary Objective of Sample Point/Well
TCA Filling Area	SB-1TCA through SB-5TCA	Soil borings	30	To determine whether the TCA Filling Area is a source of VOCs in the groundwater.
	SB-6TCA through SB-14TCA ⁴	Soil borings	12	As necessary, to evaluate the nature and extent of VOCs in the clay soil beneath the TCA Filling Area.
Southeast Degreaser Area	SB-1SE SB-2SE SB-3SE	Soil borings	35	To evaluate whether the Southeast Degreaser Area is a source of VOCs in the groundwater of sufficient magnitude to warrant further consideration for remedial action.
	SB-4SE SB-5SE SB-6SE	Soil borings	12	To evaluate whether the Southeast Degreaser Area is a source of VOCs in the groundwater of sufficient magnitude to warrant further consideration for remedial action.
	SB-7SE ⁵ SB-8SE ⁵ SB-9SE ⁵	Soil borings	12	As necessary, to evaluate the nature and extent of VOCs in the clay soil beneath the Southeast Degreaser Area.
Recycling Docks Area	SB-1RD SB-2RD SB-3RD	Soil borings	35	To evaluate the nature and extent of VOCs in the soil and groundwater beneath the Recycling Docks Area.
	SB-4RD SB-5RD SB-6RD	Soil borings	12	To evaluate the nature and extent of VOCs in the clay soil beneath the Recycling Docks Area.
	SB-7RD through SB-10RD ⁶	Soil borings	12	As necessary, to evaluate the nature and extent of VOCs in the clay soil beneath the Recycling Docks Area.

TABLE 1 (CONTINUED)

**PROPOSED DRILLING PROGRAM
TECUMSEH PRODUCTS COMPANY**

Investigative Area	Proposed Boring(s)	Type of Boring or Monitoring Well	Estimated Depth (feet)	Primary Objective of Sample Point/Well
Recycling Docks Area (continued)	VE-1	Soil vapor extraction well	13	To test soil vapor extraction as a potential remediation technology.
	AS-1	Air sparging well	20	To test air sparging as a complementary technology for improving the efficiency of soil vapor extraction.
	VMW-1 ⁷ VMW-2 ⁷	Pilot test monitoring points	13	To monitor the radial influence of soil vapor extraction in the unsaturated zone. To monitor the radial influence of the air sparging well in the saturated zone.
Downgradient groundwater VOC investigation	MW-18BR MW-19BR	Bedrock monitoring wells	240	To determine whether there is an off-site VOC plume of concern and, if present, in what direction it is migrating.
	MW-20BR ⁸ MW-21BR ⁸	Bedrock monitoring wells	340	As necessary, to assess whether the off-site VOC plume reaches Village Well #3.
	MW-22BR ¹⁰ MW-23BR ¹⁰	Bedrock monitoring wells	400	As necessary, to assess <ul style="list-style-type: none"> • Whether the off-site VOC plume reaches Village Well #7; and • Whether the plume continues eastward, beyond the Village.

TABLE 1 (CONTINUED)

**PROPOSED DRILLING PROGRAM
TECUMSEH PRODUCTS COMPANY**

NOTES:

- ¹ MW-16 is a contingency well. It will be installed if VOCs are detected in SB-18VOC, SB-19VOC, or SB-20VOC. If VOCs are detected in any of these borings, MW-16 will be installed near the boring with the highest VOC concentrations.
- ² SB-24VOC, SB-25VOC, and SB-26VOC are contingency borings. If VOCs are detected in SB-23VOC, they will be installed within Village right-of-ways west of the plant to identify the source of the VOCs. If VOCs are not detected in SB-23VOC, they will be installed on-site to better delineate the extent of contamination in the vicinity of MW-11.
- ³ SB-5WD through SB-8WD are contingency borings. They will be installed if VOCs are observed in borings SB-1WD through SB-4WD at concentrations that could potentially result in impacts to groundwater.
- ⁴ SB-6TCA through SB-14TCA are contingency borings. They will be installed if the observed groundwater concentrations in borings SB-1TCA through SB-5TCA suggest that this area may be a VOC source.
- ⁵ SB-7SE, SB-8SE, and SB-9SE are contingency borings. They will be installed if the observed VOC concentrations in borings SB-1SE through SB-6SE suggest that the Southeast Degreaser Area is a VOC source.
- ⁶ SB-7RD through SB-10RD are contingency borings. They will be installed if borings SB-1RD through SB-6RD have not adequately defined the nature and extent of VOCs beneath the Recycling Docks Area.
- ⁷ Vapor monitoring points VMW-1 and VMW-2 will both be installed with three small-diameter probes in a single borehole—two of the probes will be screened in the unsaturated zone and one will be screened across the water table.
- ⁸ MW-20BR and MW-21BR are contingency wells. They will be installed if wells MW-18BR and/or MW-19BR indicate significant concentrations of VOCs in the bedrock aquifer.
- ⁹ MW-22BR and MW-23BR are contingency wells. They will be installed if wells MW-20BR and/or MW-21BR indicate significant concentrations of VOCs in the bedrock aquifer.

- If VOCs are detected by in-field analysis in any of the three soil borings installed along the northern plant property line, install a water table well near the boring with the highest VOC concentrations, in accordance with Chapter NR 141, Wisconsin Administrative Code. Complete the well with a stick-up casing and locking cover.
- In all of the above-described borings, collect soil samples with a split-spoon sampler at 2.5-foot intervals until the water table is encountered. Describe the soil samples according to the Unified Soil Classification System (USCS). Below the water table, collect soil and groundwater samples at alternating 4-foot intervals. As necessary, modify the groundwater sampling intervals to be able to collect groundwater samples from sandy intervals. Collect the groundwater samples using a Hydropunch® sampler.
- Analyze the headspace concentrations above the clay soil samples and the groundwater samples for the following VOCs using a portable (in-field) gas chromatograph (GC): 1,1-DCE; cis-1,2-DCE; trans-1,2-DCE; trichloroethene (TCE); 1,1,1-trichloroethane (TCA); toluene; and xylenes.
- Laboratory-analyze up to two clay soil samples per boring for VOCs using USEPA Method 8021. The soil samples submitted for analysis will be selected on the basis of the portable GC results and the visual observations of the soil. The soil sampling program is summarized in Table 2.
- Abandon the soil borings in accordance with Chapter NR 141 regulations.
- Develop the monitoring wells by surging and bailing, in accordance with Chapter NR 141 regulations.
- Collect a round of groundwater level measurements from all of the wells that have been installed as part of this project to evaluate the horizontal and vertical groundwater flow directions. If the wells installed by the WDNR (IT Corporation, 1989) are functional as monitoring wells, measure the water levels in these wells also. If necessary, survey the elevation of the WDNR wells relative to the National Geodetic Vertical Datum.
- Place the soil cuttings in properly labeled 55-gallon drums, and store the drums at an on-site location.
- Collect and analyze a composite sample of the investigation-derived wastes for disposal characterization.
- Collect the decontamination, purge, and development waters in 55-gallon drums. On the basis of the results of the portable GC analysis, discharge the water to the sanitary sewer with the permission of the Village of Grafton.

TABLE 2

SUMMARY OF SOIL ANALYTICAL PROGRAM

Area	Analytical Group ⁽¹⁾							Comments
	A	B	C	D	E	F	G	
1. Upgradient property line in the vicinity of MW-11	Up to 14						1	Up to 2 clay samples per boring for VOC analysis. Up to 7 borings.
2. Upgradient property line along the northern plant property line	Up to 6							Up to two clay samples per boring for VOC analysis. Up to 3 borings. IDW ⁽²⁾ from this area will be composited with IDW from borings in the vicinity of MW-11.
3. West Dock Area	Up to 16	4	4				1	Up to 2 clay samples per boring for VOC analysis. Up to 8 borings. Samples analyzed for PAHs will also be analyzed for VOCs.
4. Background			1					
5. TCA Filling Area	Up to 28			4	4		1	Up to 2 clay samples per boring for VOC analysis. Up to 14 borings.
6. Southeast Degreaser Area	Up to 18			6	3	2	1	Up to 2 clay samples per boring for VOC analysis. Up to 9 borings. 3 samples of clayey soil and 3 samples of sandy soil.
7. Recycling Docks Area	Up to 20	5	5	8	4	2	1	Up to 2 clay samples per boring for VOC analysis. Up to 10 borings. Samples analyzed for PAHs will also be analyzed for VOCs. 4 samples of clayey soil and 4 samples of sandy soil.
Total Number of Samples	102	9	10	18	11	4	5	

TABLE 2 (CONTINUED)

SUMMARY OF SOIL ANALYTICAL PROGRAM

NOTES:

⁽¹⁾ Analytical Group A: Volatile organic compounds quantified under USEPA Method 8021

Analytical Group B: Polynuclear aromatic hydrocarbons (PAHs) quantified under USEPA Method 8270A, as follows:

Acenaphthene	Benzo(g,h,i)perylene	Indeno(1,2,3-cd)pyrene
Acenaphthylene	Benzo(a)pyrene	1-Methylnaphthalene
Anthracene	Chrysene	2-Methylnaphthalene
Benzo(a)anthracene	Dibenz(a,h)anthracene	Naphthalene
Benzo(b)fluoranthene	Fluoranthene	Phenanthrene
Benzo(k)fluoranthene	Fluorene	Pyrene

Analytical Group C: Biodegradation constituents, as follows:

Ammonia nitrogen	Potassium	Percent air-filled pore space
Microbial degrader population	pH	Soil moisture content
Nitrate + nitrite nitrogen	percent organic matter	
Total Kjeldahl nitrogen (TKN)	percent total solids	
Ortho-phosphate		

Analytical Group D: Grain-size distributions and moisture content

Analytical Group E: Atterberg limits

Analytical Group F: Bulk density

Analytical Group G: Waste disposal parameters

⁽²⁾ IDW = Investigation-derived waste

2.2 Downgradient Groundwater VOC Extent Investigation

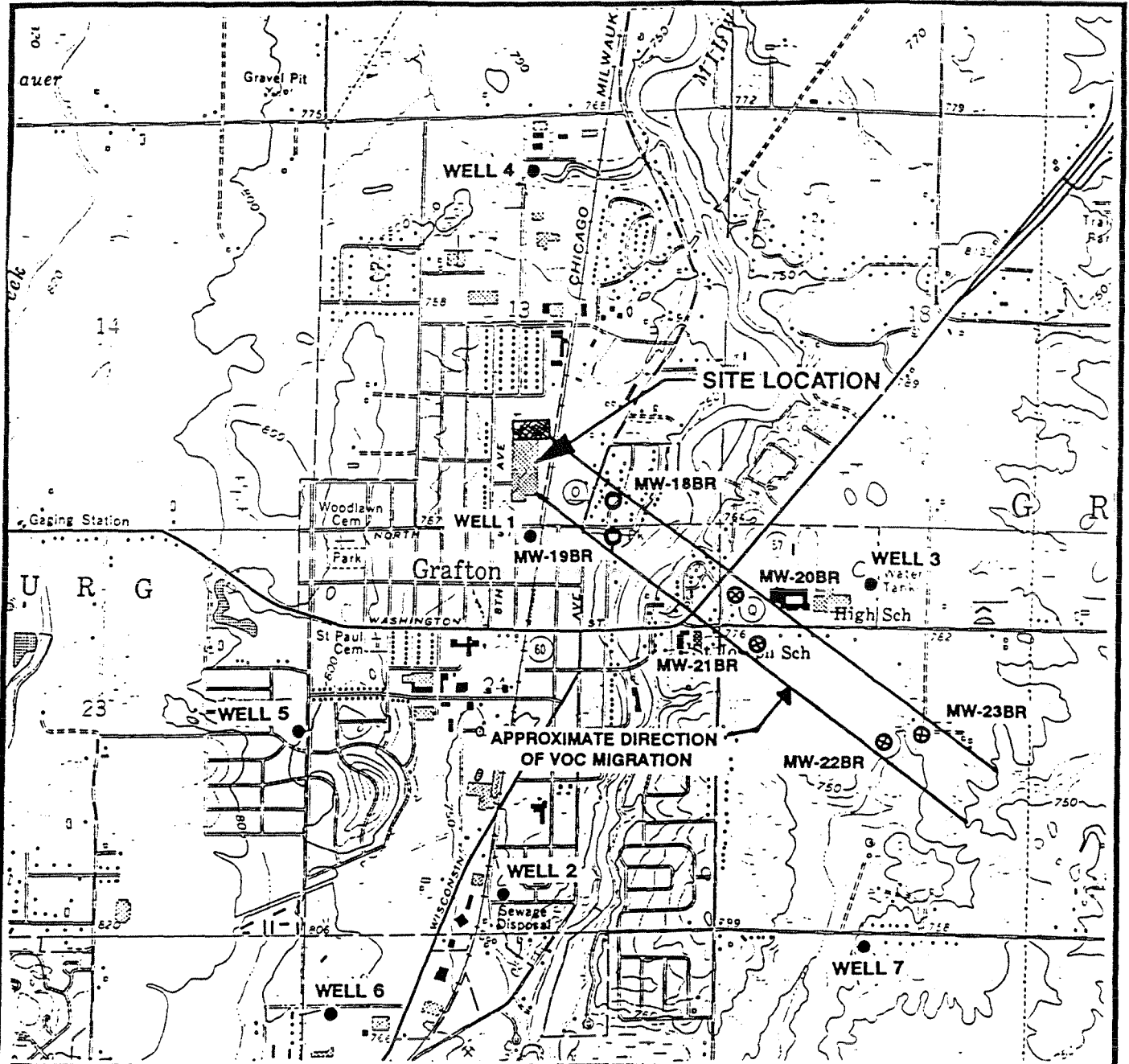
The objective of the downgradient investigation is to continue to delineate the areal (i.e., horizontal) extent of VOCs in groundwater that are migrating from the plant within the area potentially influenced by Village water supply wells #3 and #7. Monitoring well-specific objectives are summarized in Table 1. The monitoring wells will be installed between the Tecumseh facility and Village wells #3 and #7 (Figure 4) in order to evaluate whether there is a potential risk to public water supplies. Determining the vertical VOC extent, or plume thickness, is not an objective of this investigation because it is not necessary to determine the plume thickness to address the issue of potential risk to water supply wells. In addition, the areal extent of the plume will only be delineated in the areas potentially influenced by Village wells #3 and #7. Wells will not be installed to the east of Village wells #3 and #7 unless there is an indication that the plume may pose a potential risk to public water supplies beyond this point.

The investigation will include the following tasks:

- Install two borings (MW-18BR and MW-19BR) into the bedrock aquifer on the west side of the Milwaukee River, within the public right-of-way on 13th Avenue at the locations shown on Figure 4. Water level measurements to be made in the bedrock monitoring wells that were installed by the WDNR (IT Corporation, 1989) may modify these locations slightly, if these wells are still functional. The borings will be installed to either the bottom of the VOC plume (i.e., to where concentrations are less than the NR 140, Wisconsin Administrative Code, Enforcement Standards) or to a maximum depth of 240 feet below grade (approximately 150 feet into the plume, as projected by available data), whichever comes first. (The groundwater sampling and analysis plans are described in later bullet items.)

If the two borings installed on 13th Avenue indicate concentrations of VOCs in the bedrock aquifer are greater than or equal to an Enforcement Standard, install two additional bedrock borings/monitoring wells (MW-20BR and MW-21BR) east of the Milwaukee River and west of Village well #3. The borings will be drilled to 340 feet below grade (approximately 150 feet into the plume, as projected by available data) or to the base of the plume, whichever comes first. The boring locations will be selected on the basis of the apparent direction of VOC migration and the horizontal hydraulic gradients measured in the monitoring wells west of the river. Preliminary locations were identified using the available hydraulic and chemical data (see Figure 4).

If VOC concentrations in excess of Enforcement Standards are found in the third and/or fourth boring, install two additional borings further southeast (MW-22BR and MW-23BR). The borings will be drilled to 400 feet below grade (approximately 150 feet into the plume, as projected by available data) or to



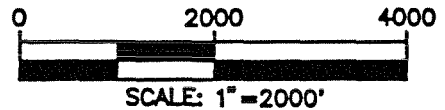
LEGEND

- GRAFTON WATER SUPPLY WELLS
- ⊗ PROPOSED BEDROCK MONITORING WELL
- ⊗ CONTINGENCY BEDROCK MONITORING WELL



STATE LOCATION

NOTE: THE CONTINGENCY WELLS WILL ONLY BE INSTALLED IF SIGNIFICANT VOC IMPACTS ARE DETECTED IN MW-18BR AND MW-19BR.



**LOCATIONS OF PROPOSED BEDROCK WELLS
TECUMSEH PRODUCTS COMPANY
GRAFTON, WISCONSIN**

SOURCE: BASE MAP FROM CEDARBURG WI. 7.5 MINUTE USGS QUADRANGLE.



DWN. BY: SPS
APPROVED BY:
DATE: DECEMBER 1994
PROJ.# 3084.07
FILE # 30840702

\$\$\$DWG\$\$\$
\$\$\$PRF\$\$\$
\$\$\$SCALE\$\$\$

the base of the plume, whichever comes first. The locations of these borings will be selected on the basis of hydraulic and chemical data from all previous monitoring wells and hydraulic head data from Village wells #3 and #7. Preliminary locations are shown on Figure 4. These wells will assess whether Village well #7 could be reached by the plume and whether the plume continues eastward, beyond the Village.

All of the bedrock borings will be drilled without soil sampling from the ground surface to the top of bedrock using the mud rotary drilling method. Bedrock is expected to occur at a depth of 2 to 60 feet below ground surface. Rock drilling will be performed using the air rotary drilling method.

- Advance boreholes for MW-18BR through MW-21BR in 30-foot intervals, and for MW-22BR and MW-23BR in 40-foot intervals. Perform packer tests in each 30- or 40-foot interval to collect information on the presence of fractures, specific capacity, and connection to VOC sources. Collect groundwater samples from each interval if fractures are encountered. Analyze the groundwater samples for the following VOCs using a portable GC: dichloroethenes (1,1-DCE; cis-1,2-DCE; and trans-1,2-DCE), TCE, TCA, toluene, and xylenes.
- Perform a downhole video inspection of each borehole after the drilling is completed to visually determine where the fractures are located.
- Complete each boring as a multiple-port sampling system. Construct each well using a 3-inch-ID Schedule 40 PVC casing that will have two 5-foot-long screened intervals. The screened intervals will be separated by at least 20 feet of 3-inch Schedule 40 PVC riser. The locations of the screened intervals will be determined on the basis of the results of the packer testing, the portable GC analysis, and the video logging.
- Install a multiple-port sampling system in the PVC casing in each bedrock well. The system will be composed of two PVC sampling/pressure ports and permanent, positive-seal packers built into a PVC casing string. Dedicated pumps will be placed within each sample port for collecting groundwater samples. If the depth to water is less than 50 feet, open tubes will be attached to each port for measuring hydraulic head. If the depth to water is greater than 50 feet, dedicated pressure transducers will be placed within each sample port for measuring hydraulic head.
- Survey the location and elevation of the new monitoring wells relative to the State Plane Coordinate System and to the National Geodetic Vertical Datum, respectively, as soon as they are installed to provide hydraulic head data for subsequent well location evaluation. Survey the location and elevation of the borings and wells installed as part of the upgradient property line investigation (Subsection 2.1) when monitoring wells MW-18BR and MW-19BR are surveyed.

- Collect a round of groundwater levels from all of the wells that have been installed as part of this project to evaluate the horizontal and vertical groundwater flow directions. If the wells installed by the WDNR (IT Corporation, 1989) are functional as monitoring wells, measure the water levels in these wells also.
- Collect one round of groundwater samples from the new and previously installed monitoring wells as summarized in Table 3. Also analyze a trip blank with each sample shipment for quality control purposes. The samples will be analyzed according to the analytical methods presented in Table 4.
- Place the drill cuttings in 55-gallon drums, and store the drums at an on-site location.
- Place the decontamination, purge, and development waters in a temporary container. On the basis of the portable GC analysis results, periodically discharge the collected water into the sanitary sewer with the permission of the Village of Grafton.

2.3 Potential On-Site Source Investigations

The objectives of the potential on-site source investigations are as follows:

- To provide confirmation of reported historical practices.
- To characterize the nature and extent of contamination in the potential on-site source areas identified during the evaluation of historical practices. Boring-specific objectives are provided in Table 1.
- To characterize key parameters for the evaluation of potential remedial technologies.

The work will include the following tasks:

West Dock Area

- Attempt to install four soil borings (two by vertical drilling and two by angle drilling) to determine whether the West Dock Area is a source of VOCs. The approximate locations of the soil borings are shown on Figure 5. Uncertain subsurface conditions and physical constraints imposed by working inside the plant may limit the success of the boring program. If VOCs are observed at concentrations that could potentially result in impacts to groundwater, complete four additional soil borings (by vertical and angle drilling) to evaluate the nature and extent of the VOCs. The vertical borings will be installed to the bedrock surface (estimated to be approximately 40 feet below grade), and the angle borings will be installed to the bottom of the sand layer.

TABLE 3

SUMMARY OF GROUNDWATER ANALYTICAL PROGRAM
TECUMSEH PRODUCTS COMPANY

Monitoring Well	Analytical Group ⁽¹⁾				Replicate Sample	Comments
	A	B	C	D		
MW-1	X					
MW-3	X					
MW-3D	X	X	X	X		
MW-3BR1	X	X		X	X	
MW-3BR2	X					
MW-3BR3	X	X				
MW-6	X			X		
MW-8	X	X	X	X		
MW-8D	X					
MW-9	X					
MW-9D	X	X				
MW-10	X	X		X		Background
MW-11	X	X				Background
MW-12	X	X			X	
MW-12BR	X					
MW-13BR1	X	X		X		
MW-13BR2	X					
MW-13BR3	X	X			X	
MW-14BR	X					
MW-15BR1	X					
MW-15BR2	X					
MW-16	X					Contingent well, background
MW-17	X					
MW-18BR1	X					
MW-18BR2	X				X	
MW-19BR1	X					
MW-19BR2	X					
MW-20BR1	X					Contingent well

TABLE 3 (CONTINUED)

SUMMARY OF GROUNDWATER ANALYTICAL PROGRAM
TECUMSEH PRODUCTS COMPANY

Monitoring Well	Analytical Group ⁽¹⁾				Replicate Sample	Comments
	A	B	C	D		
MW-20BR2	X					Contingent well
MW-21BR1	X					Contingent well
MW-21BR2	X					Contingent well
MW-22BR1	X					Contingent well
MW-22BR2	X					Contingent well
MW-23BR1	X					Contingent well
MW-23BR2	X					Contingent well
GMW01S	X					WDNR well, background
GMW01D	X					WDNR well, background
Total Number of Samples	41	13	2	7		

NOTES:

⁽¹⁾ Analytical Group A: volatile organic compounds quantified under USEPA Method 8021 and in-field pH and conductivity determination.

Analytical Group B: Major cations and anions, as follows:

Calcium	Alkalinity
Magnesium	Sulfate
Sodium	Chloride
Potassium	Total dissolved solids
Iron	Manganese

Analytical Group C: polynuclear aromatic hydrocarbons (PAHs) quantified under USEPA Method 8270A, as follows:

Acenaphthene	Benzo(g,h,i)perylene	Indeno(1,2,3-cd)pyrene
Acenaphthylene	Benzo(a)pyrene	1-Methylnaphthalene
Anthracene	Chrysene	2-Methylnaphthalene
Benzo(a)anthracene	Dibenz(a,h)anthracene	Naphthalene
Benzo(b)fluoranthene	Fluoranthene	Phenanthrene
Benzo(k)fluoranthene	Fluorene	Pyrene

Analytical Group D: bioremediation constituents, including:

- In-field dissolved oxygen and redox potential
- Ammonia
- Nitrate + nitrite nitrogen
- Total Kjeldahl nitrogen (TKN)
- Ortho-phosphate
- Total organic carbon (as NPOC)
- Biochemical oxygen demand

TABLE 4

**PROPOSED GROUNDWATER ANALYTICAL PARAMETERS AND DETECTION LIMITS
TECUMSEH PRODUCTS COMPANY**

Analyte	Method ¹	Detection Limit (µg/L)
Analytical Group A		
Volatile organic compounds	8021	1.0
Analytical Group B		
Calcium (ICP)	200.7	500
Magnesium (ICP)	200.7	500
Sodium (ICP)	200.7	500
Potassium (ICP)	200.7	500
Iron (ICP)	200.7	100
Alkalinity	310.1	20,000
Sulfate	9036 ²	10,000
Chloride	325.1	2.0
Total dissolved solids	160.1	20,000
Manganese (ICP)	200.7	5
Analytical Group C		
Polynuclear Aromatic Hydrocarbons listed in Table 2	8270A	10
Analytical Group D		
Dissolved oxygen	Field measurement	--
Redox potential	Field measurement	--
Ammonia	350.2	100
Nitrate + nitrite	353.2	50
Total Kjeldahl nitrogen	351.3	100
Ortho-phosphate	365.2	100
Total organic carbon (as NPOC)	415.1	250
Biochemical oxygen demand	405.1	2,000

NOTES:

¹ Methods are EPA-600 except as noted.

² Method SW-846

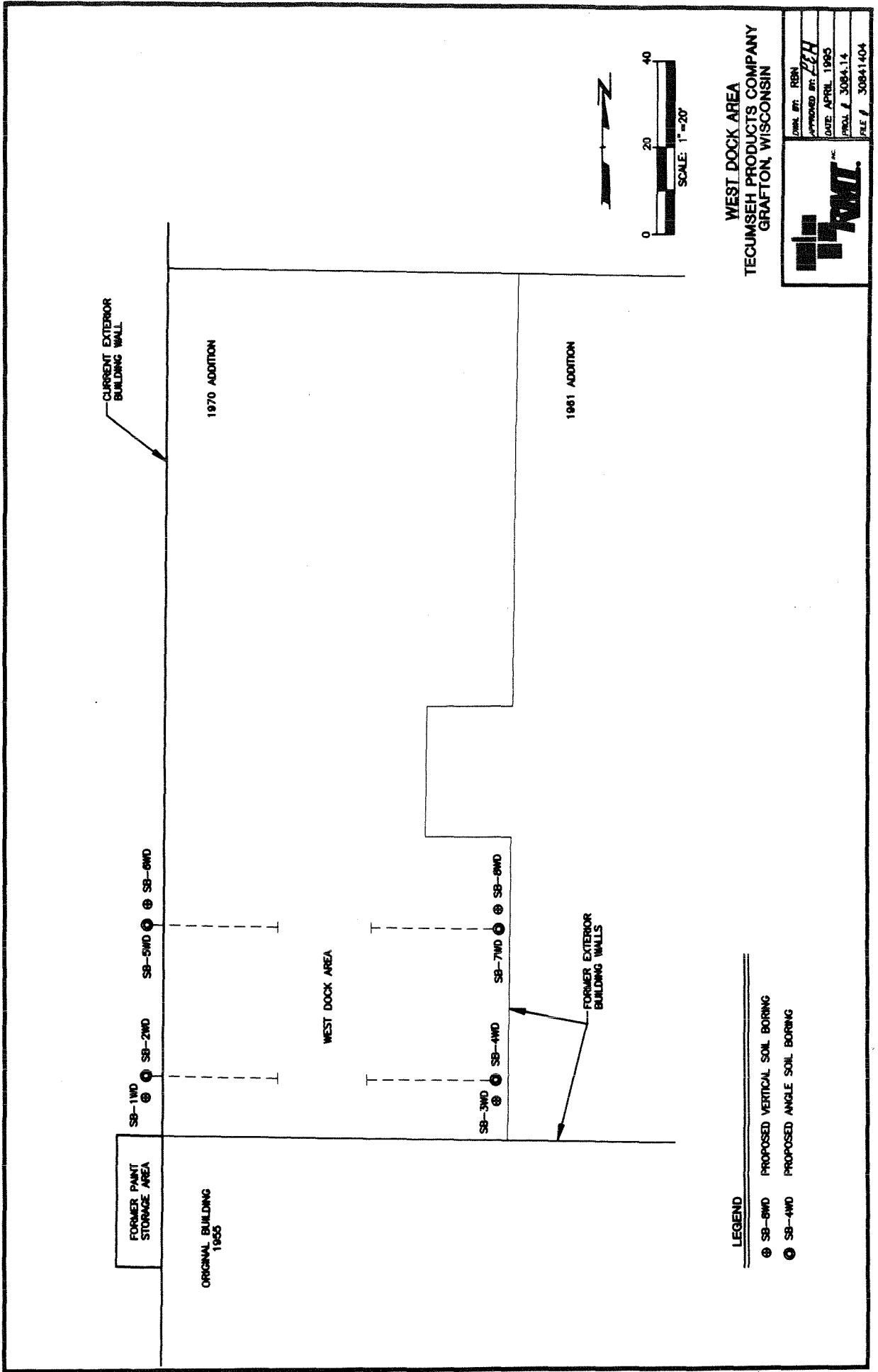


FIGURE 5

Drawing File = H:\3084.14\30841404
 Plot File = 30841404.PLF
 Scale = 2000000.000000
 Plot Date = Mon Apr 24 12:55:17 1995

- Collect soil samples with a 2-foot-long split-spoon sampler at 2.5-foot intervals until the water table is encountered. Collect soil and groundwater samples (from the sandy soil only) at alternating 4-foot intervals below the water table until either the bottom of the sand is reached (for the angle borings) or until bedrock is reached (for the vertical borings). Modify the groundwater sampling intervals as necessary to be able to collect the groundwater samples from sandy intervals. Collect the groundwater samples using a Hydropunch® sampler.
- Analyze the headspace concentrations of the clay soil samples and the groundwater samples for the following VOCs using a portable GC: dichloroethenes (1,1-DCE; cis-1,2-DCE; and trans-1,2-DCE), TCE, TCA, toluene, and xylenes.
- Laboratory-analyze two clay soil samples from each boring for VOCs using USEPA Method 8021. The soil samples submitted for analysis will be selected on the basis of the portable GC results and the visual observations of the soil. Four of the samples will also be analyzed for polynuclear aromatic hydrocarbons using USEPA Method 8270A. The soil sampling program is summarized in Table 2.
- Collect four soil samples from the West Dock Area and one soil sample from a background location, and submit the samples for laboratory determination of biodegradation potential of petroleum hydrocarbons and chlorinated VOCs. Each soil sample will be analyzed for the following constituents: microbial degrader population, ammonia nitrogen, nitrate + nitrite nitrogen, total Kjeldahl nitrogen (TKN), ortho-phosphate, potassium, pH, percent organic matter, percent total solids, percent air-filled pore space (by measuring bulk density), and soil moisture content.

TCA Filling Area

- Install five soil borings to the bedrock surface (approximately 30 feet below grade) to determine whether the TCA Filling Area is a source of VOCs in the groundwater. One of the borings will be placed inside the building adjacent to the suspected point of release. The approximate locations of the borings are shown on Figure 6. If the observed groundwater and soil concentrations produced by in-field analyses suggest that this area may be a VOC source, complete up to nine additional soil borings in an area approximately 50 feet by 100 feet around the suspected point of release. The nine soil borings will be installed to the bottom of the near-surface clay layer, which is estimated to extend to approximately 12 feet below grade.
- Collect soil samples with a 2-foot-long split-spoon sampler at 2.5-foot intervals until the water table is encountered. In the deeper soil borings, collect soil and groundwater samples at alternating 4-foot intervals below the water table

APPROXIMATE LOCATION,
ENGINE ASSEMBLY
DEGREASER (1979-1992)

APPROXIMATE LOCATION,
4,000 GALLON SOLVENT
STORAGE TANK

SB-1TCA ⊕

ABOVE-GROUND FILL PIPE

EAST WALL
OF PLANT

FORMER WASTE PAINT CROCK

⊕ SB-6TCA

⊕ SB-4TCA

SB-2TCA ⊕

⊕ SB-13TCA

FORMER PAINT
STORAGE AREA

⊕ SB-7TCA

⊕ SB-9TCA

⊕ SB-3TCA

⊕ SB-5TCA

⊕ SB-15VOC

⊕ SB-8TCA

⊕ SB-10TCA

⊕ SB-11TCA

⊕ SB-12TCA

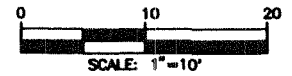
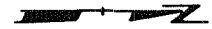
⊕ SB-14TCA

LEGEND

- ⊕ SB-15VOC EXISTING SOIL BORING
- ⊕ SB-8TCA PROPOSED SOIL BORING

NOTES

1. A 20-FOOT SCALE GRID WAS ADDED TO THE MAP TO AID IN PLACEMENT OF THE BORINGS IN THE FIELD.



TCA FILLING AREA
TECUMSEH PRODUCTS COMPANY
GRAFTON, WISCONSIN

	DRAWN BY: RBN
	APPROVED BY: <i>PEH</i>
	DATE: APRIL 1995
	PROJECT # 3084.14
	FILE # 30841405

Drawing File = H:\3084_14\30841405
 Plot File = P:\30841405.PRF
 SCALE = 10000000.000000
 Plot Date = Mon Apr 24 13:50:19 1995

FIGURE 6

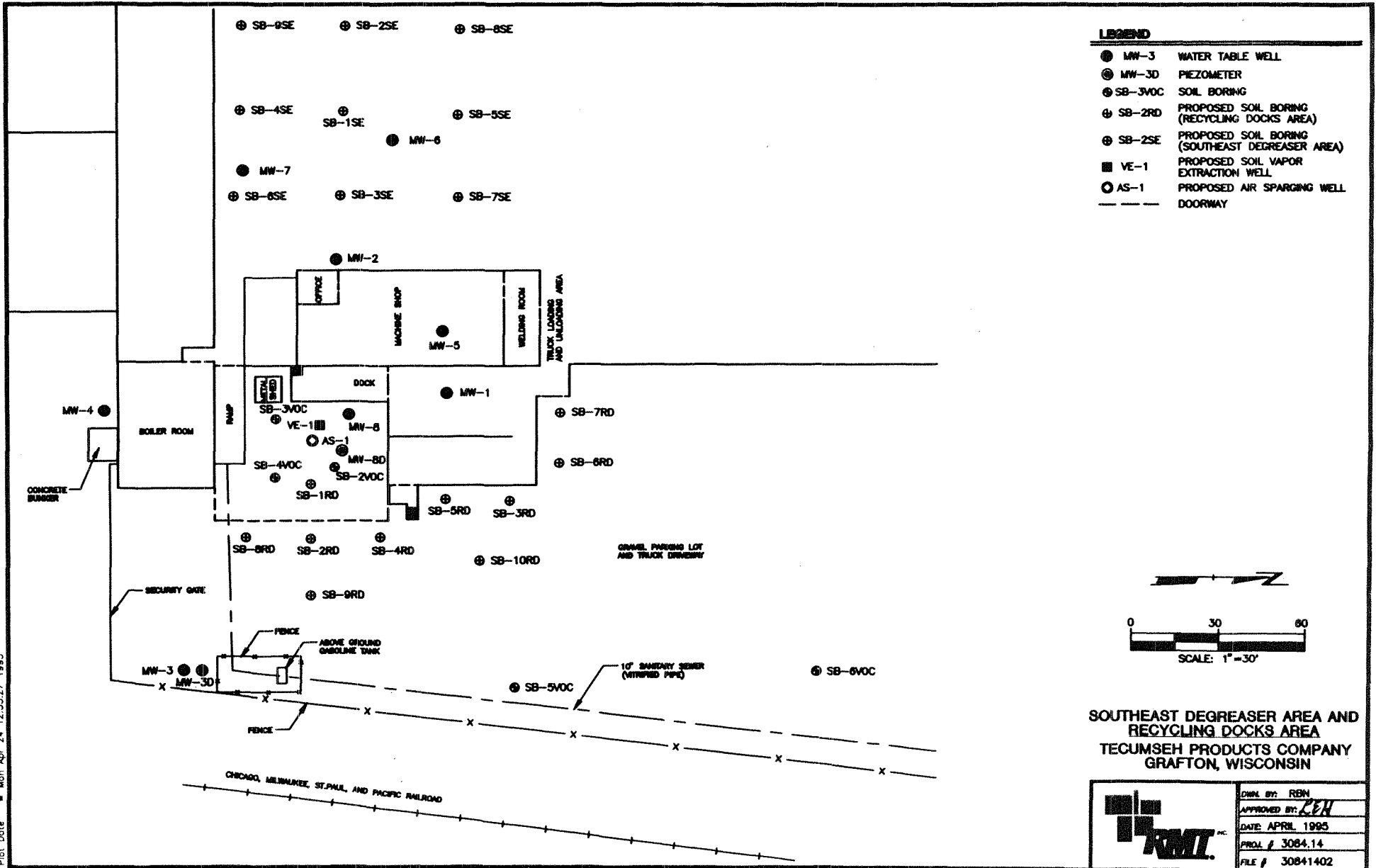
until bedrock is reached (modify the groundwater sampling intervals as necessary to be able to collect the groundwater samples from sandy intervals). Collect the groundwater samples using a Hydropunch® sampler.

- Analyze the headspace concentrations of the clay soil samples and the groundwater samples for the following VOCs using a portable GC: dichloroethenes (1,1-DCE; cis-1,2-DCE; and trans-1,2-DCE), TCE, TCA, toluene, and xylenes. Vertically profile the distribution of these constituents throughout the unconsolidated material.
- Laboratory-analyze two clay soil samples from each boring for VOCs using USEPA Method 8021. The soil samples submitted for analysis will be selected on the basis of the portable GC results and the visual observations of the soil.
- If the clay is found to be contaminated, submit four samples of clay to the laboratory for grain-size distributions, moisture content, and Atterberg limit analyses for use in potential remedial design.

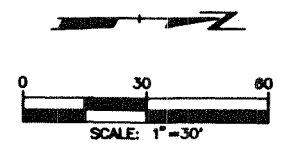
Southeast Degreaser Area

- Install up to nine soil borings in the Southeast Degreaser Area to evaluate whether this area is a source of VOCs in the groundwater of sufficient magnitude to warrant further consideration for remedial action. The approximate locations of the borings are shown on Figure 7. Install up to six soil borings to the bottom of the clay layer, which is estimated to be approximately 12 feet below grade, and three soil borings to the bedrock surface, which is estimated to be approximately 35 feet below grade.
- Collect soil samples with a 2-foot-long split-spoon sampler at 2.5-foot intervals until the water table is encountered. In the soil borings that extend to bedrock, collect soil and groundwater samples at alternating 4-foot intervals below the water table until bedrock is reached (modify the groundwater sampling intervals as necessary to be able to collect the groundwater samples from sandy intervals). Collect the groundwater samples using a Hydropunch® sampler.
- Analyze the headspace concentrations of the clay soil samples and the groundwater samples for the following VOCs using a portable GC: dichloroethenes (1,1-DCE; cis-1,2-DCE; and trans-1,2-DCE), TCE, TCA, toluene, and xylenes. Vertically profile the distribution of these constituents throughout the unconsolidated material.
- Laboratory-analyze two clay soil samples from each boring for VOCs using USEPA Method 8021. The soil samples submitted for analysis will be selected on the basis of the portable GC results and the visual observations of the soil.

Drawing File = H:\3084_14\30841402
 Plot File = P:\30841402.PRF
 SCALE = 3000000.000000
 Plot Date = Mon Apr 24 12:53:27 1995



LEGEND	
●	MW-3 WATER TABLE WELL
⊙	MW-3D PIEZOMETER
⊕	SB-3VOC SOIL BORING
⊕	SB-2RD PROPOSED SOIL BORING (RECYCLING DOCKS AREA)
⊕	SB-2SE PROPOSED SOIL BORING (SOUTHEAST DEGREASER AREA)
■	VE-1 PROPOSED SOIL VAPOR EXTRACTION WELL
○	AS-1 PROPOSED AIR SPARGING WELL
- - -	DOORWAY



SOUTHEAST DEGREASER AREA AND RECYCLING DOCKS AREA
TECUMSEH PRODUCTS COMPANY
GRAFTON, WISCONSIN

	DRAWN BY: RBN
	APPROVED BY: <i>CEH</i>
	DATE: APRIL 1995
	FILE # 3084.14

FIGURE 7

- Complete grain-size distributions, moisture content, and Atterberg limit analyses for three samples of clayey soil. Complete grain-size distributions and moisture content analyses for three samples of sandy soil. One clay sample and one sand sample will also be submitted for bulk density analysis.

Recycling Docks Area

- Install up to ten soil borings in the Recycling Docks Area, at the locations shown on Figure 7. Install seven soil borings to the bottom of the clay layer, which is estimated to be approximately 12 feet below grade, and three soil borings to the bedrock surface, which is estimated to be approximately 35 feet below grade.
- Collect soil samples with a 2-foot-long split-spoon sampler at 2.5-foot intervals until the water table is encountered. In the deeper soil borings, collect soil and groundwater samples at alternating 4-foot intervals below the water table until bedrock is reached (modify the groundwater sampling intervals as necessary to be able to collect the groundwater samples from sandy soil intervals). Collect the groundwater samples using a Hydropunch® sampler.
- Analyze the headspace concentrations of the clay samples and the groundwater samples for the following VOCs using a portable GC: dichloroethenes (1,1-DCE; cis-1,2-DCE; and trans-1,2-DCE), TCE, TCA, toluene, and xylenes. Vertically profile the distribution of these constituents throughout the unconsolidated material.
- Laboratory-analyze two clay soil samples from each boring for VOCs using USEPA Method 8021. The soil samples submitted for analysis will be selected on the basis of the portable GC results and the visual observations of the soil. Five of the samples will also be analyzed for polynuclear aromatic hydrocarbons (PAHs) using USEPA Method 8270.
- Complete grain-size distributions, moisture content, and Atterberg limit analyses for four samples of clayey soil. Complete grain-size distributions and moisture content analyses for four sandy soil samples. Submit one sample each of clayey and sandy soil samples for bulk density analysis.
- Collect five soil samples from the Recycling Docks Area, and submit the samples to a laboratory for determination of degrader microbe populations and nutrient analysis. Each soil sample will be analyzed for the following constituents: microbial degrader population, nitrate + nitrite nitrogen, ammonia nitrogen, total Kjeldahl nitrogen (TKN), ortho-phosphate, potassium, pH, percent organic matter, percent total solids, percent air-filled pore space (based on bulk density), and soil moisture content. The results of the laboratory analyses will be used to develop a baseline evaluation of *in situ* bioremediation of soil at the site.
- Install a soil vapor extraction well, an air sparging well, and two pilot test

monitoring points for use in future pilot-scale testing of remediation systems.

All Potential On-Site Source Areas

- Segregate and place the drill cuttings from each potential on-site source area in 55-gallon drums and store the drums at an on-site location.
- Collect a composite sample from each of the cuttings from the TCA Filling Area, the West Dock Area, the Southeast Degreaser Area, and the Recycling Docks Area. Analyze the samples for the constituents relevant to the disposal of the investigation-derived wastes.
- Place the decontamination, purge, and development waters in 55-gallon drums. On the basis of the portable GC analysis results, periodically discharge the collected water into the sanitary sewer with the permission of the Village of Grafton.

2.4 Third Interim Status Report Preparation

Upon completion of the fieldwork and laboratory analyses described above, RMT will prepare a third interim status report for review by the WDNR. The objectives of the third interim status report are as follows:

- To report the status of the hydrogeologic investigation following the third phase of the fieldwork and laboratory analyses
- To determine whether site conditions have been sufficiently characterized to complete an evaluation of remedial options for each source area and for groundwater

The work will include the following tasks:

- Update the tables, figures, and findings and conclusions contained in the January 1995 interim status report for this site to incorporate the results of the field investigations and laboratory analyses described in Subsections 2.1, 2.2, and 2.3.
- Meet with the WDNR and Tecumseh Products at the WDNR Southeast District Office to discuss the contents of the third interim status report and future plans for the site.

Section 3
SCHEDULE

The schedule for completing the third phase of the project is shown on Figure 8.

Project Schedule Tecumseh Products - Grafton Operations Phase III Investigation

Page 1 of 1

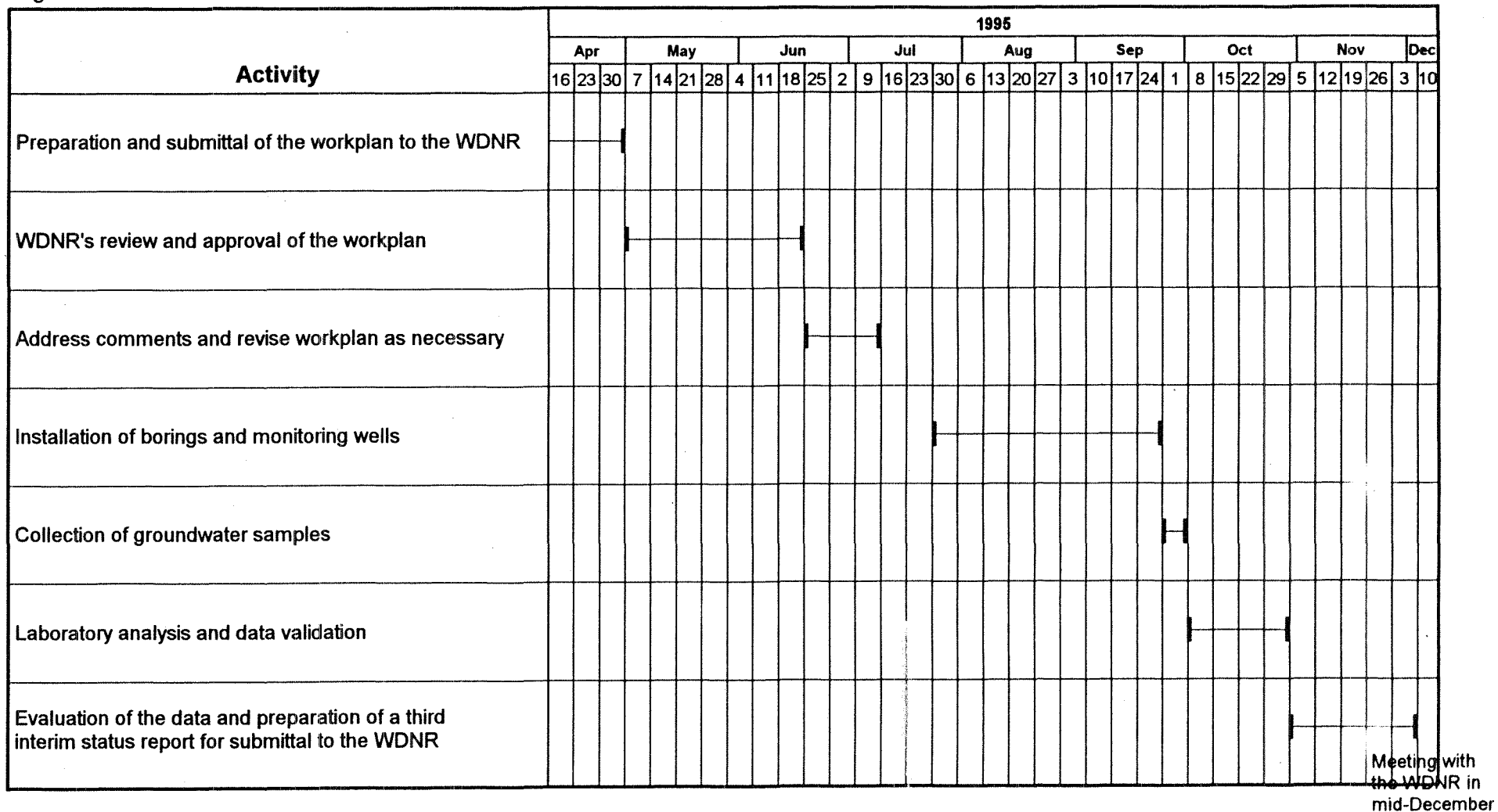


Figure 8

Section 4

REFERENCES CITED

- IT Corporation. 1989. Groundwater investigation of volatile organic compounds occurrence in Grafton, Wisconsin. WDNR Project No. 8707-14. August 1989.
- RMT, Inc. 1994a. Workplan to evaluate the extent of chlorinated VOCs in groundwater at the Tecumseh Products Company, Grafton, Wisconsin, facility. August 1994.
- RMT, Inc. 1994b. Interim status report on the subsurface investigative activities at the Tecumseh Products Company Grafton Operation. October 1994.
- RMT, Inc. 1994c. Phase II workplan to evaluate the extent of chlorinated VOCs in groundwater at the Tecumseh Products Company, Grafton, Wisconsin, facility. October 1994.
- RMT, Inc. 1995. Interim status report on the Phase II subsurface investigative activities at the Tecumseh Products Company Grafton Operation. January 1995.

APPENDIX A
FIELD METHODS

APPENDIX A
FIELD METHODS

1. Drilling and Soil Sampling

Soil borings outside the plant will be advanced by a truck-mounted drilling rig using 4.25-inch-inner-diameter (minimum) hollow-stemmed augers (HSAs). Samples of unconsolidated material will be collected using a 2-inch-inside-diameter, split-barrel sampler (split-spoon) as described in ASTM D1586-84, with the exception that the sampler will be driven 2 feet beyond the end of the augers. Soil samples will be collected at 2.5-foot intervals in the unsaturated zone and at 4-foot intervals below the water table. When the auger is advanced to the top of the desired sampling interval, the decontaminated split-spoon will be lowered into the hollow-stemmed auger on the end of an appropriate drill rod. The split-spoon will be driven 24 inches or to refusal (more than 60 blow counts per 6 inches) using a 140-pound weight. The number of blows required to drive each 6-inch increment will be noted by the driller and also recorded by RMT personnel. Once driven, the split-spoon and rod will be withdrawn from the auger, and the split-spoon will be removed from the rods. The split-spoon will be opened, and the amount of sample recovery will be measured. The split-spoon will be decontaminated before each sample is collected. (See Subsection 5.2 for decontamination procedures.)

Soil borings inside the plant will be advanced by a skid-mounted drilling rig using the dual-tube, reverse circulation, rotary drilling method. Using this method, air is forced down the annulus between the two tubes and is directed up the center of the inner tube, bringing drill cuttings with it. A minimal amount of clear water or drilling mud is added during drilling in the unsaturated zone to increase the competency of the drilling fluid (air). Samples of the unconsolidated material will be collected using a 2-inch-inside-diameter split-spoon sampler, as described above.

A portion of each sample collected during soil sampling will be retained to develop a log of the borehole. Soil samples will be classified according to the Unified Soil Classification System (USCS), in accordance with ASTM D2488-90. Boring logs will be prepared on WDNR Form 4400-122 in accordance with Chapter NR 141, Wisconsin Administrative Code.

2. Plugging and Sealing of Drill Holes

Soil borings that are not converted to groundwater monitoring wells will be abandoned by backfilling the borehole to the ground surface with bentonite chips. Borehole abandonment will be documented on WDNR Form 3300-5B in accordance with NR 141. The area around the borehole will be restored to its original condition.

3. Soil Sampling

Soil samples will be collected using a split-spoon sampler, and a portion of each sample will be retained for potential laboratory chemical analysis. Samples collected for laboratory analysis will be stored in appropriate containers and preserved where necessary. The samples will be immediately placed on ice and transported to the laboratory under chain-of-custody documentation.

4. Groundwater Sampling using a Hydropunch® Sampler

Groundwater samples will be collected at 4-foot intervals in the unconsolidated material using a Hydropunch® II sampler. The groundwater samples will be collected at alternating intervals with the split-spoon soil samples. When the auger is advanced to the top of the desired sampling interval, the Hydropunch® II will be lowered into the hollow-stemmed augers on the end of an appropriate drill rod. The Hydropunch® II will be driven 24 inches beyond the end of the augers. The tool will then be pulled back approximately 6 inches to expose the intake screen. From 5 to 15 minutes will be required to collect sufficient groundwater for the in-field GC analysis. The Hydropunch® II will be withdrawn and opened, and the groundwater will be transferred to a glass vial with a Teflon® septum seal. The vial will be taken to the portable GC laboratory for analysis.

The Hydropunch® II will be decontaminated between each sample using the procedures outlined in Subsection 5.2.

5. Decontamination Methods

5.1 Drilling Equipment

The downhole equipment (both augers and drill rods) will be steam-cleaned before startup and after each boring. Decontamination of the drilling rig and downhole equipment will take place on a temporary decontamination pad constructed at an on-

site location specified by the Owner. Decontamination water will be placed in a temporary container and, based on the results of the portable GC analysis, will be discharged periodically to the sanitary sewer, as verbally approved by the Village of Grafton.

5.2 Sampling Equipment

Precautions will be taken to minimize the potential for contamination between samples. The split-spoon sampler will be cleaned prior to its initial use on-site and between samples. Cleaning procedures will involve scrubbing away soil material with a stiff brush using a trisodium phosphate soap and water solution, and then double-rinsing in clean, potable water.

At the end of drilling at a borehole, the split-spoons will be steam-cleaned, followed by the washing and rinsing procedures. Other reusable sampling equipment (bowls, spatulas, etc.) will be decontaminated by the washing and rinsing procedures. Spent decontamination liquids from the sampling equipment will be handled in the same manner as the water from the drilling equipment decontamination procedures.

6. Investigation-Derived Wastes

Soil and rock cuttings generated during the performance of the soil and bedrock borings will be segregated by the area from which they were generated and placed in WDOT-approved, 55-gallon drums, labeled and stored on-site. Composite samples from each area will be collected and analyzed for the parameters needed to determine the disposal requirements for the investigation-derived wastes.

Soil cuttings from the downgradient locations are not expected to have contacted VOC-bearing groundwater. The soil cuttings will be containerized and moved to the Tecumseh facility simply to maintain clean off-site locations.

Purge and development water will be placed in a temporary container and, based on results of the portable GC analysis, will be discharged periodically to the sanitary sewer, per the verbal approval of the Village of Grafton.

7. Portable Gas Chromatograph Analyses

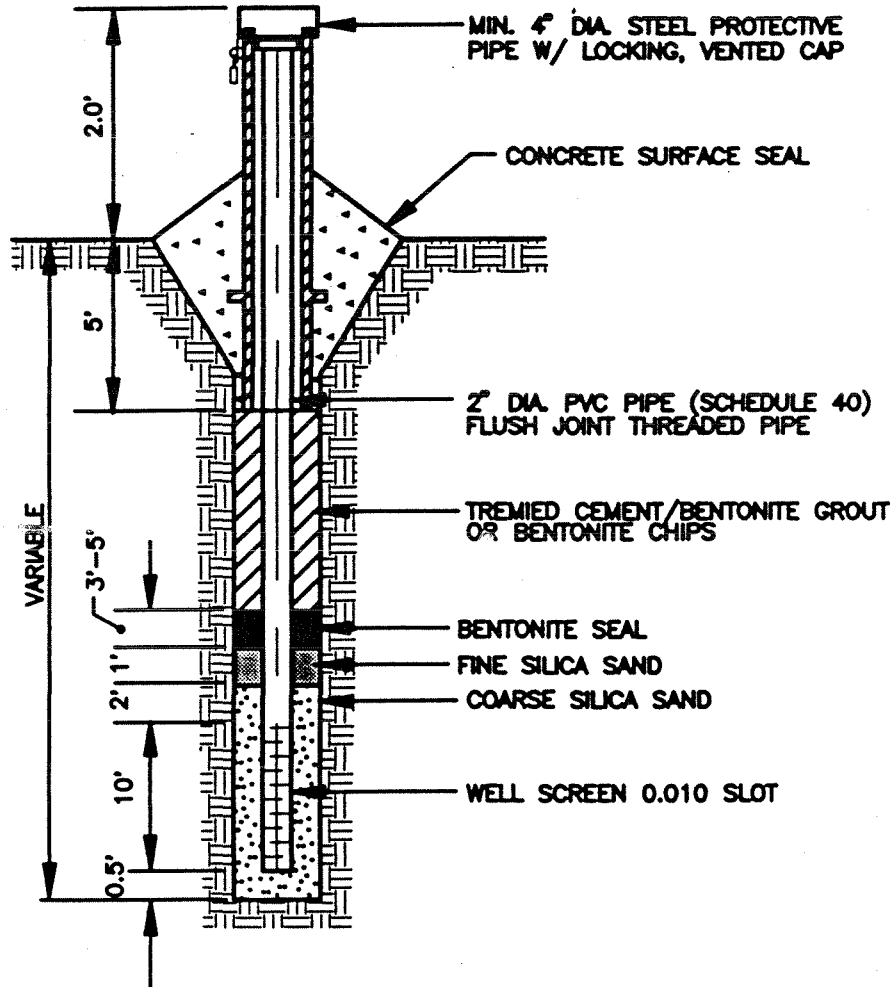
Groundwater samples will be field-screened for selected VOCs using a Photovac® Model 10S50 GC portable gas chromatograph (GC). The portable GC analysis will be used to characterize the presence and relative concentration of selected VOCs in the headspace on a near real-time basis. The headspace will be analyzed for dichloroethenes (1,1-DCE; cis-1,2-DCE; and trans-1,2-DCE), trichloroethene (TCE); 1,1,1-trichloroethane; toluene; and xylenes. Standard operating procedures for the portable GC are included in Appendix B.

8. Shallow Monitoring Well Installation and Development


The water table wells in the unconsolidated material will be constructed using 2-inch-diameter Schedule 40 PVC with flush-threaded joints. The water table wells will have 10-foot-long screens and will be constructed as shown on Figures A-1 or A-2, depending on the surface finish. The wells will have a locking protective steel pipe over the stick-up casing unless traffic patterns in the area create too much potential for damage to the surface casing. As-built well construction diagrams will be prepared on WDNR Form 4400-113A.

The monitoring wells will be installed through the augers (minimum inside diameter of 4.25 inches). The bottom of the well will be firmly seated on sand, and the sand pack (medium-grained silica sand) will extend approximately 2 feet above the well screen. A 2-foot-thick fine silica sand layer will be placed on top of the filter pack, and a 2-foot-thick bentonite chip seal will be placed over the fine sand. The remaining annular space above the filter pack seal will be filled with bentonite chips or a bentonite slurry grout. A lockable protective steel pipe or surface cover will be placed over the riser pipe.

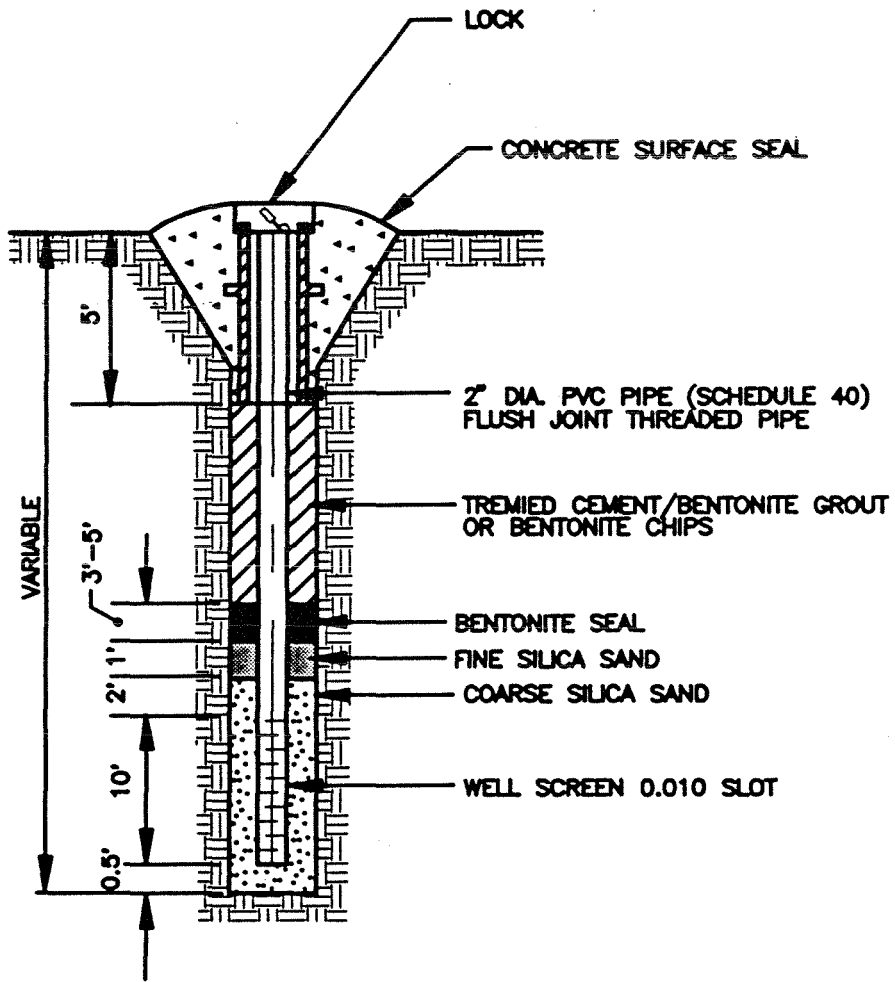
After completion of the well installations, the wells will be developed in accordance with NR 141, Wisconsin Administrative Code, to improve the hydraulic connection between the well and the surrounding formation and to reduce the amount of sediment in the groundwater samples. The wells will be developed by surging a dedicated bailer across the screened interval of the well for 30 minutes, and then pumping the well until 10 well volumes have been removed or until the well is bailed dry three times. Well development will be documented on WDNR Form 4400-113B.



**WATER TABLE WELL
CONSTRUCTION DETAIL
(STICK-UP SURFACE CASING)
TECUMSEH PRODUCTS COMPANY
GRAFTON, WISCONSIN**

	DWN. BY: MDD
	APPROVED BY: <i>PEH</i>
	DATE: APRIL 1995
	PROJ. # 3084.03
	FILE # 30840306


Drawing File = H:\3084_03\30840306
 Plot File = P:\30840306.PRF
 SCALE = 100000000.000000



**WATER TABLE WELL
CONSTRUCTION DETAIL
(FLUSH-MOUNT COVER)**

**TECUMSEH PRODUCTS COMPANY
GRAFTON, WISCONSIN**

Drawing File = H:\3084_03\30840307
Plot File = P:\30840307.PRF
SCALE = 100000000.000000

	OWN. BY: MDD
	APPROVED BY: <i>PEH</i>
	DATE: APRIL 1995
	PROJ # 3084.03
	FILE # 30840307

The vertical elevation of the top of the PVC casing of each well will be surveyed to an accuracy of 0.01 foot and will be referenced to the National Geodetic Vertical Datum (NGVD). The horizontal location of each well will be referenced to the State Plane Coordinate System.

9. Installation of Soil Vapor Extraction, Air Sparging, and Pilot-Test Monitoring Points

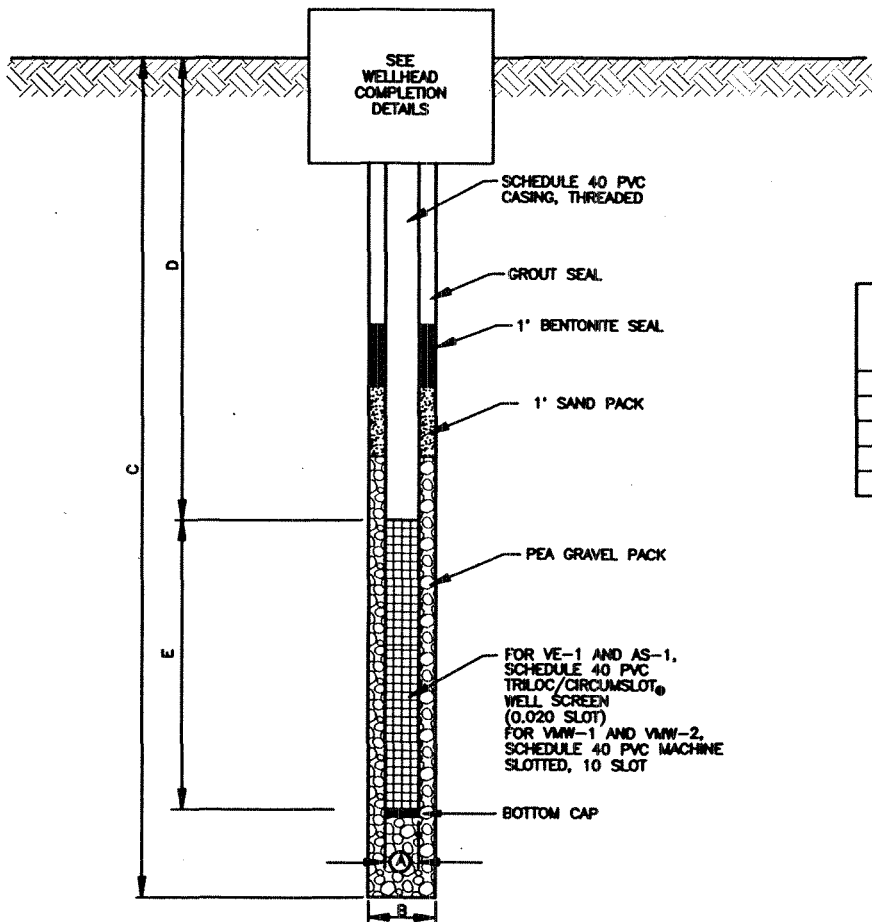
The soil vapor extraction well (VE-1) will be constructed of 4-inch-inner-diameter flush-threaded Schedule 40 PVC casing and Schedule 40 PVC triloc/circumslot well screen. The well screen will be 10 feet long and will have a slot size of 0.020 inch, as shown on Figure A-3. The bottom of the well screen will be installed approximately 1 to 2 feet below the water table surface.

The air sparging well (AS-1) will be constructed of 2-inch-inner-diameter flush-threaded Schedule 40 PVC casing and Schedule 40 PVC triloc/circumslot well screen. The well screen will be 3 feet long and will have a slot size of 0.020 inch, as shown on Figure A-4. The well screen will be installed approximately 10 feet below the water table surface.

Vapor monitoring points VMW-1 and VMW-2 will both be installed with three small-diameter probes in a single borehole—two of the probes will be screened in the unsaturated zone and one will be screened across the water table. The probes will be installed to depths of 3, 7, and 13 feet, respectively, and the screened intervals will be separated by bentonite chips. The 2- and 7-foot-deep probes in each borehole will be constructed of 1-inch-inner-diameter Schedule 40 PVC, and the well screens will be 1 foot long. The 13-foot probe in each borehole will be constructed of 2-inch-inner-diameter Schedule 40 PVC, and the well screen will be 3 feet long.

10. Bedrock Monitoring Well Installation

The boreholes for bedrock well installation will be advanced through the unconsolidated material using 12-inch mud rotary. The boreholes will be drilled without sampling shallow soil or groundwater. After bedrock is reached, 8-inch steel well casing will be installed in the boreholes. The casing will not be grouted in place. The boreholes will be advanced through the bedrock using 8-inch air rotary. The bedrock wells will be advanced to the bottom of the



WELL NUMBER	(A) CASING DIA., in.	(B) BOREHOLE DIA., in.	(C) BORING DEPTH, ft.	(D) DEPTH TO SCREEN, ft.	(E) LENGTH OF SCREEN, ft.
AS-1	2	8	20	17	3
VE-1	4	10	13	5	8
VMW-1	1,1,2	10	13	2,6,10	1,1,3
VMW-2	1,1,2	10	13	2,6,10	1,1,3

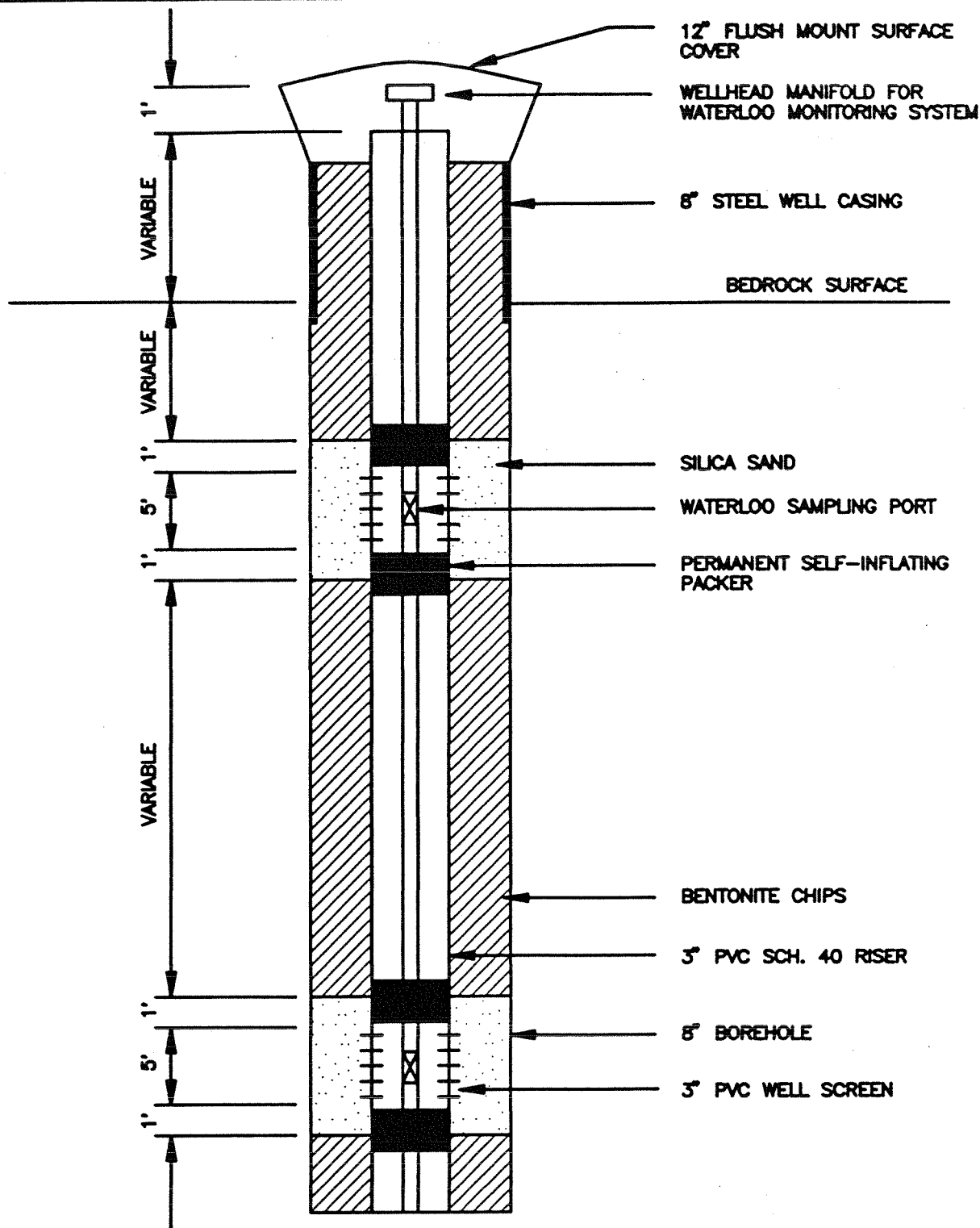
NOTES

1. MONITORING POINTS VMW-1 AND VMW-2 WILL BOTH BE INSTALLED WITH THREE SMALL-DIAMETER PROBES IN A SINGLE BOREHOLE-TWO SCREENED IN THE UNSATURATED ZONE AND ONE SCREENED ACROSS THE WATERTABLE.

SOIL VAPOR EXTRACTION,
AIR SPARGING, AND
ASSOCIATED MONITORING WELLS
TECUMSEH PRODUCTS COMPANY
GRAFTON, WISCONSIN


	DRN. BY: RBN
	APPROVED BY: <i>PEH</i>
	DATE: APRIL 1995
	PROJ. # 3084.14
	FILE # 30841408

FIGURE A-3



**BEDROCK WELL CONSTRUCTION DETAIL
WITH WATERLOO MULTILEVEL MONITORING SYSTEM
TECUMSEH PRODUCTS COMPANY
GRAFTON, WISCONSIN**

Drawing File = H:\3084_14\30841401
 Plot File = P:\30841401.PRF
 SCALE = 10000000.000000

	DWN BY RBN
	APPROVED BY <i>LEH</i>
	DATED APRIL 1995
	PROJ # 3084.14
	FILE # 30841401

APR 24 1995 **FIGURE A-4**

VOC plume or to a maximum of 150 feet into the plume, whichever comes first. Crushed bedrock samples will be collected from the air stream as they are brought to ground surface to allow classification of the subsurface material.

Drilling in the bedrock will be completed in 30-foot intervals in borings MW-18BR through MW-21BR and in 40-foot intervals in borings MW-22BR and MW-23BR. Groundwater samples will be collected from each interval using a single-packer system and a Grundfos 2-inch sampling pump. At each 30- or 40-foot interval, the pump will be lowered downhole and the packer will be inflated above the pump. Each interval will be pumped for approximately 15 minutes (if the interval yields water) before a sample is collected. The pumping rate will be recorded with clock and bucket methods, and hydraulic head declines will be noted with a pressure transducer. The sample will be collected under low pumping flow conditions and transferred to a glass vial with a Teflon® septum seal. The vial will be taken to the portable GC laboratory area for immediate analysis.

After the boreholes are advanced to completion depth, a downhole video inspection will be performed on each borehole to determine where the fractures are located. A maximum of two monitoring zones will be selected based on the fracture locations identified with the video inspection, the pumping rate and head observations, and on the results of the in-field GC analysis.

The bedrock wells will be constructed using 3-inch-inner-diameter Schedule 40 PVC casing that will have up to two 5-foot-long screened intervals. Each screened interval will be separated by at least 20 feet of 3-inch Schedule 40 PVC riser. The locations of the screened intervals will be determined based on the results of the packer testing, portable GC analysis, and the video logging. The wells will be constructed as shown on Figure A-4. A No. 30 sand pack will be installed in the annular space between each screen and the borehole, extending from approximately 1 foot below the bottom of the screen to 1 foot above the top of the screen. A one-foot-thick fine sand seal will be installed above the filter sand pack in each screened interval. The screened intervals will be separated by bentonite chips. The bentonite chips will be placed from the top of the fine sand seal in one screened interval to approximately 1 foot below the well screen in the next screened interval. The bentonite chips will be added through a tremie pipe to minimize the problem of bridging or void formation.

The volume of the borehole will be determined prior to installing the chips to estimate the volume of chips needed for the annular space seal. The chips will be placed in one continuous operation so that the integrity of the filter pack is not disturbed. As the chips are added to the borehole, the depth to the top of the chips will be continuously measured to determine when a sufficient seal has been placed. The estimated and actual volume of sealing material will be calculated and reported to the WDNR.

A Waterloo Multilevel Groundwater Monitoring System, manufactured by Solinst Canada, Ltd., of Ontario, Canada, will be installed inside the 3-inch PVC casing. The Multilevel Monitoring System is composed of PVC sample/pressure ports, permanent positive-seal packers, various casing lengths, a base plug, and a surface manifold. Permanent self-inflating packers will be installed at the top and bottom of each monitoring port to provide a continuous seal within the borehole. The packers and sampling ports will effectively isolate each monitoring interval and will allow for the monitoring of discrete zones within the bedrock. Each monitoring port will be fitted with a dedicated sampling pump for collecting groundwater samples. If the depth to water is less than 50 feet, open tubes will be attached to each port for measuring hydraulic head. If the depth to water is greater than 50 feet, dedicated pressure transducers will be placed within each sampling port for measuring hydraulic head.

The modular components of the Multilevel Groundwater Monitoring System will be threaded together in the appropriate order and lowered down the borehole one section at a time. Casing clamps will be used for support, and water will be added to the casing string to overcome buoyancy, as required. After installation of the Waterloo system, water will be added to the casing string, causing packer expansion. It will take approximately 24 to 48 hours for the packers to effectively seal the borehole.

The bedrock wells will be completed with permanent 12-inch flush-mounted surface covers. The PVC riser will be cut off approximately 1 foot below ground surface to allow room for the multi-level wellhead manifold to be installed within the flush-mounted surface cover.

11. Groundwater Sampling and Decontamination Procedures

Static water levels will be measured in the monitoring wells prior to purging or sampling. Groundwater levels in the monitoring wells installed in the unconsolidated material and in the bedrock monitoring wells installed with open tubes will be measured using a reference point established on the well casing. The reference point will be the highest point of the well casing. In order to prevent cross-contamination, the water level measuring device will be decontaminated between wells by rinsing with distilled water. Groundwater levels in the bedrock monitoring wells installed with dedicated in-line pressure transducers will be measured using a GK-403 vibrating wire readout unit, which will be connected to the transducers for automatic water level readings.

The monitoring wells will be purged to remove stagnant water to ensure that the samples collected are fresh formation water. Before sampling each well, a total of four well volumes will be purged. The monitoring wells in the unconsolidated material will be purged using a pre-cleaned PVC bailer. The bailer will be dedicated for use in only one well.

Groundwater samples in the bedrock monitoring wells will be collected using a dedicated in-line double-valve pump system. The drive pressure for the pump will be provided by a nitrogen tank and an automatic pump control unit. Using the vent cycle of pumping, water flows from the formation into the pump and associated tubing. Water is displaced to the surface from the pump and associated tubing during the pressure cycle of pumping. The pump is cycled from vent to pressure as needed until the appropriate purge volume is obtained. All sampling ports within a well will be purged simultaneously.

Groundwater samples will be collected from the monitoring wells immediately after purging. The procedures for the sampling of the monitoring wells are as follows:

- Set up and prepare meters.
- Prepare bottles by writing the date, the sampler's name, and the time of day in the sampler section.
- Collect samples from the monitoring wells in the unconsolidated material using a pre-cleaned PVC bailer and a bottom-discharging device to prevent excessive amounts of agitation and aeration. The bailer will be dedicated for use in only one well.

- Collect samples from the bedrock monitoring wells directly from the dedicated dual-line tubing.
- Place the samples on ice immediately.
- Perform field measurements for pH, temperature, and specific electrical conductance.
- Complete documentation of the sample collected in the sample log book and on the chain-of-custody forms.

The tests conducted in the field and the instrument calibration procedures are described below:

- **Temperature** - The temperature of the groundwater sample will be recorded immediately after the sample is removed from the well.
- **Specific Conductance** - The specific conductance of the liquid will be measured in the same groundwater sample used for the temperature measurement. A portable specific conductance meter will be used to measure the specific conductance of the groundwater sample.
- **pH** - The pH measurements will be made electrometrically using a combination electrode and portable pH meter. Portable meters with provisions for temperature compensation will be used. The meter and electrode will be checked against standard buffer solutions of known pH values (4 and 7).

All equipment used for sampling that is not dedicated (e.g., bailers, water level measuring devices, etc.) will be decontaminated prior to initial use by the following methods:

- Prepare a soapy water bath using laboratory-grade detergent.
- Unwind and soak water level measuring devices in soapy water, and wipe clean with a cloth.
- Rinse all equipment with tap water.
- Rinse all equipment, except water level measuring devices, inside and outside, with diluted 1:1 nitric acid.
- Rinse all equipment with deionized water.
- Dry all equipment, except water level measuring devices, in the oven at 105°C, and seal in polypropylene plastic to prevent contamination.

12. Chain-of-Custody Procedures

The possession of samples will be traceable from the time of collection through the use of chain-of-custody procedures. Specific chain-of-custody forms will accompany all sample shipping containers to document the transfer of the shipping containers and samples from the field collection point to the laboratory receiving the samples for analysis. The procedures to be implemented are as follows:

- Properly identify and label the samples in the field.
- Complete a chain-of-custody form in the field, indicating sample identification, the number of containers filled, the sampling date, the sampling time, and the sample collector's name.
- Pack shipping container with samples, chain-of-custody forms, and ice. The sample container should be assigned a chain-of-custody form, which travels with the container.
- Seal, date, and ship the coolers to the appropriate laboratory using an overnight delivery service or via RMT field vehicle.
- Receive and check shipping containers in the laboratory for broken seals or damaged sample containers.

APPENDIX B

**RMT STANDARD OPERATING PROCEDURE FOR
PORTABLE GC ANALYSIS OF GROUNDWATER SAMPLES**

APPENDIX B

RMT STANDARD OPERATING PROCEDURE FOR PORTABLE GC ANALYSIS OF GROUNDWATER SAMPLES

1. Parameters To Be Analyzed

The parameters to be analyzed by the portable GC for this investigation are the dichloroethenes (1,1-DCE, cis-1,2-DCE, and trans-1,2-DCE), trichloroethene, 1,1,1-trichloroethane, toluene, and xylenes. These parameters were selected on the basis of previously identified constituents in groundwater and soil, and on the sensitivity of the portable GC to these parameters. The peak area of targeted parameters will be determined for each sample. Quantitation of the specified compounds is determined by comparing peak areas of standards to those of the field samples.

2 & 3. Range of Measurement and Limits of Detection

The anticipated limits of detection are presented in Table B-1. These detection limits are based on the concentration represented by the minimum recorded peak area for the GC (0.1 v-sec) at normal operating conditions. The maximum measurable concentrations for the different parameters are around 1,000 $\mu\text{L/L}$ (parts per million by volume). The $\mu\text{L/L}$ (or ppm) units will be used to avoid confusion between concentration units in water and air.

4. Sample Matrix

The concentrations of VOCs in water will be estimated by measuring the headspace concentration over the water in a VOA vial. At equilibrium, the VOCs partition between the headspace and water in accordance with Henry's Law, as follows:

$$H = \frac{\text{concentration in air}}{\text{concentration in water}}, \text{ where } H \text{ is a constant}$$

Standards will be prepared using the procedures suggested in the Photovac® Technical Bulletin #27 (Attachment 1). The standards will be analyzed at the same time as the samples, and each parameter's operational partitioning coefficient will be calculated. The operational partitioning coefficient is the reciprocal Henry's Law constant, with the effects of temperature, equilibration time, kinetics, and relative volumes of water and headspace included.

TABLE B-1	
DETECTION LIMITS FOR SELECTED CHLORINATED VOCs AND XYLENES ANALYZED BY PORTABLE GC	
Parameter	$\mu\text{L/L}$
1,1-Dichloroethene	0.05
cis-1,2-Dichloroethene	0.05
trans-1,2-Dichloroethene	0.05
Trichloroethene	0.1
1,1,1-Trichloroethane	0.3
Toluene	0.03
m,p-xylenes	0.03
o-xylene	0.04

The operational partitioning coefficient (OPC) is calculated as follows:

$$\text{OPC} = \frac{(\text{original concentration in water, } \mu\text{g/L})(\text{gain})(\text{injection volume})}{\text{concentration in headspace, v-sec}}$$

Water concentrations will be determined by preparing samples and standards, and then multiplying the sample concentration by the OPC and dividing by gain and injection volume, as follows:

$$\text{Water concentration, } \mu\text{g/L} = \frac{(\text{OPC})(\text{GC response, v-sec})}{(\text{gain})(\text{injection volume, } \mu\text{L})}$$

5. Principle, Scope, and Application

Headspace analysis is a convenient means of screening for VOC contamination. In principle, VOCs contained in water will partition between the water and the air in contact with the water, with partitioning dependent on the VOC concentration in the water as well as on several other factors (Devitt, et al., 1987). Analysis of the headspace gas can be done in the field using a portable gas chromatograph, and can provide near real-time screening analysis of VOCs. Due to the variability of factors that influence VOC partitioning between the water and air, headspace analysis is best used for screening VOC levels rather than for quantitatively analyzing the VOC content in the field. However, measurement of the VOC concentration in the gas itself is a quantitative measurement.

Headspace screening is useful for locating areas of contamination and relative levels of contamination, for selecting samples for further laboratory analysis, and for determining the areas that should be further investigated (e.g., soil borings or monitoring well installation).

6. Interferences and Corrective Action

Interferences are uncommon in the analysis for the parameters analyzed under standard operating conditions. However, components of gasoline coelute with di- and trichloroethylene and, if gasoline is present, it is difficult to quantify di- and trichloroethylene. Generally, however, gasoline and the chlorinated ethylenes are not found in the same sample. In addition, ethylbenzene and m- and p-xylene peaks overlap. If both peaks are present, the peak is calculated as if it contained the constituent giving the large peak, and a note is made that both compounds were present.

Dirty apparatus can cause problems with a portable GC, since many surfaces (notably teflon) can adsorb and desorb gaseous constituents. Several precautions and cleanup steps are used to avoid such cross-contamination. First, standards are transported separately from the syringes, septa, etc., so that no cross-contamination during transport occurs. Second, column and syringe blanks are run whenever contamination is suspected. Third, syringes are cleaned between each run by removing the plunger and allowing the contamination to disperse, or by purging the syringe or plunger with compressed air from the air cylinder. If syringe contamination is suspected, a syringe blank is run in which room air or compressed air is injected into the GC with the syringe in question. Syringes that remain contaminated after purging are baked overnight in a portable oven. Ambient air contamination has not typically been found to be a problem.

7. Safety Precautions

Samples will be contained in 40-mL VOA vials, and the analyst will not come in direct contact with the sample. If samples need to be transferred from one vial to another, or if a vial breaks, the analyst will follow the standard procedures used when working with chemicals. All pure solvents used for making standards will also be kept in 40-mL VOA vials, and the analyst will not come into contact with the solvents.

Standard laboratory practices will be taken when working with the gas cylinders used for gas supply to the GC. The cylinders will be either secured to the wall by chains or, in places where no wall mountings are available, supported by a gas cylinder stand.

8. Sample Size, Collection, Preservation, and Handling.

Water samples will be collected in 40-mL VOA vials with a septum top. The vials will be filled approximately half full. The vials will be allowed to equilibrate at room temperature for at least 30 minutes. No preservatives will be used in the samples. After the equilibration time, an aliquot of the headspace will be removed with a syringe through the septum, and injected into the GC for analysis. Injections will be repeated until the peaks of interest are on scale. The sample will be disposed of with other potentially affected waters.

9. Apparatus

The GC used is a Photovac® Model 10S50 Portable Gas Chromatograph. Other sampling equipment used for the headspace analysis is listed in Table B-2.

10. Routine Preventive Maintenance

The routine preventive maintenance procedures used in day-to-day operation of the GC are described in Section 14 below. The procedures include running column and syringe blanks at the start of a day's operation, and when syringe or instrument contamination is suspected. The injection port septa is changed after 50 to 75 injections. VOA vial blanks are run if vial contamination is suspected.

The neat solvents used for preparing standards will be stored and transported separately from the other GC equipment to avoid cross-contamination. Septa, syringes, and the plastic portions of the gas sample bottles will be stored in organic contamination-free areas.

A common analytical problem is clogging or partial clogging of the injection syringe needles. Occurrence of partial clogging can be determined by running replicate samples. If the results cannot be replicated after several runs, the syringe needle will be changed. Clogged syringes can be detected by injecting air into a water-filled vial. If no bubbles are observed, then the needle will be changed.

11. Reagents and Calibration Standards

Pure solvents and calibration standards will be purchased from chemical supply companies. Commercially prepared gas standards will be purged into the gas sample bottles from pressurized gas cylinders. An example of standard concentrations is shown in Table B-3. Water standards will be prepared by appropriate dilution of pure solvent. Water standards will be prepared in 40-mL VOA vials using methanol and water as diluents. The final working solution will contain 20 mL of liquid in the 40-mL VOA vial. The constituents in water will be allowed to come into equilibrium with the headspace of the VOA vial prior to injection of this headspace to the GC. A new standard is prepared when the septum on the gas bottle becomes too perforated, or when the solvent volatilizes through the septum. A Photovac® Model 10S50 can analyze only phase-phase samples, so all samples and standards need to be in the gas phase prior to injection.

TABLE B-2

PORTABLE GC FIELD EQUIPMENT CHECKLIST

<u>EQUIPMENT</u>	<u># NEEDED</u>	<u>CHECKOFF</u>
INSTRUMENTS		
Photovac® 10S50		
Battery pack for oven		
Electrical cord for using GC with 110 V		
Electrical cord for charging battery pack		
Electrical cord for GC from battery pack		
Gas flow meter and connecting gas lines		
Gas tank regulator and connecting lines or internal tank refill gas line		
0.1-ppm grade air tank		
GC SUPPLIES		
Plotter pens		
Plotter paper		
Extra UV lamp		
White Teflon®-coated septa for GC		
PAPERWORK		
Field GC logbook		
Field notebook		
Photovac® GC instruction manual		
SYRINGES		
10 µL		
25 µL		
100 µL		
250 µL		
1,000 µL		
Syringe needles		

TABLE B-2 (CONTINUED)

PORTABLE GC FIELD EQUIPMENT CHECKLIST

<u>EQUIPMENT</u>	<u># NEEDED</u>	<u>CHECKOFF</u>
SAMPLE CONTAINERS		
VOA vials		
1-L gas sample bottles		
250-mL gas sample bottles		
Green septa for sample bottles		
Labels for vials/sample bottles		
Standards (pure solvent/gas STD)		
TOOLS		
Adjustable wrench for gas cylinder		
Small wrench for gas line fittings		
Slotted screwdriver		
Phillips head screwdriver		
MISCELLANEOUS		
Kim Wipes®		
Paper hand towels		
Markers		
Pens		
Calculator		
Knife		
Rubber bands		
Paper clips		
Water bottle		

Compound	Gas Concentration ppm (μL/L)
1,1-Dichloroethene	19.5
cis-1,2-Dichloroethene	20.1
trans-1,2-Dichloroethene	9.9
Trichloroethene	15.4
1,1,1-Trichloroethane	150.0
Toluene	19.9
m- and p-xylenes	40.8
o-xylene	20.8

Chromatograms of the standard will be compared with previous standard chromatograms to ensure that the standard was prepared properly.

12. Calibration Procedures

- A. Standards will be prepared according to the protocol given above.
- B. A standard should be run after the column blank when starting the instrument. For the most accurate results, standards should be prepared daily. The standard can be used for calibrating the instrument response factor on the first run or runs, and then for peak identification for the rest of the day.
- C. After the instrument is calibrated, a second standard should be run to verify that the first standard is reasonable. If the results differ by more than 5 percent, rerun and recalibrate (if necessary) the instrument using a different syringe or a different needle.
- D. Record on the strip chart both the V-sec and ppm readings on standards that are used for calibration, so that the calibration factor the instrument is using can be calculated.
- E. If there is a question on the identity of a given peak in a sample run, run a standard to determine the retention time of the compound of interest. Peak identification by the GC can be in error if the airflow rate or column temperature drift. The analyst should be familiar with the peak patterns of the compounds of interest, and should check to ensure that the GC is correctly identifying peaks, and check retention times against standards if questions arise.

13. Sample Preparation

Sample preparation was discussed in Section 8 above.

14 & 15. Step-by-Step Analytical Methodology

The daily operation of the GC, including routine procedures, preventive maintenance, and daily quality control procedures, is described below:

- A. Connect the power supply for the GC (unless using the internal battery).
- B. Connect the battery for the column oven to the external DC input connector. Set column to the desired temperature, and allow to heat for approximately 30 minutes to reach operating temperature.
- C. Connect the exhaust gas lines to the gas flow meter. The left side of the flow meter measures flow through the detector and is connected to the "Detector Out" port, while the right side is connected to the needle valve on the "Aux Out" post.

- D. Connect the input gas lines, turn the gas flow on, adjust the flow through the column, and backflush to the appropriate values. The backflush flow should be set slightly higher than the column flow. If using the internal tank, fill the tank before adjusting the flow. The gas flow through both the detector and backflush lines is set by the "A + B" valve at the center left of the front panel. The backflush flow is also controlled by the "Aux Out" needle valve. Note that the internal gas pressure should be set at 40 psi.
- E. Turn the instrument on (Note: gas must be flowing past detector before the lamp is turned on). The instrument will read "LAMP NOT READY. PLEASE WAIT" for a few minutes after turning the instrument on. If the lamp does not come on after several minutes, as indicated by the instrument reading "READY," turn the instrument off ("OFF", then "ENTER") and then back on, and wait for a minute. If the lamp still does not turn on, use the special Teflon® screwdriver to adjust the lamp power supply on the lamp box inside the unit. If the lamp still does not light, change the detector bulb.
- F. Set daily information, using USE button. Also enter project information, if necessary, using INFO button.
- G. If unsure of the GC's valve timing, press "TEST" then "ENTER." The GC will print out the Event timing. Event 1 should be set for an ON time of 8 (sec) and one OFF time of 10 (sec). Event 1 controls the buzzer for sample injection, and the injection port sequence. Event 3 controls the backflush start time. The ON time should be 0 (sec), and the OFF time should be one-fourth to one-fifth of the retention run time of the slowest analyte of interest. The run time is set by the CYCLE button.
- H. Set gain to desired value. (Note: Gain defaults to 2 when instrument is turned off.)
- I. Change septum on injection port, if necessary (septa are good for approximately 50 injections).
- J. Prepare daily injection log. All runs should be recorded on log.
- K. Run a column blank (no injection) and a syringe blank.
- L. Prepare appropriate standards (if necessary). Directions for standards preparation are given in Section II.
- M. Run standard. Recalibrate instrument, if necessary (see Calibrating the GC in Section II-12). If possible, obtain the peak areas in V-sec as well as ppm-V, so that the instrument calibration factor (in $\mu\text{L/L}/\text{V-sec}$) can be determined.
- N. If time permits, run a syringe blank (an injection of room air or 0.1 air) to ensure syringe cleanliness using the syringes that will be used in the day's work.
- O. Run samples. Adjust the injection volume until the peaks of interest are on scale and preferably more than 1/4 of maximum size for chart paper. If time permits, runs should be duplicated and average values should be used for quantification.

- P. Record sample ID, injection volume, and gain on the injection log. Also record sample ID and injection volume on chromatogram at the start of the run.
- Q. Record the results of the run on the calculation sheet for the project. Correct the GC output for injection volume (and gain if results are in mV or V-sec) to those values used for standard. When two replicate runs are made, calculate for both separately, and then average the results.
- R. Record the corrected results on the results sheet for the project. One copy of the results sheet should be given to the technical coordinator, and one copy should be placed in the project notebook.
- S. Clean syringes by removing the plunger after an injection and letting the plunger air.
- T. If replicate runs are not satisfactory (a < 10 percent difference is a suggested guideline), reinject the sample. If third run is still inconsistent, replace the needle on the syringe, and then rerun the sample. Also check for syringe contamination by running a syringe blank. Check for plugged syringes by injecting air into a vial filled with water.
- U. If instrument is not recognizing obvious peaks, recalibrate the known peak. If unsure of peak ID, run standard for peak identification. (Note: Once the septa is punctured in the gas sample bottle, the VOCs are slowly lost from the bottle. Therefore, the standard should be used for calibrating the concentration only shortly after the standard is prepared. The standard can still be used for peak identification until the peaks disappear.)
- V. Standards should be run periodically throughout the day, for peak identification (not for recalibration of concentration) and at any time when questions on peak identification arise. At least three standards should be run each day.
- W. Column and syringe blanks should be run periodically throughout the day, and if any questions of syringe contamination arise. Column and syringe blanks are particularly important when the sample concentration is low, or if there is a sharp drop in sample concentration (< factor of 5 change in concentration).
- X. Under normal operation, the maximum gain is 20, and under all conditions, the maximum injection volume is 1,000 μ L.
- Y. After 50 to 60 injections, change the injection septum.
- Z. After the last run has been completed, disconnect the oven battery from the instrument, and then shut the power off to the instrument. After the instrument has turned off, turn off the airflow, either by closing the tank or decreasing the regulator (if using an external tank). If using the internal tank, turn off the flow by using the instrument flow control knob.
- AA. At the end of a day's run, tear off the chart paper and mark the end with the date, project name and number, and if possible, the samples run.

- BB. If the instrument is using the internal power supply, then it should be recharged overnight. Fill the internal gas tank in the instrument, and bring the GC to a place where there is a 110 v power supply. Plug the instrument in, turn the airflow to a very slow rate (5 to 10 mL/min), and then turn the instrument on overnight. Be sure the air tank is full or that it has sufficient air to keep air running through the detector throughout the night.

16. Data Treatment

The Photovac® measures the area under peaks for the compounds in the injected gas sample. When using a "Library," the area, in V-sec or MV-sec, is converted to $\mu\text{L/L}$ (ppm-V) in the gas phase by calibrating the instrument using a known concentration of the compound in question (with gas standards). The instrument compares areas of standards with sample peak areas to determine the concentration of the unknown. The instrument corrects for gain, but not for injection volume. The instrument's concentration output should be corrected for injection volume as follows:

$$(\text{actual conc.}, \mu\text{L/L}) = (\text{instrument reading}, \mu\text{L/L}) \left(\frac{\text{injection volume of standard}}{\text{injection volume of sample}} \right)$$

If the reading is given in V-sec, a correction needs to be made for gain as well as for injection volume, i.e.,

$$(\text{actual conc.}, \mu\text{L/L}) = (\text{instrument reading}, \text{V-sec}) \left(\text{response factor } \frac{\mu\text{L/L}}{\text{V-sec}} \right) \left(\frac{\text{injection volume of standard}}{\text{injection volume of sample}} \right) \left(\frac{\text{gain setting for standard}}{\text{gain setting for sample}} \right)$$

where the injection volume and gain are the values for the standard at the time the instrument was calibrated.

The response factor is the conversion factor for the V-sec given by the detector at a given standard concentration, i.e.,

$$\text{response factor} = \left(\frac{\text{standard concentration, } \mu\text{L/L}}{\text{instrument reading, V-sec}} \right)$$

The response factor is specific for the injection volume, gain, and detector response.

Gas measurements are commonly reported in ppm or $\mu\text{g/m}^3$. A gas phase unit of ppm is a $\mu\text{L/L}$. To avoid confusion between measurements made on different matrices (air, water, or soil) units of $\mu\text{L/L}$ are used in the calculations.

17. Data Deliverables

Portable GC result notebooks will be prepared. The notebook will consist of the following sections:

- A. Project information
- B. Standards preparation and SOP for the sample handling and GC operation
- C. Injection logs
- D. Calculation sheets
- E. Results summary sheets
- F. Replicate comparison and standards results sheets
- G. Chromatograms

After the fieldwork is completed, the chromatograms will be copied and placed in the appropriate section. Replicates will be recorded separately, and compared in a separate section of the notebook. The calculation and results summary sheets will be checked by the QC reviewer. The notebook will be comb bound and placed in the project file. The calculation and results summary sheets can be copied and stored at the GC operator's desk for later reference, if appropriate.

The notebooks contain the information required to follow the results from the original chromatogram to the final results sheet. Standards will be included so that retention times can be checked. However, syringe or column blanks, runs that went off-scale, and other miscellaneous runs will not be included. The original chromatograms are stored in the RMT Applied Chemistry Laboratory.

18. Quality Control

The degree of QA/QC for the portable GC use is dependent on the use of the results, and should be adjusted as appropriate. It should be recognized that the GC itself is a precise analytical instrument, capable of providing as consistent and reliable results as a laboratory GC, if used under optimum conditions. However, use in the field under less controlled conditions increases the analytical variation in the results.

During field operation of the GC, the operator checked for syringe clogging or contamination, machine malfunction, and miscalibration as discussed in Sections 14 and 15. If replicate runs vary by more than 10 percent difference between the results, the sample is reanalyzed by repeating the injections until the results do replicate or the cause of the poor replication is identified.

The purpose of the QA/QC procedures can be divided into three areas, as follows:

A. Verification

Much of the verification of peak identification, syringe cleanliness, and proper operation is done during machine operation, and was discussed in Section 12, Calibration Procedures. During the QC check of the results, the following steps are needed:

- i. Sample and standard peak retention times and peak patterns are compared. GC identification of the peaks is checked. Incorrect GC peak identification is noted on the chromatogram.
- ii. If a question of peak identification arises that cannot be resolved by comparing sample peak retention time with that of the standard, relative retention times for the unknown and for a known compound are calculated and compared between the sample and standard.
- iii. If a question of peak identification arises after a relative retention time check, the peak is identified as the compound of interest with a note saying "Tentative Identification."

B. Data and Calculation Checks

- i. All results to be reported should be recorded on the calculation sheet.
- ii. The results should be corrected for injection volume and gain. Note: the Photovac® automatically corrects for gain if the reports are presented in ppm, but does not correct for gain if the results are presented as V-sec.
- iii. Further calculations should be recorded on the DATA CALCULATION SHEET.
- iv. The corrected results should be recorded on the sample results sheet. All results should be reported as $\mu\text{L/L}$ (ppm-V).
- v. All data transcriptions and calculations should be checked by a QC person, unless otherwise instructed. The QC person should check the results for accuracy of transcription, and spot check the calculations. Furthermore, the QC person should compare the final results for reasonableness, based on previous results or anticipated results.
- vi. A xerox of the chromatograms used for calculation should be made. The xerox facilitates QC checking and project file documentation. If duplicate injections were made, both chromatograms should be recorded. Further, if there is any uncertainty about peak identification, then the standards used for retention time calibration should be copied too.
- vii. The QA/QC person should initial and date each page of data calculation or results sheet checked and any corrections that are made. Corrections should be in a different color ink (e.g., blue or red) than the original.

C. Documentation

- i. A portable GC project notebook should be used unless there are instructions not to. The project notebook should consist of the following sections:

Section Topic

- a. General Project Information
 - Includes the proposed Scope of Services if available
- b. Standard Operating Conditions
 - Standards preparation forms
 - Standards chromatogram
 - Calculation equations
 - Sample handling instructions (if prepared)
- c. Results summary forms
- d. Daily injection log

- e. Calculation sheets and chromatograms
- ii. While the project is active, the notebook should be kept in a 3-ring binder (unless otherwise specified).
- iii. After the project is completed, the notebook should be comb bound, with a cover page, and stored in the project files. The GC operator is responsible for putting the final notebook together.
- iv. The original chromatograms should be stored in the Applied Chemistry Laboratory. The chromatograms should be organized by project and date.

19. References

Devitt, D.A., R.B. Evans, W.A. Jury, T.R. Starks, B. Eklund and A. Gholson. 1987. Soil gas sensing for detection and mapping of volatile organics. EPA 600/8-87-036, USEPA, Las Vegas, Nevada.

Photovac® - Technical bulletin #27. Photovac, Inc., Huntington, New York.

ATTACHMENT 1
PHOTOVAC® TECHNICAL BULLETIN #27

PHOTOVAC

Technical Bulletin

27

PREPARATION OF AQUEOUS STANDARDS FOR
GROUNDWATER ANALYSIS

Many of the chemicals mentioned herein are of a hazardous nature. Photovac expressly disclaims liability for any loss or injury arising out of the use of information, materials, equipment or practices described. Safe use of any procedure, equipment or material is the responsibility of the user.

For further information on contents of this bulletin or on Photovac products, please contact:

PHOTOVAC
incorporated

United States
PHOTOVAC INTERNATIONAL
INCORPORATED
741 Park Avenue
Huntington
New York 11743
USA

Worldwide
PHOTOVAC INCORPORATED
134 Doncaster Avenue
Unit 2
Thornhill, Ontario
Canada
L3T 1L3

PREPARATION OF AQUEOUS STANDARDS FOR GROUNDWATER ANALYSIS

This procedure is based on an actual site investigation conducted with E.P.A. approval and is intended to provide a guide for similar investigations. Local site conditions and the type of compounds present will obviously be different and approval of the planned procedure will need local E.P.A. approval.

PREPARATION OF WATER STANDARDS

This is a general guideline to be used when making water standards of volatile compounds. The example given is for Benzene and TCE, two compounds commonly found in groundwater contamination. The volumes used for generating the initial stock solution and subsequent dilutions are readily dispensable to allow the preparation of low concentration standards.

The accuracy of the standards is dependent on the precautions taken in the transfers of liquids and care taken to prevent headspace loss. Cross contamination by using contaminated syringes must also be avoided.

APPARATUS: The following apparatus is required, with care being taken to decontaminate the various items using only spectroscopic grade solvents:

1. 40 ml. VOA bottles
2. Gas tight syringes (50 ul to 100 ul).
3. Volumetric pipettes to measure 20 ml and 40 ml volumes. (Other glassware of compatible accuracy can be used as alternatives).
4. Analytical balance (and pan balance if available).

REAGENTS

1. 100ml Methanol
2. Approximately 20 ml each of other desired reagents.
3. Organic-free water.

PROCEDURE

If analytical balances are available, then the preferred method of making standards is to weigh small quantities of the volatile organic compounds in gas-tight syringes. These quantities are transferred to 20 ml of Methanol and the whole reweighed (See appendix A "Procedure for weighing liquids with a syringe"). Concentration is then calculated directly on a wt/wt basis ($\text{ppm} = \text{ug/g}$).

If analytical balances are not available, the densities of the compounds are used to determine the weight of known volumes. The following is an example for making water standards at low ppb concentrations of Benzene and TCE. The procedure consists of 3 parts: A) Making a stock solution in Methanol (approx. 1000-5000 ppm), B) 1/800 dilution in water, C) 1/500 dilution in water.

A) STOCK SOLUTION IN METHANOL

1. Using a 20 ml volumetric pipette, transfer 20 ml of Methanol

to a 40 ml VOA bottle. Cap the bottle immediately.
 The density of Methanol is $\frac{.7915 \text{ g}}{\text{ml}}$ at 20°C, 20 ml should weigh:

$$\frac{.7915 \text{ g}}{\text{ml}} \times 20 \text{ ml} = 15.83 \text{ g of Methanol}$$

2. Using a gas tight 100 μl syringe, transfer 40 μl of TCE into the 20 ml of Methanol. The density of TCE is $\frac{1.465 \text{ g}}{\text{ml}}$ at 20°C therefore 40 μl weighs

$$\frac{1.465 \text{ g}}{\text{ml}} = \frac{1465 \text{ mg}}{\text{ml}} = \frac{1465 \text{ mg}}{1000 \mu\text{l}} = \frac{1.465 \text{ mg}}{\mu\text{l}}$$

$$\text{Therefore, } 40 \mu\text{l} \times \frac{1.465 \text{ mg}}{\mu\text{l}} = 58.6 \text{ mg TCE}$$

3. With a clean syringe, transfer 60 μl of Benzene to the TCE/Methanol mixture. The density of Benzene at 20°C is $\frac{.8794 \text{ g}}{\text{ml}}$ therefore 60 μl =

$$\frac{0.8794 \text{ g}}{\text{ml}} = \frac{0.8794 \text{ mg}}{\mu\text{l}} \times 60 \mu\text{l} = 52.76 \text{ mg Benzene}$$

Concentration of stock solution

$$\text{for Benzene} - \frac{52.76 \text{ mg Benzene}}{52.76 \text{ mg Benzene} + 58.6 \text{ mg TCE} + 15.83 \text{ g Methanol}} =$$

$$\frac{52.76 \text{ mg Benzene}}{15.94 \text{ g total}} = \frac{52.760 \mu\text{g}}{15.94 \text{ g}} = \frac{3310 \mu\text{g}}{1 \text{ g}} = 3310 \text{ ppm}$$

$$\text{for TCE} - \frac{58.60 \text{ mg TCE}}{58.60 \text{ mg TCE} + 52.76 \text{ mg Benzene} + 15.83 \text{ g Methanol}} =$$

$$\frac{58.60 \text{ mg TCE}}{15.94 \text{ g total}} = \frac{3676 \mu\text{g}}{1 \text{ g}} = 3676 \text{ ppm}$$

This mixture is Solution A.

B) 1st Dilution of Stock:

Withdraw 50 μl of stock solution with a 100 μl syringe and transfer into 40 ml of organic-free water within a VOA bottle. Mix by shaking for a few minutes and let stand for 15 minutes.

$$\text{Concentration} = \frac{.050 \text{ ml stock}}{40 \text{ ml water}} = \frac{1}{800} = 4.6 \text{ ppm TCE}$$

and 4.14 ppm Benzene (Solution B)

C) 2nd Dilution:

Using Solution B, withdraw 40 μl and expel into 20 ml water in a 40 ml VOA bottle. Invert the bottle and swirl a few minutes.

Let the solution sit 30 minutes to equilibrate before using.

Concentration : $\frac{40 \text{ } \mu\text{l Solution B}}{20 \text{ ml water}} =$

$\frac{.40 \text{ ml}}{20 \text{ ml}} = \frac{1}{500}$ dilution = 9.2 ppb TCE + 8.3 ppb Benzene (Solution)

Solution C is the working Standard.

NOTE: Follow chemical manufacturer's recommended safety information for the reagents used.

Precautionary Notes

1. Care should be taken not to inject liquid into the G. C.
2. When using a 10S50 or 10S70 G. C. use a separate library for water standard data. By listing the headspace concentration as the liquid concentration, from the standards, the G. C. will then print results based on liquid concentration for field samples. This approach will prevent confusion with air calibration data and negates the need for using Henry's Law to calculate vapor concentrations with respect to liquid samples.
3. When working with samples in the parts-per-billion concentration range, freshly prepared aqueous standards should be used on a daily basis. The standards should be stored with the septum screw capped VOA vial inverted.
4. Depending upon the volume of headspace used for injection into the G. C., using a clean gas-tight syringe, transfer the same volume of UZ air to replenish the headspace. Allow the standard to equilibrate for approximately 1/2 hour.
5. Typically, injection volume of headspace range from 100-500 μl .

APPENDIX A

PROCEDURE FOR WEIGHING LIQUIDS WITH A SYRINGE

Cautions/Limitations:

1. The minimum amount of liquid to be weighed is 20 μ l.
2. Use only about 50-60% of the capacity of the syringe, therefore, the minimum size syringe that can be used is 50 μ l.
3. Perform procedure as quickly as possible to avoid exposure and possible volatilization.
4. For liquids that are very volatile, it is necessary to draw total sample back into syringe barrel, before weighing, to prevent liquid volatilization during weighing procedure.

Procedure

1. Use a 50 μ l syringe and withdraw at least 20 μ l of liquid.
2. Carefully wipe the needle and syringe dry.
3. Place syringe on analytical balance and weigh. (Tare and sample).
4. Depress plunger to empty syringe into a suitable flask containing solvent. To prevent volatilization of liquid, be sure to empty contents of the syringe under the surface of the solvent.
5. Reweigh syringe (tare), and by difference calculate the weight of the liquid taken.