October 10, 1994

Ms. Pamela A. 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:

As you requested, we have prepared an interim status report on the subsurface investigative activities that we are conducting at the Grafton facility on behalf of the Tecumseh Products Company. We have enclosed two copies of the interim status report for your and Scott Ferguson's review prior to our meeting on October 13. Kerry DeKeyser of Tecumseh Products, Bernd Rehm, and I plan to attend this meeting.

This report includes the significant findings and conclusions from RMT's August 1994 investigation, as well as recommendations for another phase of investigation, which includes installing up to four bedrock monitoring wells. Because additional work is needed at this site, parts or all of the figures in the interim status report are still in hand-drawn format. We will upgrade the graphics and will also include a more comprehensive discussion of the results in our final version of the report.

In addition, we have provided in the report a schedule for the proposed field program. We would like to complete the fieldwork before Thanksgiving to avoid the typically harsher weather of December. If you can provide verbal approval of the Workplan, which we will submit shortly after our meeting, by November 2, we could start the drilling on about November 7.

Please call either Kerry at 414-898-5711, or me if you have any questions in advance of our meeting about the information we have sent.

Sincerely,

Linda Hicken

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

gjg

Enclosures

cc: Kerry DeKeyser, Tecumseh Products Company

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

INTERIM STATUS REPORT
ON THE
SUBSURFACE INVESTIGATIVE ACTIVITIES
AT THE TECUMSEH PRODUCTS COMPANY
GRAFTON OPERATION

PREPARED FOR
TECUMSEH PRODUCTS COMPANY
GRAFTON, WISCONSIN

PREPARED BY
RMT, INC.
MADISON, WISCONSIN

OCTOBER 1994

RMT INC.

→ 246009170

INTERIM STATUS REPORT
ON THE
SUBSURFACE INVESTIGATIVE ACTIVITIES
AT THE TECUMSEH PRODUCTS COMPANY
GRAFTON OPERATION

PREPARED FOR
TECUMSEH PRODUCTS COMPANY
GRAFTON, WISCONSIN

246009170

PREPARED BY
RMT, INC.
MADISON, WISCONSIN

OCTOBER 1994

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

Section 1
INTRODUCTION

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. The process equipment and processes associated with the engine assembly operations included underground storage tanks for engine testing, vapor degreasers for parts/engine cleaning, and painting of assembled engines.

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. Evidence of releases was noted during five of the eight tank abandonments. During the course of investigating the extent of subsurface contamination, which may have been associated with the Stoddard solvent tank, chlorinated volatile organic compounds (VOCs) were detected in the groundwater and soil.

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 migration, and to define the extent of chlorinated solvents identified in groundwater during the previous UST removals. The investigation included the installation of eight soil borings, as outlined in the Workplan submitted to the WDNR in August 1994. Two of the soil borings were converted to water table wells, and three of the soil borings were converted to piezometers. The locations of the soil borings are shown on Figures 2 and 3.

Purpose and Scope

The purpose of this technical memorandum is to summarize the findings of the first phase of investigation conducted at the site in August 1994, and to present recommendations for a second phase of investigation. A more detailed report of the results of the first and second phases of investigation will be submitted to the WDNR after the second phase of investigation is completed.

Section 2

SUMMARY OF THE AUGUST 1994 INVESTIGATIVE ACTIVITIES

The objective of the August 1994 investigation was to assess the extent and degree of VOCs in groundwater in the southeastern corner of the Tecumseh Products Company Grafton facility. The work included the following tasks:

- Observed and documented the installation of one shallow water table well and one deep soil boring upgradient of the Tecumseh facility to characterize background water quality and to measure the water table elevation at the western edge of the site.

- Observed and documented the installation of six soil borings at the eastern edge of the Tecumseh facility to evaluate the vertical and horizontal extent of the VOCs and to better define the hydrogeologic conditions in the soil beneath the facility. One of the soil borings was converted into a water table well, and three of the soil borings were converted into piezometers.

- Analyzed the headspace concentrations of selected VOCs associated with the unsaturated soil samples from MW-8D using a portable gas chromatograph (GC). The soil sample with the highest portable GC reading was submitted for laboratory analysis of VOCs to further characterize the vertical extent of VOCs in the soil beneath the recycling dock.

- Collected groundwater samples in five of the soil borings installed at the eastern edge of the site and in one of the soil borings installed at the western edge of the site. As the borings were advanced, groundwater samples were collected at 4-foot intervals, or where sand was encountered, using a Hydropunch sampler. The water samples were analyzed in the field for selected VOCs using a portable GC. The results of the portable GC analysis were used to vertically profile the concentration of the selected VOCs in the unconsolidated material.

- Collected a complete round of groundwater level measurements from the new and previously installed monitoring wells to evaluate horizontal and vertical groundwater flow directions.

- Collected one round of groundwater samples from the new monitoring wells and from MW-3 and MW-8. The samples were analyzed for VOCs. The groundwater sample from MW-3 was also analyzed for total phosphorus, total Kjeldahl nitrogen, chloride, and sulfate to determine whether the anomalously high water level observed in MW-3 is due to leakage from the underground sanitary sewer line.

- Performed in-field hydraulic conductivity tests on three of the new monitoring wells and on three of the previously installed monitoring wells to characterize the hydraulic conductivity of the geologic materials.

- Collected a composite sample of the soil cuttings generated during the field activities for disposal characterization. The samples were analyzed for the volatile, semivolatile, and metal fractions of the TCLP.

- Removed approximately 2 gallons of free product from MW-2 using a bailer.

Section 3

FINDINGS AND CONCLUSIONS

1. The surface topography of the site slopes gently from west to east. The surface soil consists of 10 to 12 feet of clay overlying a saturated sand layer. At the eastern edge of the site, the sand layer extends from the base of the clay to the bedrock surface, which is present at approximately 30 to 40 feet below ground surface. The saturated sand layer thins to the west of the site where it is underlain by a thick layer of clay. The site geology is depicted on the geologic cross sections shown on Figures 4 and 5.

2. The depth to groundwater beneath the site ranges from 8 to 16 feet below grade. The groundwater flow direction is to the east toward the Milwaukee River, with a horizontal hydraulic gradient of approximately 0.004. The vertical gradient is approximately 0.005 downward, based on data from well nests MW-8/MW-8D and MW-9/MW-9D. The water table elevations are presented in Table 1, and a water table contour map is presented on Figure 3.

3. The water level in MW-3 has been consistently higher than the water levels in the other on-site monitoring wells. Somewhat elevated levels of chloride and sulfate were detected in the groundwater sample collected from MW-3 (see Appendix E). This result supports the hypothesis that the higher water level may be due to leakage from the underground vitrified clay sanitary sewer line that runs adjacent to the well.

4. Hydraulic conductivity values calculated for the monitoring wells are generally consistent between wells, with the exception of MW-3. The calculated hydraulic conductivity of five of the on-site monitoring wells ranged from 3.2×10^{-3} cm/s to 2.9×10^{-2} cm/s, with a geometric mean of approximately 8×10^{-3} cm/s. The calculated hydraulic conductivity of MW-3 (9.1×10^{-5} cm/s) was approximately two orders of magnitude lower than the hydraulic conductivity values calculated from the other on-site wells. Hydraulic conductivity values are presented in Table 2, and the calculations are included in Appendix C.

5. The results of the in-field GC analysis of soil samples collected from the boring for MW-8D indicate elevated levels of VOCs (see Table 3). Based on the results of the in-field analysis, the sample from the 5- to 7-foot interval was submitted for laboratory analysis. Elevated levels of VOCs were also detected in the sample submitted for laboratory analysis (see Appendix D).

6. No VOCs were detected in groundwater samples collected from the upgradient soil boring (SB-8VOC) that was installed on the west side of the Tecumseh facility (see Table 4).

7. Results of the in-field analysis indicate elevated levels of VOCs in groundwater samples collected from MW-8D, which is located in the southeastern corner of the plant (see Table 4). The dominant VOC that was detected under the southeastern corner of the plant was 1,1,1-Trichloroethane. Vertically, TCA extends from the water

table to the top of the bedrock. Whether, and to what extent there is downward migration of TCA in the bedrock aquifer is unknown. Based on the results of the in-field analysis, the concentration of TCA appears to increase with depth.

8. Three soil borings were installed along the eastern edge of the Tecumseh property to evaluate the northern extent of the VOC plume (SB-5VOC, SB-6VOC, and MW-9D). In-field GC analysis was used to obtain a horizontal and vertical profile of constituent distribution. The results of the in-field analysis indicated increasing VOC concentrations in the groundwater to the north, with the highest concentrations being detected in MW-9D, located in the east-central portion of the plant (see Table 4). Trichloroethene (TCE) is the dominant VOC that was detected under the east-central portion of the plant site. The portable GC results for TCE and TCA are shown on the geologic cross section on Figure 4. TCE is found from the water table to the top of the bedrock. The extent of this plume to the north is unknown. Whether, and to what extent there is downward VOC migration in the bedrock is unknown.

9. The results of the laboratory analyses from the new monitoring wells and from MW-3 and MW-8 are generally consistent with results of the in-field analysis, with the exception of MW-8D (see Table 5). The results of the in-field GC analysis indicated 1,710 μg/L of TCA at the bedrock surface in MW-8D; however, laboratory analysis of the groundwater sample from MW-8D indicated low levels of VOCs, including 7.4 μg/L TCA, in the well. The discrepancy between these two results will be further investigated and resolved in the next phase of investigation.

10. No volatile or semivolatile constituents were detected in the TCLP analysis of a composite soil sample collected from the soil cuttings generated during the field investigation (see Appendix D). Barium was the only RCRA metal that was detected. It was detected at a concentration below the regulatory level. These results indicate that the soil cuttings are not characteristically hazardous.

Section 4

RECOMMENDATIONS

1. Install up to four soil borings and up to two shallow monitoring wells north of the borings that were completed in August. The locations of the proposed soil borings are shown on Figure 2. The purpose of the proposed soil borings is to attempt to determine the northern extent of the VOC plume. The borings will be installed to the bedrock surface (approximately 40 feet below grade). Groundwater samples will be collected as the borings are advanced using a Hydropunch sampler and will be field-screened using a portable GC. Results of the field GC analyses will be used to obtain a vertical profile of VOC distribution in the unconsolidated material.

2. Drill two borings into the bedrock along the eastern property line, one in the TCA-dominated area downgradient of MW-8D, and one in the center of the TCE-dominated area (to be determined under recommendation 1). The locations of the proposed bedrock wells are shown on Figure 2. The purpose of the proposed bedrock borings is to determine whether, and to what extent there is downward migration of VOCs in the bedrock aquifer beneath the site. Each well will be drilled to the bottom of the VOC plume or to a maximum depth of 100 feet, whichever comes first. The groundwater will be sampled and analyzed as the borings are advanced. The presence, hydraulic effectiveness, and connection to VOC sources will be evaluated with packer testing, portable GC analysis, and video logging. Each boring will be completed as a multiple-port monitoring well. Vendor information on the proposed multiple-port monitoring system is included in Appendix F. The multiple-port wells are recommended because they allow monitoring of static water levels, permeability testing, and collection of groundwater samples at multiple depths in a single borehole. The depths of the well inlets will be determined based on the results of the packer testing, portable GC analysis, and video logging.

3. Install two shallow water table wells on the west side of the Milwaukee River within public right-of-ways in the residential area (see Figure 1). If the on-site bedrock borings/wells indicate the presence of VOCs in the bedrock aquifer, additional multiple-port bedrock monitoring wells will also be installed adjacent to the water table wells. The purpose of the wells in this area is to assess the horizontal extent of VOCs in groundwater in the soil and bedrock to the east of the facility. Hydraulic head data from these well clusters will be used to assess the degree to which the Milwaukee River intercepts groundwater flowing from the facility.

Section 5

SCHEDULE

The following is the proposed schedule for the implementation of the second phase of investigation at the site:

Tasks	Date
Meet with the WDNR to discuss the information included in this document	October 13, 1994
Submit a Workplan for the second phase of the investigation to the WDNR	October 31, 1994
Receive verbal approval of the Workplan from the WDNR	November 2, 1994
Conduct the field Investigation	November 7-23, 1994

TABLE 1

GROUNDWATER ELEVATION DATA
TECUMSEH PRODUCTS COMPANY
(AUGUST 25, 1994)

Well Identification	Top of Casing Elevation (feet above M.S.L.)	Depth to Water (feet)	Water Table Elevation (feet above M.S.L.)
MW-1	762.84	15.30	747.54
MW-2	762.81	17.50	745.31[1]
MW-3	758.35	7.90	750.45
MW-3D[2]	758.60	11.38	747.22
MW-4	762.12	14.59	747.53
MW-5	762.93	15.31	747.62
MW-6	762.97	15.04	747.93
MW-7	763.01	15.08	747.93
MW-8	762.40	14.88	747.52
MW-8D	758.98	11.56	747.42
MW-9	760.72	13.59	747.13
MW-9D	760.58	13.51	747.07
MW-10	772.01	8.19	763.82

NOTES:

1 There was approximately 2.77 feet of free product (machine oil) in MW-2. This was removed after the depth to the water table was measured.

2 The "D" suffix indicates that the well is a piezometer.

TABLE 2

RESULTS OF THE IN-FIELD HYDRAULIC CONDUCTIVITY TESTS[1]
TECUMSEH PRODUCTS COMPANY

Well Identification	Hydraulic Conductivity
MW-3	9.1×10^{-5} cm/s
MW-3D	6.6×10^{-3} cm/s
MW-4	3.2×10^{-3} cm/s
MW-7	9.1×10^{-3} cm/s
MW-9	2.9×10^{-2} cm/s
MW-9D	7.6×10^{-3} cm/s

NOTE:

[1] Hydraulic conductivities calculated using the method of Bouwer and Rice (1976).

TABLE 3

RESULTS OF THE PORTABLE GC ANALYSIS OF SOIL SAMPLES[1] (µL/L)
TECUMSEH PRODUCTS COMPANY

Boring I.D.	Boring MW-8D			
Sample Depth (feet below ground surface)	2.5 - 4.5	5 - 7	7.5 - 9.5	10 - 12
1,1,1-Trichloroethane	582	853	609	401
1,1-Dichloroethene	35	46	41	2.3
trans-1,2-Dichloroethene	ND	ND	23	9.5
cis-1,2-Dichloroethene	92	189	302	145
Trichloroethene	72	114	19	22
Tetrachloroethene	ND	ND	ND	ND
Benzene	ND	ND	ND	ND
Toluene	92	140	80	48
Ethylbenzene	ND	54	5.7	6.4
m,p-Xylenes	36	188	27	22
o-Xylenes	12	113	15	8.5

NOTES:

[1] Concentrations are reported for the headspace gas above the soil sample.
ND Not detected.

TABLE 4

RESULTS OF THE PORTABLE GC ANALYSIS OF GROUNDWATER SAMPLES[1,2] (µg/L)
TECUMSEH PRODUCTS COMPANY

Boring I.D.	Sample Depth (feet below ground surface)	1,1,1-TCA	1,1-DCE	trans-1,2-DCE	cis-1,2-DCE	TCE	PCE	Benzene	Ethylbenzene	Toluene	m,p-Xylenes	o-Xylenes
MW-3D	14 - 16	ND	ND	ND	ND	258	29	ND	ND	ND	ND	ND
	18 - 20	ND	ND	ND	ND	19	ND	47	344	23	108	ND
	22 - 24	ND/ND	ND/ND	ND/ND	ND/ND	6.4/6.1	ND/ND	ND/ND	6.7/7.6	ND/2.0	ND/ND	ND/ND
	26 - 28	ND/ND	ND/ND	ND/ND	ND/ND	19/19	1.8/2.0	1.1/1.5	11/5.6	2.2/2.0	2.4/ND	ND/ND
	30 - 31.5	ND/ND	ND/ND	ND/ND	ND/ND	6.0/6.2	ND/ND	ND/ND	2.6/2.5	1.6/1.8	ND/ND	ND/ND
SB5VOC	13 - 14	< 5/ND	4.7/4.4	1.5/ND	17/15	75/75	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
	16 - 18	ND	ND	ND	ND	15	ND	ND	ND	ND	ND	ND
	20 - 22	ND/ND	ND/ND	ND/ND	ND/ND	14/13	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
	28 - 30	< 5/< 5	ND/ND	ND/ND	ND/ND	2.7/2.4	ND/ND	ND/ND	ND/ND	ND/1.1	ND/ND	ND/ND
	32 - 34	ND	ND	ND	ND	7.3	ND	ND	ND	3.0	1.3	ND
SB6VOC	12 - 14	89/139	38/34	ND/ND	5.2/8.5	24/21	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
	16 - 18	ND	3.2	ND	ND	13	ND	ND	ND	ND	ND	ND
	20 - 22	ND	ND	ND	5.5	14	ND	ND	ND	ND	ND	ND
	24 - 26	ND/ND	2.2/1.7	ND/ND	3.0/2.7	17/16	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
	28 - 30	< 5	ND	ND	1.8	11	ND	ND	1.3	ND	1.5	ND
	32 - 34	ND	12	ND	10	103	ND	ND	ND	ND	ND	ND
SB8VOC	20 - 22	< 5/< 5	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
	24 - 26	< 5/< 5	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
MW-8D	15 - 17	ND	70	76	570	16	26	ND	146	703	499	193
	19 - 21	ND/ND	69/75	16/17	106/111	14/16	ND/ND	ND/ND	ND/ND	19/17	25/26	ND/ND
	24 - 26	864	39	19	190	44	42	ND	58	245	222	68
	28 - 30	563/600	11/12	7.4/7.9	83/83	14/15	20/23	ND/ND	42/44	160/157	170/170	83/58
	32 - 33	1710	35	26	283	26	138	ND	230	535	664	660
MW-9D	12 - 14	ND/ND	87/107	ND/ND	172/184	724/1030	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
	16 - 18	ND	106	ND	ND	981	ND	ND	ND	ND	ND	ND
	20 - 22	ND/ND	96/104	ND/ND	ND/ND	677/771	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND
	24 - 26	ND	17	ND	237	444	ND	ND	ND	ND	ND	ND
	28 - 30	ND/ND	97/99	ND/ND	242/300	537/576	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND	ND/ND

NOTES:

1 Samples were collected August 15 through 18, 1994.

2 Two vials were collected from each sample interval. Field GC results are reported for both vials when two vials were analyzed.

ND Not detected (detection limit for all compounds, unless otherwise stated, is considered to be 1 µg/L).

TABLE 5

GROUNDWATER ANALYTICAL RESULTS (µg/L)[1]
TECUMSEH PRODUCTS COMPANY

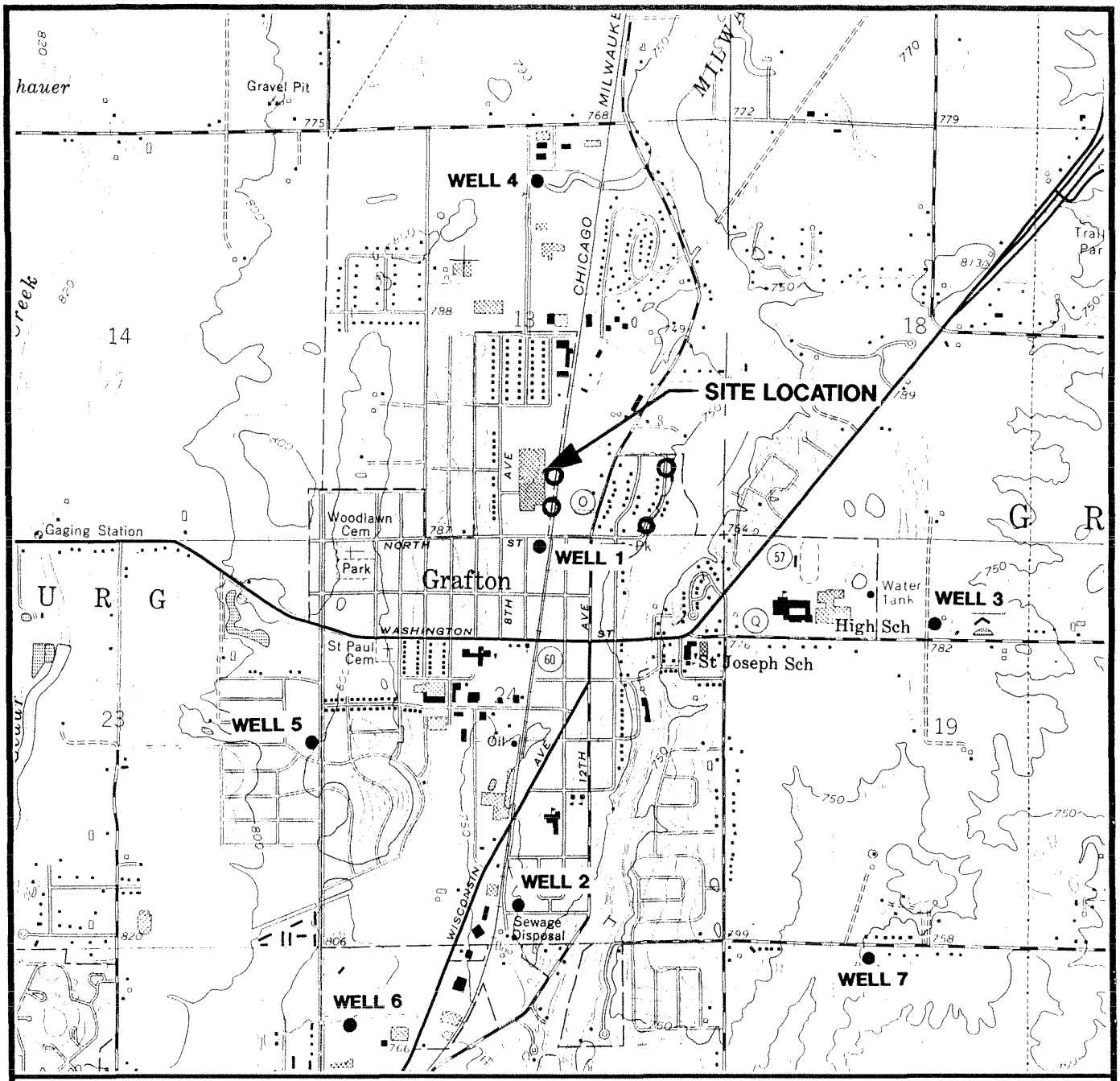
Parameter	Well						NR 140 Groundwater Standards	
	MW-3	MW-3D	MW-8	MW-8D	MW-9	MW-9D	Enforcement Standard	Preventive Action Limit
Vinyl chloride	<1.0	6.1	77	<1.0	<100	<100	0.2	0.02
1,1-Dichloroethene	<1.0	24	<50	<1.0	<100	<100	7	0.7
1,1-Dichloroethane	<1.0	7.2	360	3.8	100	290	850	85
cis-1,2-Dichloroethene	<1.0	6.8	130	1.3	1500	330	70	7
1,1,1-Trichloroethane	<1.0	21	670	7.4	530	700	200	40
Trichloroethene	39	88	<50	7.0	3000	1200	5	0.5
Toluene	<1.0	<5.0	160	2.0	<100	<100	343	68.6
Ethylbenzene	<1.0	54	<50	<1.0	<100	<100	700	140
Xylenes, total	<3.0	18	160	3.6	<300	<300	620	124
1,3,5-Trimethylbenzene	<1.0	<5.0	<50	1.6	<100	<100	NE	NE
1,2,4-Trimethylbenzene	<1.0	30	110	4.6	<100	<100	NE	NE
sec-Butylbenzene	<1.0	<5.0	<50	1.3	<100	<100	NE	NE
p-Isopropyltoluene	<1.0	<5.0	<50	1.4	<100	<100	NE	NE
n-Butylbenzene	<1.0	<5.0	<50	4.5	<100	<100	NE	NE
Naphthalene	<5.0	<25	280	5.0	<500	<500	40	8

NOTES:

NE Not established

[1] This table includes only those compounds that were detected in at least one sample.

FIGURES



STATE LOCATION

0 2000 4000

SCALE: 1"=2000'

SITE LOCATOR MAP
TECUMSEH PRODUCTS COMPANY
GRAFTON, WISCONSON

O PROPOSED MONITORING WELL

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

RMT INC.

DWN. BY:	DPR
APPROVED BY:	
DATE:	JULY 1994
PROJ.#	3084.01
FILE #	30840104

FIGURE 1

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

RESIDENTIAL AREA

PROPERTY LINE

8TH AVENUE

GRASS

MW-10

WDNR-1

GRASS

PARKING

SB-8VOC

POND

NORTH STREET

OFFICE

FORMER DEGREASER AND LOADING DOCK

APPROXIMATE DIRECTION OF GROUNDWATER FLOW

FORMER DEGREASER

TECUMSEH PRODUCTS COMPANY
GRAFTON PLANT

DRAINAGE DITCH

POWER STREET

RESIDENTIAL AREA

RECYCLING DOCK

2500 KVA OIL CIRCUIT BREAKER

FORMER DEGREASER

PARKING

6" CITY WATER

AREA SHOWN IN DETAIL ON FIGURE 3

SB-5VOC

PROPANE

SB-6VOC

MW-9D

MW-9

PROPANE

MW-3

MW-3D

10" VIT

CULVERT

RESIDENTIAL AREA

COMMERCIAL/INDUSTRIAL AREA

LEGEND

- MW-10 WATER TABLE WELL
- MW-9D PIEZOMETER
- WDNR-1 PIEZOMETER (OWNED BY THE WDNR)
- SB-8VOC SOIL BORING
- W WATER
- GAS GAS
- PP PROPANE
- SS STORM SEWER
- SAN SANITARY SEWER
- E ELECTRIC
- FIRE PROTECTION LOOP
- RAILROAD
- PROPERTY LINE
- OTHER SUBSURFACE DRAIN

NOTES

1. THE LOCATION OF THE MONITORING WELLS INSTALLED NEAR THE RECYCLING DOCK ARE SHOWN ON FIGURE 3.
2. FACILITY LAYOUT ADAPTED FROM DRAWINGS PROVIDED BY TECUMSEH PRODUCTS COMPANY.
3. THE LOCATIONS OF THE FORMER DEGREASERS AND LOADING DOCK ARE APPROXIMATE AND NOT TO SCALE.

⊕ PROPOSED SOIL BORING LOCATION

⊙ PROPOSED BEDROCK WELL LOCATION

0 150 300

SCALE: 1"=150'

SITE PLAN

TECUMSEH PRODUCTS COMPANY
GRAFTON, WISCONSIN

RMT, INC.

DWN. BY:	DJW
APPROVED BY:	
DATE:	SEPTEMBER 1994
PROJ. #	3084.03
FILE #	30840301

FIGURE 2

Drawing File = h:\wp\84_cad\30840301
Plot File = P:\30840301.PRF
Scale = 15000000.000000

TRIMMING MACHINE LINE

MW-6 (747.93)

MW-7 (747.93)

747.8 747.8

ABOVE GROUND GAS LINE

STOCK STORAGE AREA

MW-2 (745.31)

OFFICE

MACHINE SHOP

WELDING ROOM

TRUCK LOADING AND UNLOADING AREA

747.6 747.6

(747.62) MW-5

STODDARD TANK EXCAVATION

RECYCLING DOCK

METAL SHED

(747.54) MW-1

KEROSENE TANK EXCAVATION

(747.53) MW-4

BOILER ROOM

RAMP

MW-8 (747.52)

MW-8D

BUILDING FLOOR IS BUILT 4 FEET ABOVE SURROUNDING GROUND SURFACE

CONCRETE PAD, FLUSH WITH GROUND SURFACE, WITH OVERHEAD CANOPY

CONCRETE BUNKER

747.4 747.4

FLAMMABLE LIQUID AND OIL DRUM STORAGE ROOM

SECURITY GATE

GRAVEL PARKING LOT AND TRUCK DRIVEWAY

748 749 750

FENCE

ABOVE GROUND GASOLINE TANK

(750.45) MW-3

MW-3D

748 FENCE

SB-5VOC

10" SANITARY SEWER (VITRIFIED PIPE)

747.2 SB-6VOC

747.2

MW-9D

MW-9 (747.13)

CHICAGO, MILWAUKEE, ST. PAUL, AND PACIFIC RAILROAD

LEGEND

- MW-3 — WATER TABLE WELL
- MW-3D — PIEZOMETER
- SB-6VOC — SOIL BORING
- UPRIGHT SUPPORTS FOR CANOPY, CEILING
- DOORWAY
- (747.62) Water table Elevation (feet above M.S.L.)
- 747.5 — Water table contour
- Approximate direction of groundwater flow

0 30 60

SCALE: 1"=30'

NOTES

1. The water level in MW-2 was not incorporated into the water table map due to the presence of 2.77 feet of free product (machine oil) in the well.
2. A sanitary sewer leak may be the source of the anomalous head at MW-3.

SITE FEATURES MAP

TECUMSEH PRODUCTS COMPANY GRAFTON, WISCONSIN

RMT, INC.

DWN. BY:	DJW
APPROVED BY:	
DATE:	SEPTEMBER 1994
PROJ. #	3084.03
FILE #	30840302

FIGURE 3

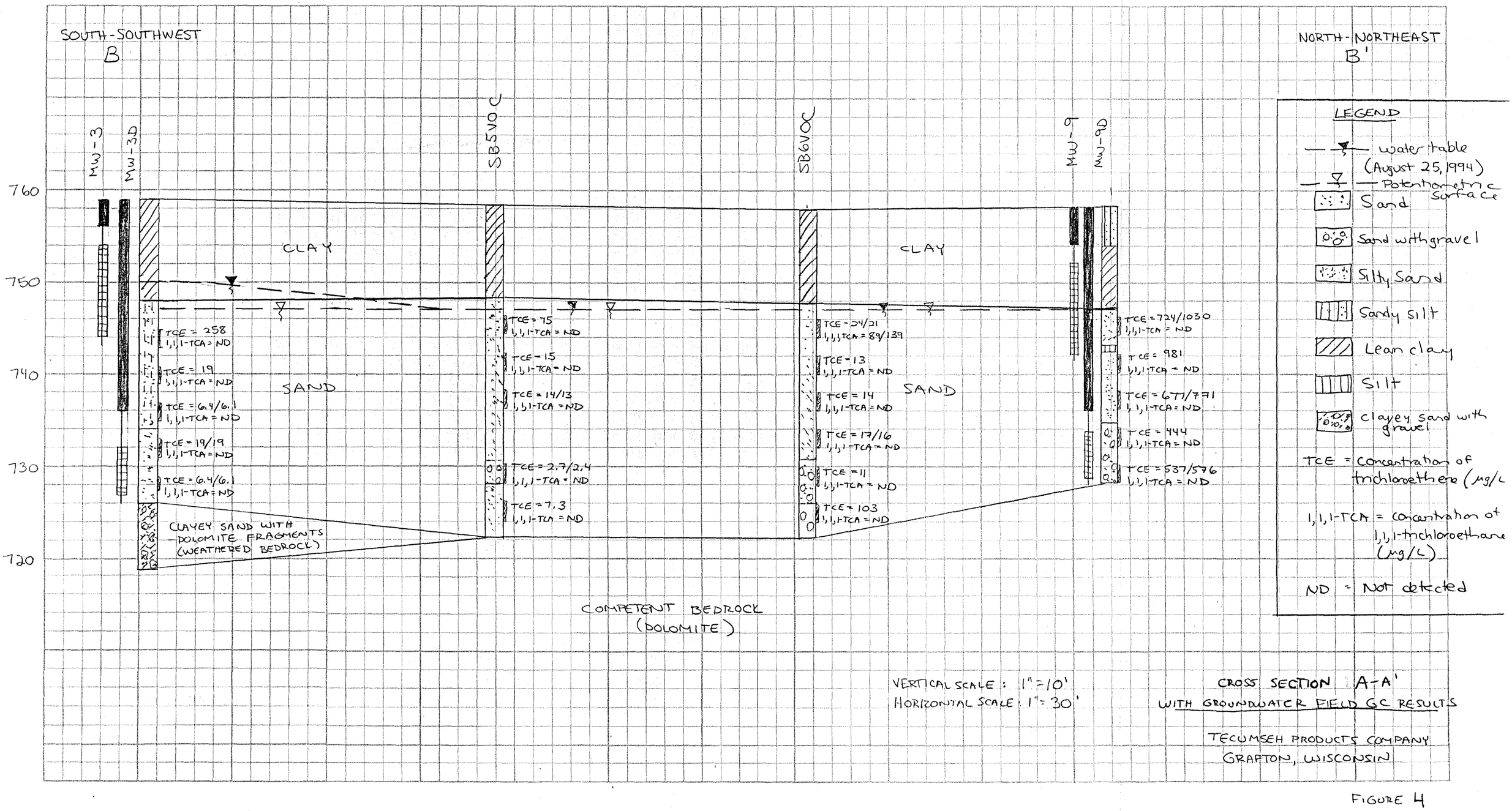
Drawing File = H:\3084_0\30840302
Xt Fil... = ...3403...F
Scale = 30000000.000000

RMT INC.
744 Heartland Trail P.O. Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX: (608) 831-3334

COMPUTATION SHEET

SHEET _____ OF _____

PROJECT/PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
Tecumseh Products Company	LSD	9-7-94			3084.03



VERTICAL SCALE: 1" = 10'
HORIZONTAL SCALE: 1" = 30'

CROSS SECTION A-A'
WITH GROUNDWATER FIELD GC RESULTS

TECUMSEH PRODUCTS COMPANY
GRAFTON, WISCONSIN

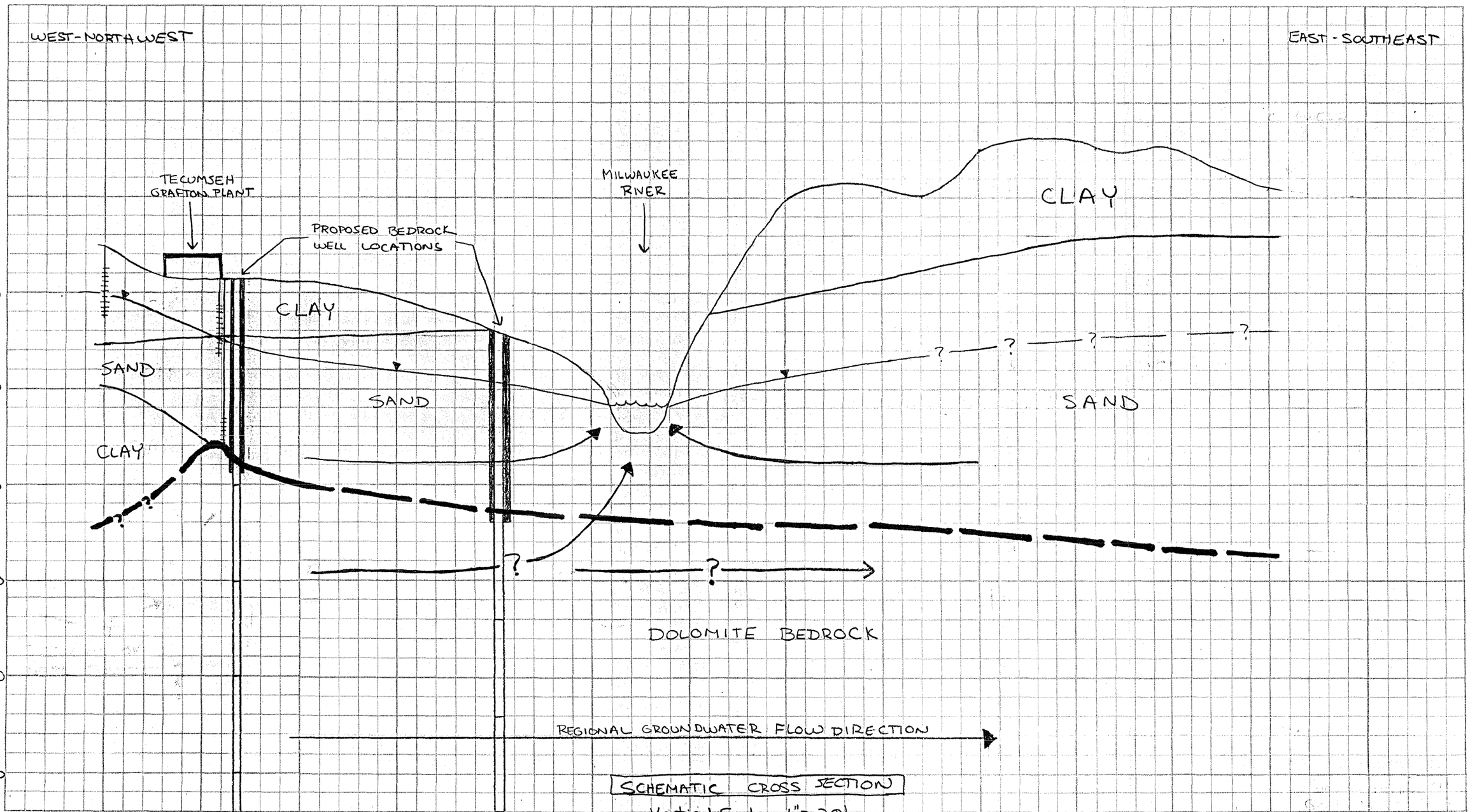
FIGURE 4

RMT INC.
744 Heartland Trail P.O. Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX: (608) 831-3334

COMPUTATION SHEET

SHEET _____ OF _____

PROJECT/PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
Tecumseh Products Company	L. Drzewiecki	9-12-94			3084.02



SCHEMATIC CROSS SECTION
Vertical Scale: 1"=20'
Horizontal Scale: 1"=500'

FIGURE 5

APPENDIX A

BORING LOGS AND BOREHOLE ABANDONMENT DOCUMENTATION

State of Wisconsin
Department of Natural Resources

Route To:
☐ Solid Waste ☐ Haz. Waste
☐ Emergency Response ☐ Underground Tanks
☐ Wastewater ☐ Water Resources
☐ Other

Soil Boring Log Information
Form 4400-122 7-91

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Tecumseh Products Co. 3084.03		MW3D

Boring Drilled By (Firm name and name of crew chief)	Date Drilling Started	Date Drilling Completed	Drilling Method
WTD, Crew Chief: Dan Zielazowski	8/16/94	8/17/94	HSA 4 1/4"

DNR Facitity Well No.	WI Unique Well No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW3D	Feet MSL	759.0 Feet MSL	8.0 Inches

Boring Location
State Plane N, E
SW 1/4 of SE 1/4 of Section 13 T 10 N,R 21E
Lat ° ' "
Long ° ' "

Local Grid Location (If applicable)
☐ N ☐ E
Feet ☐ S Feet ☐ W

County	DNR County Code	Civil Town/City/ or Village
Ozaukee	46	Grafton

Sample Number	Sample Length (Ft) Recovered	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plastic Limit	P 200	RQD/ Comments
A	20	9	1–4	**LEAN CLAY (CL)**, little silt, trace gravel, medium plasticity, yellowish brown 10YR 5/4, stiff.	CL				1.25	D				SS
B	20	17	5–7	As above (CL), 5% coarse sand, brown 10YR 5/3, very stiff.					2.75	D				SS
C	22	27	8–9	As above (CL).					3.75	D				SS
D	20	30	10	As above (CL), no sand, gray brown 10YR 5/2, stiff.					1.75	M				SS
			11–12	**SILTY SAND (SM)**, 25% silt, sand very fine grained, light yellowish	SM					W				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: Lisa A. Bzowski

Firm: RMT
744 Heartland Trail, Madison Wisconsin
Tel: 608-831-4444, Fax: 608-831-3334

State of Wisconsin
Department of Natural Resources

Soil Boring Log Information Supplement
Form 4400-122A 7-91

Boring Number **MW3D** Use only as an attachment to Form 4400-122. Page 2 of 3

Sample Number	Sample Length (Ft) Recovered	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plastic Limit	P 200	RQD/ Comments
E	18	14	13	brown 2.5Y 6/4, dense. As above, less silt (15%), light brownish gray 10YR 6/2, medium dense.						W				SS
			14											HP
			15											
F	20	12	16	**POORLY GRADED SAND WITH SILT (SP-SM)**, 10% silt, sand fine grained, light brownish gray 10YR 6/2, medium dense.	SP-SM					W				SS
			17											
			18											HP
			19											
G	20	29	20	As above (SP-SM).						W				SS
			21											
			22											HP
			23											
H	12	20	24	As above (SP-SM).						W				SS
			25	**POORLY GRADED SAND (SP)**, sand fine to medium grained, dark gray 10YR 4/1, medium dense.	SP									
			26											HP
			27											
I	18	15	28	As above (SP), sand fine grained, 5-10% silt, light brown gray 10YR 6/2.						W				SS
			29											
			30	Could only drive the hydropunch sampler to 31.5 Ft.										HP
			31											
			32											

Boring Number **MW3D** Use only as an attachment to Form 4400-122. Page 3 of 3

Sample Number	Sample Length (Ft) Recovered	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plastic Limit	P 200	RQD/ Comments
J	2	100/4"	33	Dolomite fragments in base of spoon. (Hard drilling from 31.5-33.0').										SS
K	6	100/3"	34	**CLAYEY SAND WITH GRAVEL (SC)**, 20% gravel (dolomite fragments), 20-25% clay, sand fine to coarse grained, brown 10YR 5/3, very dense (Weathered Bedrock).	SC									SS
			35											
L		100/2"	36	No recovery.										SS
			37											
M	6	100/3"	38	As above (SC).										SS
			39											
			40	**Auger Refusal at 40 Ft.** Dolomite Bedrock										

State of Wisconsin
Department of Natural Resources

Route To:
☐ Solid Waste ☐ Haz. Waste
☐ Emergency Response ☐ Underground Tanks
☐ Wastewater ☐ Water Resources
☐ Other

Soil Boring Log Information
Form 4400-122 7-91

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Tecumseh Products Co. 3084.03		MW8D

Boring Drilled By (Firm name and name of crew chief)	Date Drilling Started	Date Drilling Completed	Drilling Method
WTD, Crew Chief: Dan Zielazowski	8/18/94	8/19/94	HSA 4 1/4"

DNR Facitity Well No.	WI Unique Well No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW8D	Feet MSL	759.2 Feet MSL	8.0 Inches

Boring Location
State Plane N, E
SW 1/4 of SE 1/4 of Section 13 T 10 N,R 21E
Lat o ' "
Long o ' "

Local Grid Location (If applicable)
☐ N ☐ E
Feet ☐ S Feet ☐ W

County	DNR County Code	Civil Town/City/ or Village
Ozaukee	46	Grafton

Sample Number	Sample Length (Ft) Recovered	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plastic Limit	P 200	RQD/ Comments
A	14	25	1–4	**SANDY SILT (ML)**, trace gravel, 15-20% clay, brown 10YR 5/3, strong solvent-like odor, medium dense. 2" fine sand layer at 4'.	ML					D				SS
B	12	21	5–7	**LEAN CLAY (CL)**, little silt, medium plasticity, brown 10YR 5/3, strong solvent-like odor, medium stiff, a few small black patches of thick oily liquid (tarry consistency).	CL				1.0	M				SS
C	16	18	8–9	As above (CL), trace gravel, gray 10YR 5/1, black oily liquid.					0.75	M				SS
D	6	17	10–12	As above (CL), little sand, soft, no more black oily liquid. A few thin sand seams.					0.5	M				SS

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: Lisa J. Zyweck

Firm: RMT
744 Heartland Trail, Madison Wisconsin
Tel: 608-831-4444, Fax: 608-831-3334

This form is authorized by Chapters 144, 147 and 162, Wis. Stats. Completion of this report is mandatory. Penalties: Forfeit not less than $10 nor more than $5,000 for each violation. Fined not less than $10 or more than $100 or imprisoned not less than 30 days, or both for each violation. Each day of continued violation is a separate offense, pursuant to ss 144.99 and 162.06, Wis. Stats.

Boring Number **MW8D** Use only as an attachment to Form 4400-122. Page 2 of 3

Sample Number	Sample Length (Ft) Recovered	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plastic Limit	P 200	RQD/ Comments
E	18	40	13	**POORLY GRADED SAND (SP),** 5-10% silt, silt content decreases downward, sand fine-grained, pale brown 10YR 6/3, solvent-like odor, dense.	SP					W				SS
			14											
			15											HP
			16											
F	24	46	17	As above (SP), solvent odor.						W				SS
			18											
			19											HP
			20											
G	22	74	21	As above (SP), light brown gray 10YR 6/2, solvent odor, very dense.						W				SS
			22											
			23											
			24											HP
			25											
H	24	55	26	As above (SP), solvent odor.						W				SS
			27											
			28											HP
			29											
I	15	100	30	As above (SP), solvent odor.						W				SS
			31											
			32											

State of Wisconsin
Department of Natural Resources

Soil Boring Log Information Supplement
Form 4400-122A 7-91

Boring Number **MW8D** Use only as an attachment to Form 4400-122. Page 3 of 3

Sample Number	Sample Length (Ft) Recovered	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plastic Limit	P 200	RQD/ Comments
			33	Could only pound hydropunch 1 ft.	SP									HP
			34	**Auger Refusal at 34 Ft.** Dolomite Bedrock										

State of Wisconsin
Department of Natural Resources

Route To:
☐ Solid Waste ☐ Haz. Waste
☐ Emergency Response ☐ Underground Tanks
☐ Wastewater ☐ Water Resources
☐ Other

Soil Boring Log Information

Form 4400-122 7-91

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Tecumseh Products Co. 3084.03		MW9

Boring Drilled By (Firm name and name of crew chief)	Date Drilling Started	Date Drilling Completed	Drilling Method
WTD, Crew Chief: Dan Zielazowski	8/19/94	8/19/94	HSA 4 1/4"

DNR Facitity Well No.	WI Unique Well No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW9	Feet MSL	758.3 Feet MSL	8.0 Inches

Boring Location
State Plane N, E
SW 1/4 of SE 1/4 of Section 13 T 10 N,R 21E
Lat ° ' "
Long ° ' "

Local Grid Location (If applicable)
☐ N ☐ E
Feet ☐ S Feet ☐ W

County	DNR County Code	Civil Town/City/ or Village
Ozaukee	46	Grafton

Sample Number	Sample Length (Ft) Recovered	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plastic Limit	P 200	RQD/ Comments
			1–16	Blind drilled to 16.5 feet. See boring log for MW9D for description.										
				End of Boring at 16.5 Ft.										

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: Lisa A. Izewski

Firm: RMT
744 Heartland Trail, Madison Wisconsin
Tel: 608-831-4444, Fax: 608-831-3334

State of Wisconsin
Department of Natural Resources

Route To:
☐ Solid Waste ☐ Haz. Waste
☐ Emergency Response ☐ Underground Tanks
☐ Wastewater ☐ Water Resources
☐ Other

Soil Boring Log Information

Form 4400-122 7-91

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Tecumseh Products Co. 3084.03		**MW9D**

Boring Drilled By (Firm name and name of crew chief)	Date Drilling Started	Date Drilling Completed	Drilling Method
WTD, Crew Chief: Dan Zielazowski	**8/18/94**	**8/18/94**	**HSA 4 1/4"**

DNR Facitity Well No.	WI Unique Well No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW9D	Feet MSL	**758.2** Feet MSL	**8.0** Inches

Boring Location
State Plane N, E
SW 1/4 of **SE** 1/4 of Section **13** T **10** N,R **21E**
Lat ° ' "
Long ° ' "

Local Grid Location (If applicable)
☐ N ☐ E
Feet ☐ S Feet ☐ W

County	DNR County Code	Civil Town/City/ or Village
Ozaukee	**46**	**Grafton**

Sample Number	Sample Length (Ft) Recovered	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plastic Limit	P 200	RQD/ Comments
A	20	15	1–4	**SANDY SILT (ML)**, little clay, sand very fine grained, black 10YR 2/1 grading to yellowish brown 10YR 5/6, medium dense.	ML					D				SS
B	20	18	5–7	**LEAN CLAY (CL)**, little silt, trace gravel, medium plasticity, yellowish brown 10YR 5/4, medium stiff.	CL				1.0	D				SS
C	18	41	8	As above (CL), very stiff.					2.5	M				SS
			9	2" fine sand layer at 8.5', then 4" sandy silt (ML).										
D	15	13	10–11	**SANDY LEAN CLAY (CL)**, trace gravel, little silt, medium plasticity, brown 10YR 5/3, very stiff. As above.	CL				4.0	M				SS
			12	**POORLY GRADED SAND (SP),**						W				

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: Lisa A. Dzielazowski

Firm: RMT
744 Heartland Trail, Madison Wisconsin
Tel: 608-831-4444, Fax: 608-831-3334

This form is authorized by Chapters 144, 147 and 162, Wis. Stats. Completion of this report is mandatory. Penalties: Forfeit not less than $10 nor more than $5,000 for each violation. Fined not less than $10 or more than $100 or imprisoned not less than 30 days, or both for each violation. Each day of continued violation is a separate offense, pursuant to ss 144.99 and 162.06, Wis. Stats.

State of Wisconsin
Department of Natural Resources

Soil Boring Log Information Supplement
Form 4400-122A 7-91

Boring Number **MW9D** Use only as an attachment to Form 4400-122. Page 2 of 2

Sample Number	Sample Length (Ft) Recovered	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plastic Limit	P 200	RQD/ Comments
			13	sand medium grained, brown 10YR 5/3, medium dense.	SP									HP
E	20	50	14	**SILTY SAND (SM)**, sand fine grained, brown 10YR 5/3, dense.	SM					W				SS
			15	**SILT (ML)**, little sand, sand content increases downward, gray 10YR 6/1.	ML									
			16	**POORLY GRADED SAND (SP)**, sand fine grained, gray 10YR 6/1.	SP									HP
			17											
F	14	47	18	As above (SP), trace gravel, sand fine to medium grained, brown 10YR 5/3, dense.						W				SS
			19											
			20	Sandy clay in tip of spoon.										HP
			21											
G	15	60	22	As above (SP), very dense.						W				SS
			23											
			24	**POORLY GRADED GRAVEL WITH SAND (GP)**, 40% fine to coarse sand, light gray 10YR 7/2.	GP									HP
			25											
H	6	100/5"	26	**WELL GRADED SAND WITH GRAVEL (SW)**, 30% gravel, sand fine to coarse grained (mostly coarse), very dense.	SW					W				SS
			27											
			28	Dolomite fragment in shoe.										HP
			29											
			30	Rock fragment.										
I	1	100/1"		**Auger Refusal at 30.1 Ft.** Dolomite Bedrock.										SS

State of Wisconsin
Department of Natural Resources

Route To:
☐ Solid Waste ☐ Haz. Waste
☐ Emergency Response ☐ Underground Tanks
☐ Wastewater ☐ Water Resources
☐ Other

Soil Boring Log Information
Form 4400-122 7-91

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Tecumseh Products Co. 3084.03		MW10

Boring Drilled By (Firm name and name of crew chief)	Date Drilling Started	Date Drilling Completed	Drilling Method
WTD, Crew Chief: Dan Zielazowski	8/19/94	8/19/94	HSA 4 1/4"

DNR Facitity Well No.	WI Unique Well No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
		MW10	Feet MSL	769.8 Feet MSL	8.0 Inches

Boring Location
State Plane N, E
SE 1/4 of SW 1/4 of Section 13 T 10 N,R 21E
Lat ° ' "
Long ° ' "

Local Grid Location (If applicable)
☐ N ☐ E
Feet ☐ S Feet ☐ W

County	DNR County Code	Civil Town/City/ or Village
Ozaukee	46	Grafton

Sample Number	Sample Length (Ft) Recovered	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plastic Limit	P 200	RQD/ Comments
A	18	21	1–4	**SANDY SILT (ML)**, 5% gravel, 35-40% fine to coarse sand, yellowish brown 10YR 5/4.	ML					M				SS
B	16	16	5–6	**SILT (ML)**, 5% fine sand, nonplastic, light yellowish brown 10YR 6/4, very soft.	ML					W				SS
C	24	25	7–8	**SANDY LEAN CLAY (CL)**, 5% gravel, 30% sand, plastic, brown 10YR 5/3.	CL					W				SS
			9	**LEAN CLAY (CL)**, medium plasticity, gray 10YR 5/1.	CL									
D	6	16	10–12	As above (CL), 5% gravel, 5% medium to coarse sand, gray brown 10YR 5/2.						W				SS

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: Lisa A. Dzewiecki

Firm: RMT
744 Heartland Trail, Madison Wisconsin
Tel: 608-831-4444, Fax: 608-831-3334

State of Wisconsin
Department of Natural Resources

Soil Boring Log Information Supplement
Form 4400-122A 7-91

Boring Number **MW10** Use only as an attachment to Form 4400-122. Page 2 of 2

Sample Number	Sample Length (Ft) Recovered	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plastic Limit	Soil Properties: P 200	RQD/ Comments
E	20	57	13 14 15	As above (CL), little silt, hard, (Till).	CL				>4.0	W				SS
				End of Boring at 15.0 Ft.										

State of Wisconsin
Department of Natural Resources

Route To:
☐ Solid Waste ☐ Haz. Waste
☐ Emergency Response ☐ Underground Tanks
☐ Wastewater ☐ Water Resources
☐ Other

Soil Boring Log Information
Form 4400-122 7-91

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Tecumseh Products Co. 3084.03		SB5VOC

Boring Drilled By (Firm name and name of crew chief)	Date Drilling Started	Date Drilling Completed	Drilling Method
WTD, Crew Chief: Dan Zielazowski	8/16/94	8/16/94	HSA 4 1/4"

DNR Facitity Well No.	WI Unique Well No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
			Feet MSL	758.3 Feet MSL	8.0 Inches

Boring Location
State Plane N, E
SW 1/4 of SE 1/4 of Section 13 T 10 N,R 21E
Lat ° ' "
Long ° ' "

Local Grid Location (If applicable)
☐ N ☐ E
Feet ☐ S Feet ☐ W

County	DNR County Code	Civil Town/City/ or Village
Ozaukee	46	Grafton

Sample Number	Sample Length (Ft) Recovered	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plastic Limit	P 200	RQD/ Comments
A	14	6	1–4	**LEAN CLAY (CL)**, trace gravel, little silt, medium plasticity, yellowish brown 10YR 5/4, no odor, stiff.	CL				1.25	D				SS
B	20	6	5–7	As above (CL), trace coarse sand.					1.0	D				SS
C	20	29	8–9	As above (CL), no gravel, brown 10YR 5/3, hard. Thin sand seam at 9 ft.					4.5	D				SS
D	18	31	10–12	**POORLY GRADED SAND WITH SILT (SP-SM)**, 10% silt, sand very fine-grained, pale brown 10YR 6/3, dense.	SP-SM					W				SS

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: Lisa A. Izewski

Firm: RMT
744 Heartland Trail, Madison Wisconsin
Tel: 608-831-4444, Fax: 608-831-3334

Boring Number **SB5VOC** Use only as an attachment to Form 4400-122. Page 2 of 3

Sample Number	Sample Length (Ft) Recovered	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plastic Limit	P 200	RQD/ Comments
			13											HP
E	24	13	14	**POORLY GRADED SAND (SP)**, sand fine-grained, pale brown 10YR 6/3, medium dense.	SP					W				SS
			15											
			16											HP
			17											
F	22	28	18	As above (SP).						W				SS
			19											
			20											HP
			21											
G		23	22	As above (SP).						W				SS
			23											
			24	Hydropunch, no recovery.										
			25											
H	16	100/4"	26	As above (SP).						W				SS
			27											
			28	**WELL GRADED SAND WITH GRAVEL (SW)**, 40% gravel, sand fine to coarse-grained.	SW									HP
			29											
			30	Coarse sand on outside of Hydropunch.										
I	16	25		**WELL GRADED SAND (SW)**, fine to coarse-grained, brown 10YR 5/3, very dense.	SW					W				SS
			31											
			32											

State of Wisconsin
Department of Natural Resources

Soil Boring Log Information Supplement
Form 4400-122A 7-91

Boring Number **SB5VOC** Use only as an attachment to Form 4400-122.

Sample Number	Sample Length (Ft) Recovered	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plastic Limit	Soil Properties: P 200	RQD/ Comments
			33											HP
J	6	50	34	As above (SW), sand fine to medium-grained.	SW					W				SS
			35											
K	1	100/3"	36	Rock fragments in shoe.										SS
				Auger Refusal at 36 Ft. Dolomite Bedrock										

State of Wisconsin
Department of Natural Resources

Route To:
☐ Solid Waste ☐ Haz. Waste
☐ Emergency Response ☐ Underground Tanks
☐ Wastewater ☐ Water Resources
☐ Other

Soil Boring Log Information
Form 4400-122 7-91

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Tecumseh Products Co. 3084.03		SB6VOC

Boring Drilled By (Firm name and name of crew chief)	Date Drilling Started	Date Drilling Completed	Drilling Method
WTD, Crew Chief: Dan Zielazowski	8/17/94	8/17/94	HSA 4 1/4"

DNR Facitity Well No.	WI Unique Well No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
			Feet MSL	757.9 Feet MSL	8.0 Inches

Boring Location
State Plane N, E
SW 1/4 of SE 1/4 of Section 13 T 10 N,R 21E
Lat o , "
Long o , "

Local Grid Location (If applicable)
☐ N Feet ☐ E
☐ S Feet ☐ W

County	DNR County Code	Civil Town/City/ or Village
Ozaukee	46	Grafton

Sample Number	Sample Length (Ft) Recovered	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plastic Limit	P 200	RQD/ Comments
A	0	6	1–4	No recovery.										SS
B	20	4	5–7	**LEAN CLAY (CL)**, little silt, medium plasticity, brown 7.5YR 5/3, medium stiff.	CL				0.75	D				SS
C	20	38	8–9	As above (CL), 5% gravel, yellowish brown 10RY 5/4, very stiff.					4.0	D				SS
D	15	21	10–12	**POORLY GRADED SAND (SP)**, sand fine to medium grained, yellowish brown 10YR 5/4, medium dense.	SP					W				SS

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: Lisa A. Zielazowski

Firm: RMT
744 Heartland Trail, Madison Wisconsin
Tel: 608-831-4444, Fax: 608-831-3334

Boring Number **SB6VOC** Use only as an attachment to Form 4400-122. Page 2 of 3

Sample Number	Sample Length (Ft) Recovered	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plastic Limit	Soil Properties: P 200	RQD/ Comments
			13											HP
E	12	37	14	As above (SP), brown 10YR 5/3, dense.	SP					W				SS
			15											
			16											HP
			17											
F	18	24	18	As above (SP), medium dense.						W				SS
			19											
			20	Bottom 2" is a sandy silt, sand very fine grained.										HP
			21											
G	1	100/5"	22	As above (SP), sand fine to medium grained, little coarse sand.						W				SS
			23											
			24											HP
			25											
H	12	41	26	As above (SP), coarsens downward.						W				SS
			27	**POORLY GRADED GRAVEL WITH SAND (GP)**, 30-40% fine to coarse sand (mostly coarse grained), wide range of colors, dense.	GP									
			28											HP
			29											
I	6	100/5"	30	As above (GP), big chunk of dolomite in shoe.						W				SS
			31											
			32											

State of Wisconsin
Department of Natural Resources

Soil Boring Log Information Supplement
Form 4400-122A 7-91

Boring Number **SB6VOC** Use only as an attachment to Form 4400-122.

Sample Number	Sample Length (Ft) Recovered	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plastic Limit	Soil Properties: P 200	RQD/ Comments
			33											HP
J	2	100/4"	34	Dolomite rock fragment in shoe.	GP									SS
			35	**Auger Refusal at 35.5 Ft.** Dolomite Bedrock.										

State of Wisconsin
Department of Natural Resources

Route To:
☐ Solid Waste ☐ Haz. Waste
☐ Emergency Response ☐ Underground Tanks
☐ Wastewater ☐ Water Resources
☐ Other

Soil Boring Log Information
Form 4400-122 7-91

Facility/Project Name	License/Permit/Monitoring Number	Boring Number
Tecumseh Products Co. 3084.03		SB8VOC

Boring Drilled By (Firm name and name of crew chief)	Date Drilling Started	Date Drilling Completed	Drilling Method
WTD, Crew Chief: Dan Zielazowski	8/15/94	8/15/94	HSA 4 1/4"

DNR Facitity Well No.	WI Unique Well No.	Common Well Name	Final Static Water Level	Surface Elevation	Borehole Diameter
			Feet MSL	767.5 Feet MSL	8.0 Inches

Boring Location
State Plane N, E
SE 1/4 of SW 1/4 of Section 13 T 10 N,R 21E
Lat ° ' "
Long ° ' "

Local Grid Location (If applicable)
☐ N ☐ E
Feet ☐ S Feet ☐ W

County	DNR County Code	Civil Town/City/ or Village
Ozaukee	46	Grafton

Sample Number	Sample Length (Ft) Recovered	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Moisture Content	Liquid Limit	Plastic Limit	P 200	RQD/ Comments
A	8	25	1–4	**SANDY SILT (ML)**, 35-40% sand, sand very fine grained, nonplastic, light yellowish brown 10YR 6/4, medium dense.	ML					M				SS
B	4	27	5–7	**LEAN CLAY WITH SAND (CL)**, trace gravel, 20-25% fine grained sand, little silt, medium plasticity, brown 10YR 5/3.	CL					W				SS
C	24	18	8–9	**LEAN CLAY (CL)**, trace gravel, medium plasticity, brown 10YR 5/3 changing to gray 10YR 5/1 at 9', stiff.	CL				1.75	W				SS
D	4	11	10–12	As above (CL), yellowish brown 10YR 5/4.										SS

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: Lisa A. Przewoda

Firm: RMT
744 Heartland Trail, Madison Wisconsin
Tel: 608-831-4444, Fax: 608-831-3334

Boring Number **SB8VOC** Use only as an attachment to Form 4400-122. Page 2 of 3

Sample Number	Sample Length (Ft) Recovered	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plastic Limit	Soil Properties: P 200	RQD/ Comments
			13											
E	22	75	14	As above (CL), little silt, gray 10YR 5/1, hard, (Till).	CL				4.5	M				SS
			15											
				1" sand seam at 15'.										
			16											
			17											
F	20	31	18	**POORLY GRADED SAND (SP)**, trace gravel, sand fine grained, light yellowish brown 10YR 6/4, dense. 4" lean clay layer at 19'.	SP					W				SS
			19											
			20											HP
			21											
G	6	23	22	As above (SP), pale brown 10YR 6/3, medium dense, little clay at base of spoon.						W				SS
			23											
			24											HP
			25											
H	20	58	26	As above (SP), 4" coarse sand and gravel layer at 26.6'.										SS
			27	**LEAN CLAY (CL)**, little silt, plastic, gray brown 10YR 5/2, stiff.	CL				1.75	W				
			28											
			29											
I	22	26	30	As above (CL), trace coarse sand.					1.5	W				SS
			31											
				1" medium sand seam at base of spoon.										
			32											
			33											

Boring Number **SB8VOC** Use only as an attachment to Form 4400-122. Page 3 of 3

Sample Number	Sample Length (Ft) Recovered	Blow Counts	Depth In Feet	Soil/Rock Description And Geologic Origin For Each Major Unit	USCS	Graphic Log	Well Diagram	PID/FID	Soil Properties: Standard Penetration	Soil Properties: Moisture Content	Soil Properties: Liquid Limit	Soil Properties: Plastic Limit	Soil Properties: P 200	RQD/ Comments
J	24	32	34–37	As above (CL), trace gravel.	CL				1.75	W				SS
K	24	42	38–39	As above (CL), no gravel.					2.0	W				SS
			39–43	**SILT (ML)**, 40% clay, low plasticity, gray brown 10YR 5/2, soft.	ML				0.5	W				
L	24	34	43–46	As above (ML), medium stiff.					0.75	W				SS
M	18	33	46–49	As above (ML), trace gravel, soft.					0.5	W				SS
N	18	68	49–52	**LEAN CLAY (CL)**, trace gravel, 30-40% silt, gray brown 10YR 5/2, stiff. Bottom 2" is a clayey sand with 25% gravel.	CL				1.5	W				SS
			52	**End of Boring at 52 Ft.**										

State of Wisconsin
Department of Natural Resources

WELL/DRILLHOLE/BOREHOLE ABANDONMENT

Form 3300-5B Rev. 8-89

All abandonment work shall be performed in accordance with the provisions of Chapters NR 111, NR 112 or NR 141, Wis. Admin. Code, whichever is applicable. Also, see instructions on back.

(1) GENERAL INFORMATION

Well/Drillhole/Borehole Location

County: Ozaukee

___ 1/4 of ___ 1/4 of Sec. ___ ; T. ___ N; R. ___ ☐ E ☐ W

(If applicable)

___ Gov't Lot ___ Grid Number

Grid Location

___ ft. ☐ N. ☐ S., ___ ft. ☐ E. ☐ W.

Civil Town Name

Street Address of Well

City, Village: Grafton

(2) FACILITY NAME

Original Well Owner (If Known)

Present Well Owner: Tecymseh

Street or Route

City, State, Zip Code: Grafton, WI

Facility Well No. and/or Name (If Applicable): SB-6VOC

WI Unique Well No.

Reason For Abandonment: Auger Refusal

Date of Abandonment: 8/17/94

WELL/DRILLHOLE/BOREHOLE INFORMATION

(3) Original Well/Drillhole/Borehole Construction Completed On

(Date) ___

☐ Monitoring Well
☐ Water Well
☒ Drillhole
☐ Borehole

Construction Report Available? ☒ Yes ☐ No

Construction Type:
☒ Drilled ☐ Driven (Sandpoint) ☐ Dug
☐ Other (Specify) ___

Formation Type:
☒ Unconsolidated Formation ☐ Bedrock

Total Well Depth (ft.) ___ Casing Diameter (ins.) ___
(From groundsurface)

Casing Depth (ft.) ___

Was Well Annular Space Grouted? ☐ Yes ☐ No ☐ Unknown
If Yes, To What Depth? ___ Feet

(4) Depth to Water (Feet) 11.0

Pump & Piping Removed?	☐ Yes	☒ No	☒ Not Applicable
Liner(s) Removed?	☐ Yes	☐ No	☒ Not Applicable
Screen Removed?	☐ Yes	☐ No	☒ Not Applicable
Casing Left in Place?	☐ Yes	☐ No	

If No, Explain ___

Was Casing Cut Off Below Surface?	☐ Yes	☐ No
Did Sealing Material Rise to Surface?	☒ Yes	☐ No
Did Material Settle After 24 Hours?	☐ Yes	☒ No
If Yes, Was Hole Retopped?	☐ Yes	☐ No

(5) Required Method of Placing Sealing Material
☒ Conductor Pipe-Gravity ☐ Conductor Pipe-Pumped
☐ Dump Bailer ☐ Other (Explain)

(6) Sealing Materials
☐ Neat Cement Grout
☐ Sand-Cement (Concrete) Grout
☐ Concrete
☐ Clay-Sand Slurry
☐ Bentonite-Sand Slurry
☒ Chipped Bentonite

For monitoring wells and monitoring well boreholes only
☐ Bentonite Pellets
☐ Granular Bentonite
☐ Bentonite - Cement Grout

(7) Sealing Material Used	From (Ft.)	To (Ft.)	No. Yards, Sacks Sealant or Volume	Mix Ratio or Mud Weight
Bentonite Chips	Surface	35.5	8 bags	
Gel			1 bag	
Benseal			2 bags	

(8) Comments: ___

(9) Name of Person or Firm Doing Sealing Work: WTD Environmental Drilling

Signature of Person Doing Work: [signature] Date Signed: 8/25/94

Street or Route: 101 Alderson Street Telephone Number: (715) 359-7090

City, State, Zip Code: Schofield, Wi 54476

(10) FOR DNR OR COUNTY USE ONLY

Date Received/Inspected	District/County
Reviewer/Inspector	
Follow-up Necessary	

DNR/COUNTY

State of Wisconsin
Department of Natural Resources

WELL/DRILLHOLE/BOREHOLE ABANDONMENT

Form 3300-5B
Rev. 8-89

All abandonment work shall be performed in accordance with the provisions of Chapters NR 111, NR 112 or NR 141, Wis. Admin. Code, whichever is applicable. Also, see instructions on back.

(1) GENERAL INFORMATION

Well/Drillhole/Borehole Location

County: Ozaukee

___ 1/4 of ___ 1/4 of Sec. ___ ; T. ___ N; R. ___ ☐ E ☐ W

(If applicable) ___ Gov't Lot ___ Grid Number

Grid Location ___ ft. ☐ N. ☐ S., ___ ft. ☐ E. ☐ W.

Civil Town Name

Street Address of Well

City, Village: Grafton

(2) FACILITY NAME

Original Well Owner (If Known)

Present Well Owner: Tecymseh

Street or Route

City, State, Zip Code: Grafton, WI

Facility Well No. and/or Name (If Applicable): SB-6VOC

WI Unique Well No.: _ _ _ _ _ _

Reason For Abandonment: Auger Refusal

Date of Abandonment: 8/17/94

WELL/DRILLHOLE/BOREHOLE INFORMATION

(3) Original Well/Drillhole/Borehole Construction Completed On

(Date) ___

☐ Monitoring Well
☐ Water Well
☒ Drillhole
☐ Borehole

Construction Report Available? ☒ Yes ☐ No

Construction Type:
☒ Drilled ☐ Driven (Sandpoint) ☐ Dug
☐ Other (Specify) ___

Formation Type:
☒ Unconsolidated Formation ☐ Bedrock

Total Well Depth (ft.) ___ Casing Diameter (ins.) ___
(From groundsurface)

Casing Depth (ft.) ___

Was Well Annular Space Grouted? ☐ Yes ☐ No ☐ Unknown
If Yes, To What Depth? ___ Feet

(4) Depth to Water (Feet): 11.0

Pump & Piping Removed?	☐ Yes	☒ No	☒ Not Applicable
Liner(s) Removed?	☐ Yes	☐ No	☒ Not Applicable
Screen Removed?	☐ Yes	☐ No	☒ Not Applicable
Casing Left in Place?	☐ Yes	☐ No	

If No, Explain ___

Was Casing Cut Off Below Surface?	☐ Yes	☐ No
Did Sealing Material Rise to Surface?	☒ Yes	☐ No
Did Material Settle After 24 Hours?	☐ Yes	☒ No
If Yes, Was Hole Retopped?	☐ Yes	☐ No

(5) Required Method of Placing Sealing Material
☒ Conductor Pipe-Gravity ☐ Conductor Pipe-Pumped
☐ Dump Bailer ☐ Other (Explain)

(6) Sealing Materials
☐ Neat Cement Grout
☐ Sand-Cement (Concrete) Grout
☐ Concrete
☐ Clay-Sand Slurry
☐ Bentonite-Sand Slurry
☒ Chipped Bentonite

For monitoring wells and monitoring well boreholes only
☐ Bentonite Pellets
☐ Granular Bentonite
☐ Bentonite - Cement Grout

(7) Sealing Material Used	From (Ft.)	To (Ft.)	No. Yards, Sacks Sealant or Volume	Mix Ratio or Mud Weight
Bentonite Chips	Surface	35.5	8 bags	
Gel			1 bag	
Benseal			2 bags	

(8) Comments: ___

(9) Name of Person or Firm Doing Sealing Work: WTD Environmental Drilling

Signature of Person Doing Work: [signature]

Date Signed: 8/25/94

Street or Route: 101 Alderson Street

Telephone Number: (715) 359-7090

City, State, Zip Code: Schofield, Wi 54476

(10) FOR DNR OR COUNTY USE ONLY

Date Received/Inspected	District/County
Reviewer/Inspector	
Follow-up Necessary	

DNR/COUNTY

State of Wisconsin
Department of Natural Resources

WELL/DRILLHOLE/BOREHOLE ABANDONMENT

Form 3300-5B Rev. 8-89

All abandonment work shall be performed in accordance with the provisions of Chapters NR 111, NR 112 or NR 141, Wis. Admin. Code, whichever is applicable. Also, see instructions on back.

(1) GENERAL INFORMATION

Well/Drillhole/Borehole Location

County: Ozaukee

___ 1/4 of ___ 1/4 of Sec. ___ ; T. ___ N; R. ___ ☐ E ☐ W

(If applicable) ___ Gov't Lot ___ Grid Number

Grid Location ___ ft. ☐ N. ☐ S., ___ ft. ☐ E. ☐ W.

Civil Town Name

Street Address of Well

City, Village: Grafton

(2) FACILITY NAME

Original Well Owner (If Known)

Present Well Owner: Tecymseh

Street or Route

City, State, Zip Code: Grafton, WI

Facility Well No. and/or Name (If Applicable): SB-8VOC

WI Unique Well No.: _ _ _ _ _ _

Reason For Abandonment: No longer needed

Date of Abandonment: 8/15/94

WELL/DRILLHOLE/BOREHOLE INFORMATION

(3) Original Well/Drillhole/Borehole Construction Completed On (Date) ___

☐ Monitoring Well
☐ Water Well
☒ Drillhole
☐ Borehole

Construction Report Available? ☒ Yes ☐ No

Construction Type:
☒ Drilled ☐ Driven (Sandpoint) ☐ Dug
☐ Other (Specify) ___

Formation Type:
☒ Unconsolidated Formation ☐ Bedrock

Total Well Depth (ft.) ___ Casing Diameter (ins.) ___
(From groundsurface)

Casing Depth (ft.) ___

Was Well Annular Space Grouted? ☐ Yes ☐ No ☐ Unknown
If Yes, To What Depth? ___ Feet

(4) Depth to Water (Feet) 11.0

Pump & Piping Removed?	☐ Yes	☒ No	☒ Not Applicable
Liner(s) Removed?	☐ Yes	☐ No	☒ Not Applicable
Screen Removed?	☐ Yes	☐ No	☒ Not Applicable
Casing Left in Place?	☐ Yes	☐ No	

If No, Explain ___

Was Casing Cut Off Below Surface?	☐ Yes	☐ No
Did Sealing Material Rise to Surface?	☒ Yes	☐ No
Did Material Settle After 24 Hours?	☐ Yes	☒ No
If Yes, Was Hole Retopped?	☐ Yes	☐ No

(5) Required Method of Placing Sealing Material
☒ Conductor Pipe-Gravity ☒ Conductor Pipe-Pumped
☐ Dump Bailer ☐ Other (Explain)

(6) Sealing Materials
☐ Neat Cement Grout
☐ Sand-Cement (Concrete) Grout
☐ Concrete
☐ Clay-Sand Slurry
☐ Bentonite-Sand Slurry
☒ Chipped Bentonite

For monitoring wells and monitoring well boreholes only
☐ Bentonite Pellets
☐ Granular Bentonite
☒ Bentonite - Cement Grout

(7)

Sealing Material Used	From (Ft.)	To (Ft.)	No. Yards, Sacks Sealant or Volume	Mix Ratio or Mud Weight
Bentonite Chips	Surface	52.0	8 bags	
Cement Bentonite Grout (Gel)			2 bags	

(8) Comments: ___

(9) Name of Person or Firm Doing Sealing Work: WTD Environmental Drilling

Signature of Person Doing Work: [signature] Date Signed: 8/25/94

Street or Route: 101 Alderson Street Telephone Number: (715) 359-7090

City, State, Zip Code: Schofield, Wi 54476

(10) FOR DNR OR COUNTY USE ONLY

Date Received/Inspected	District/County
Reviewer/Inspector	
Follow-up Necessary	

APPENDIX B

WELL CONSTRUCTION AND DEVELOPMENT DOCUMENTATION

State of Wisconsin
Department of Natural Resources

Route to: Solid Waste ☐ Haz. Waste ☐ Wastewater ☐
Env. Response & Repair ☐ Underground Tanks ☐ Other ☐

MONITORING WELL CONSTRUCTION
Form 4400-113A Rev. 4-90

Facility/Project Name Tecumseh Products Company 3084.02	Local Grid Location of Well ☐ N. ☐ E. ft. ☐ S. ft. ☐ W.	Well Name MW-3D
Facility License, Permit or Monitoring Number	Grid Origin Location Lat. ___ ___ ___ Long. ___ ___ ___ or	Wis. Unique Well Number DNR Well Number ___ ___ ___ ___ ___ ___ ___ ___ ___
Type of Well: Water Table Observation Well ☐ 11 Piezometer ■ 12	St. Plane ft. N, ft. E.	Date Well Installed 08 / 17 / 94 MM DD YY
Distance Well is From Waste/Source Boundary ft.	Section Location of Waste/Source ■ E. SW¼ of SE¼ of Sec.13, T10N, R21 ☐ W.	Well Installed By: (Persons' Name and Firm) Dan Zielazowski WTD Environmental Drilling
Is Well A Point of Enforcement Std. Application? ☐ Yes ☐ No	Location of Well Relative to Waste/Source U ☐ Upgradient S ☐ Sidegradient D ■ Downgradient N ☐ Not Known	

A. Protective pipe, top elevation ____.__ ft. MSL

B. Well casing, top elevation 758.60 ft. MSL

C. Land surface elevation 759.0 ft. MSL

D. Surface seal, bottom 758.0 ft. MSL or 1.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ■
SM ☐ SC ■ ML ☐ MH ☐ CL ☐ CH ☐
Bedrock ☐

13. Sieve analysis attached? Yes ☐ No ■

14. Drilling method used: Rotary ☐ 50
Hollow Stem Auger ■ 41
_____ Other ☐

15. Drilling fluid used: Water ☐ 02 Air ☐ 01
Drilling Mud ☐ 03 None ■ 99

16. Drilling additives used? Yes ☐ No ■

Describe _____

17. Source of water (attach analysis):

E. Bentonite seal, top 758.0 ft. MSL or 1.0 ft.

F. Fine sand, top 736.0 ft. MSL or 23.0 ft.

G. Filter pack, top 734.0 ft. MSL or 25.0 ft.

H. Screen joint, top 732.0 ft. MSL or 27.0 ft.

I. Well bottom 727.0 ft. MSL or 32.0 ft.

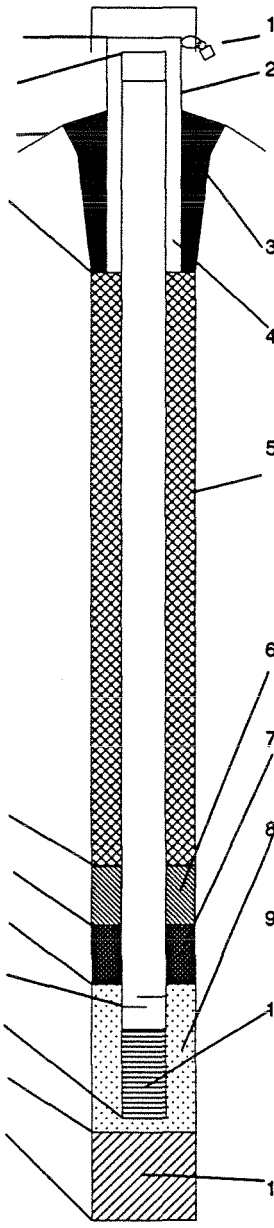
J. Filter pack, bottom 726.0 ft. MSL or 33.0 ft.

K. Borehole, bottom 719.0 ft. MSL or 40.0 ft.

L. Borehole, diameter 8.0 in.

M. O.D. well casing 2.20 in.

N. I.D. well casing 2.00 in.



1. Cap and lock? ■ Yes ☐ No

2. Protective cover pipe:
a. Inside diameter: 8.0 in.
b. Length: 1.0 ft.
c. Material: Steel ☐ 04
Cast Aluminum Other ■
d. Additional protection? ☐ Yes ☐ No
If yes, describe: _____

3. Surface seal: Bentonite ☐ 30
Concrete ■ 01
_____ Other ☐

4. Material between well casing and protective pipe:
Bentonite ■ 30
Annular space seal ☐
_____ Other ☐

5. Annular space seal: a. Granular Bentonite ☐ 33
b. ___ Lbs/gal mud weight..Bentonite-sand slurry ☐ 35
c. ___ Lbs/gal mud weight..... Bentonite slurry ☐ 31
d. ___ % Bentonite..... Bentonite-cement grout ☐ 50
e. ___ lb volume added for any of the above
f. How installed: Tremie ☐ 01
Tremie pumped ☐ 02
Gravity ☐ 08

6. Bentonite seal: a. Bentonite granules ☐ 33
b. ☐ 1/4 in. ☐3/8 in. ☐ 1/2 in. Bentonite pellets ☐ 32
c. 3/8" Bentonite Chips Other ■

7. Fine sand material: Manufacturer, product name, mesh size
a. Badger Mining Corp. BB#7
b. Volume added 50 lb

8. Filter pack material: Manufacturer, product, mesh size
a. Red Flint #30 Sand
b. Volume added 250 lb

9. Well casing: Flush threaded PVC schedule 40 ■ 23
Flush threaded PVC schedule 80 ☐ 24
_____ Other ☐

10. Screen Material: Schedule 40 PVC
a. Screen type: Factory cut ■ 11
Continuous slot ☐ 01
_____ Other ☐
b. Manufacturer Northern Air
c. Slot size: 0.010 in.
d. Slotted length: 5.0 ft.

11. Backfill material (below filter pack): None ☐14
3/8" bentonite chips Other ■

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature Lori A Izquierdo Firm RMT, Inc.

Please complete both sides of this form and return to the appropriate DNR office listed at the top of this form as required by chs. 144, 147 and 160, Wis. Stats., and ch. NR 141, Wis. Adm. Code. In accordance with ch. 144, Wis. Stats., failure to file this form may result in a forfeiture of not less than $10, nor more than $5,000 for each day of violation. In accordance with ch. 147, Wis. Stats., failure to file this form may result in a forfeiture of not more than $10,000 for each day of violation. NOTE: Shaded areas are for DNR use only. See instructions for more information including where the completed form should be sent.

State of Wisconsin
Department of Natural Resources

Route to: Solid Waste ☐ Haz. Waste ☐ Wastewater ☐
Env. Response & Repair ☐ Underground Tanks ☐ Other ☐

MONITORING WELL CONSTRUCTION

Form 4400-113A Rev. 4-90

Facility/Project Name Tecumseh Products Company 3084.02	Local Grid Location of Well ☐ N. ☐ E. ft. ☐ S. ft. ☐ W.	Well Name MW-8D
Facility License, Permit or Monitoring Number	Grid Origin Location Lat. ___ ___ ___ Long. ___ ___ ___ or	Wis. Unique Well Number / DNR Well Number ___ ___ ___ ___ ___ ___ / ___ ___ ___
Type of Well: Water Table Observation Well ☐ 11 Piezometer ■ 12	St. Plane ft. N, ft. E.	Date Well Installed 08 / 19 / 94 MM DD YY
Distance Well is From Waste/Source Boundary ft.	Section Location of Waste/Source ■ E. SW¼ of SE¼ of Sec.13, T10N, R21 ☐ W.	Well Installed By: (Persons' Name and Firm) Dan Zielazowski WTD Environmental Drilling
Is Well A Point of Enforcement Std. Application? ☐ Yes ☐ No	Location of Well Relative to Waste/Source U ☐ Upgradient S ☐ Sidegradient D ■ Downgradient N ☐ Not Known	

A. Protective pipe, top elevation ____.__ ft. MSL

B. Well casing, top elevation 758.98 ft. MSL

C. Land surface elevation 759.2 ft. MSL

D. Surface seal, bottom 758.2 ft. MSL or 1.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ■
SM ☐ SC ☐ ML ☐ MH ☐ CL ☐ CH ☐
Bedrock ☐

13. Sieve analysis attached? Yes ☐ No ■

14. Drilling method used: Rotary ☐ 50
Hollow Stem Auger ■ 41
_____ Other ☐

15. Drilling fluid used: Water ☐ 02 Air ☐ 01
Drilling Mud ☐ 03 None ■ 99

16. Drilling additives used? Yes ☐ No ■
Describe _____

17. Source of water (attach analysis):

E. Bentonite seal, top 758.2 ft. MSL or 1.0 ft.

F. Fine sand, top 733.2 ft. MSL or 26.0 ft.

G. Filter pack, top 732.2 ft. MSL or 27.0 ft.

H. Screen joint, top 730.9 ft. MSL or 28.3 ft.

I. Well bottom 725.9 ft. MSL or 33.3 ft.

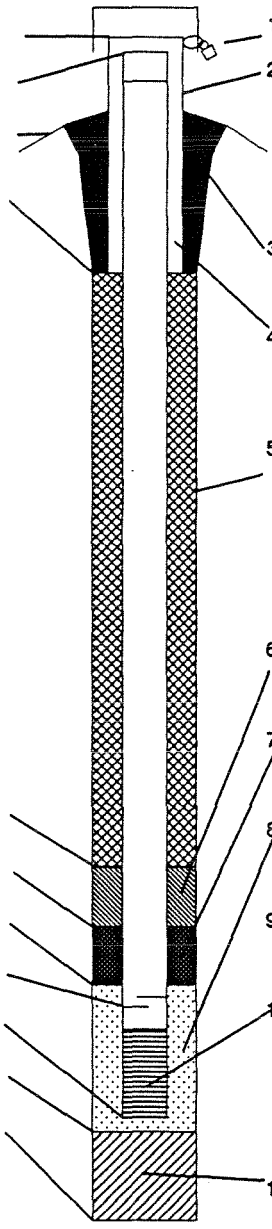
J. Filter pack, bottom 725.9 ft. MSL or 33.3 ft.

K. Borehole, bottom 725.2 ft. MSL or 34.0 ft.

L. Borehole, diameter 8.0 in.

M. O.D. well casing 2.20 in.

N. I.D. well casing 2.00 in.



1. Cap and lock? ■ Yes ☐ No

2. Protective cover pipe:
a. Inside diameter: 8.0 in.
b. Length: 1.0 ft.
c. Material: Steel ☐ 04
Cast Aluminum Other ■
d. Additional protection? ☐ Yes ☐ No
If yes, describe: _____

3. Surface seal: Bentonite ☐ 30
Concrete ■ 01
_____ Other ☐

4. Material between well casing and protective pipe:
Bentonite ■ 30
Annular space seal ☐
_____ Other ☐

5. Annular space seal: a. Granular Bentonite ☐ 33
b. ___ Lbs/gal mud weight..Bentonite-sand slurry ☐ 35
c. ___ Lbs/gal mud weight..... Bentonite slurry ☐ 31
d. ___ % Bentonite..... Bentonite-cement grout ☐ 50
e. ___ lb volume added for any of the above
f. How installed: Tremie ☐ 01
Tremie pumped ☐ 02
Gravity ☐ 08

6. Bentonite seal: a. Bentonite granules ☐ 33
b. ☐ 1/4 in. ☐3/8 in. ☐ 1/2 in. Bentonite pellets ☐ 32
c. 3/8" Bentonite Chips Other ■

7. Fine sand material: Manufacturer, product name, mesh size
a. Badger Mining Corp. BB#7
b. Volume added 50 lb

8. Filter pack material: Manufacturer, product, mesh size
a. Red Flint #30 Sand
b. Volume added 150 lb

9. Well casing: Flush threaded PVC schedule 40 ■ 23
Flush threaded PVC schedule 80 ☐ 24
_____ Other ☐

10. Screen Material: Schedule 40 PVC
a. Screen type: Factory cut ■ 11
Continuous slot ☐ 01
_____ Other ☐
b. Manufacturer Northern Air
c. Slot size: 0.010 in.
d. Slotted length: 5.0 ft.

11. Backfill material (below filter pack): None ☐14
Native soil Other ■

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature: Lisa M. Theurer | Firm: RMT, Inc.

Please complete both sides of this form and return to the appropriate DNR office listed at the top of this form as required by chs. 144, 147 and 160, Wis. Stats., and ch. NR 141, Wis. Adm. Code. In accordance with ch. 144, Wis. Stats., failure to file this form may result in a forfeiture of not less than $10, nor more than $5,000 for each day of violation. In accordance with ch. 147, Wis. Stats., failure to file this form may result in a forfeiture of not more than $10,000 for each day of violation. NOTE: Shaded areas are for DNR use only. See instructions for more information including where the completed form should be sent.

State of Wisconsin
Department of Natural Resources

Route to: Solid Waste ☐ Haz. Waste ☐ Wastewater ☐
Env. Response & Repair ☐ Underground Tanks ☐ Other ☐ _____

MONITORING WELL CONSTRUCTION

Form 4400-113A Rev. 4-90

Facility/Project Name Tecumseh Products Company 3084.02	Local Grid Location of Well ☐ N. ☐ E. ft. ☐ S. ft. ☐ W.	Well Name MW-9
Facility License, Permit or Monitoring Number	Grid Origin Location Lat. ___ ___ ___ Long. ___ ___ ___ or	Wis. Unique Well Number DNR Well Number ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
Type of Well: Water Table Observation Well ■ 11 Piezometer ☐ 12	St. Plane ft. N, ft. E.	Date Well Installed 08 / 19 / 94 MM DD YY
Distance Well is From Waste/Source Boundary ft.	Section Location of Waste/Source ■ E. SW¼ of SE¼ of Sec.13, T10N, R21 ☐ W.	Well Installed By: (Persons' Name and Firm) Dan Zielazowski WTD Environmental Drilling
Is Well A Point of Enforcement Std. Application? ☐ Yes ☐ No	Location of Well Relative to Waste/Source U ☐ Upgradient S ☐ Sidegradient D ■ Downgradient N ☐ Not Known	

A. Protective pipe, top elevation 760.77 ft. MSL

B. Well casing, top elevation 760.72 ft. MSL

C. Land surface elevation 758.3 ft. MSL

D. Surface seal, bottom _____ ft. MSL or 0.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ■
SM ■ SC ☐ ML ■ MH ☐ CL ■ CH ☐
Bedrock ☐

13. Sieve analysis attached? Yes ☐ No ■

14. Drilling method used: Rotary ☐ 50
Hollow Stem Auger ■ 41
_____ Other ☐

15. Drilling fluid used: Water ☐ 02 Air ☐ 01
Drilling Mud ☐ 03 None ■ 99

16. Drilling additives used? Yes ☐ No ■

Describe _____

17. Source of water (attach analysis):

E. Bentonite seal, top 758.3 ft. MSL or 0.0 ft.

F. Fine sand, top 754.3 ft. MSL or 4.0 ft.

G. Filter pack, top 753.3 ft. MSL or 5.0 ft.

H. Screen joint, top 752.3 ft. MSL or 6.0 ft.

I. Well bottom 742.3 ft. MSL or 16.0 ft.

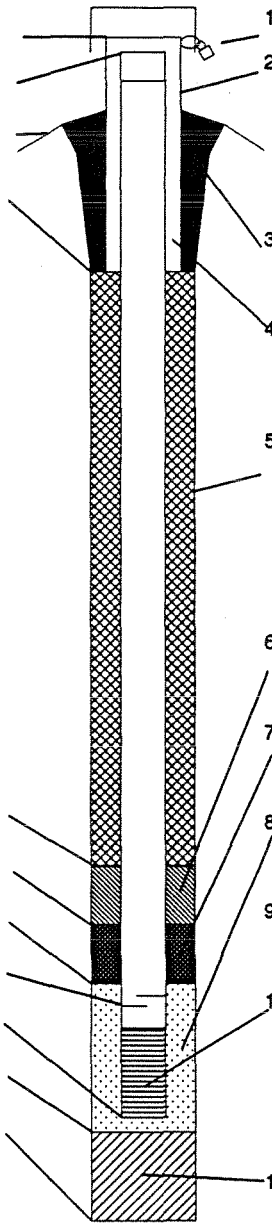
J. Filter pack, bottom 741.8 ft. MSL or 16.5 ft.

K. Borehole, bottom 741.8 ft. MSL or 16.5 ft.

L. Borehole, diameter 8.0 in.

M. O.D. well casing 2.20 in.

N. I.D. well casing 2.00 in.



1. Cap and lock? ■ Yes ☐ No

2. Protective cover pipe:
a. Inside diameter: 4.0 in.
b. Length: 6.0 ft.
c. Material: Steel ■ 04
Other ☐
d. Additional protection? ■ Yes ☐ No
If yes, describe: Bumper Posts

3. Surface seal: Bentonite ■ 30
Concrete ☐ 01
_____ Other ☐

4. Material between well casing and protective pipe:
Bentonite ☐ 30
Annular space seal ☐
Red Flint #30 Sand Other ■

5. Annular space seal: a. Granular Bentonite ☐ 33
b. ___ Lbs/gal mud weight...Bentonite-sand slurry ☐ 35
c. ___ Lbs/gal mud weight..... Bentonite slurry ☐ 31
d. ___ % Bentonite..... Bentonite-cement grout ☐ 50
e. ___ lb volume added for any of the above
f. How installed: Tremie ☐ 01
Tremie pumped ☐ 02
Gravity ☐ 08

6. Bentonite seal: a. Bentonite granules ☐ 33
b. ☐ 1/4 in. ☐ 3/8 in. ☐ 1/2 in. Bentonite pellets ☐ 32
c. 3/8" Bentonite Chips Other ■

7. Fine sand material: Manufacturer, product name, mesh size
a. Badger Mining Corp. BB#7
b. Volume added 50 lb

8. Filter pack material: Manufacturer, product, mesh size
a. Red Flint #30 Sand
b. Volume added 350 lb

9. Well casing: Flush threaded PVC schedule 40 ■ 23
Flush threaded PVC schedule 80 ☐ 24
_____ Other ☐

10. Screen Material: Schedule 40 PVC
a. Screen type: Factory cut ■ 11
Continuous slot ☐ 01
_____ Other ☐
b. Manufacturer Northern Air
c. Slot size: 0.010 in.
d. Slotted length: 10.0 ft.

11. Backfill material (below filter pack): None ■ 14
_____ Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature Lisa A. Brewer | Firm RMT, Inc.

Please complete both sides of this form and return to the appropriate DNR office listed at the top of this form as required by chs. 144, 147 and 160, Wis. Stats., and ch. NR 141, Wis. Adm. Code. In accordance with ch. 144, Wis. Stats., failure to file this form may result in a forfeiture of not less than $10, nor more than $5,000 for each day of violation. In accordance with ch. 147, Wis. Stats., failure to file this form may result in a forfeiture of not more than $10,000 for each day of violation. NOTE: Shaded areas are for DNR use only. See instructions for more information including where the completed form should be sent.

State of Wisconsin
Department of Natural Resources

Route to: Solid Waste ☐ Haz. Waste ☐ Wastewater ☐
Env. Response & Repair ☐ Underground Tanks ☐ Other ☐

MONITORING WELL CONSTRUCTION

Form 4400-113A Rev. 4-90

Facility/Project Name Tecumseh Products Company 3084.02	Local Grid Location of Well ☐ N. ☐ E. ft. ☐ S. ft. ☐ W.	Well Name MW-9D
Facility License, Permit or Monitoring Number	Grid Origin Location Lat. ___ ___ ___ Long. ___ ___ ___ or	Wis. Unique Well Number DNR Well Number ___ ___ ___ ___ ___ ___ ___ ___ ___
Type of Well: Water Table Observation Well ☐ 11 Piezometer ■ 12	St. Plane ft. N, ft. E.	Date Well Installed 08 / 18 / 94 M M D D Y Y
Distance Well is From Waste/Source Boundary ft.	Section Location of Waste/Source ■ E. SW¼ of SE¼ of Sec.13, T10N, R21 ☐ W.	Well Installed By: (Persons' Name and Firm) Dan Zielazowski WTD Environmental Drilling
Is Well A Point of Enforcement Std. Application? ☐ Yes ☐ No	Location of Well Relative to Waste/Source U ☐ Upgradient S ☐ Sidegradient D ■ Downgradient N ☐ Not Known	

A. Protective pipe, top elevation 760.64 ft. MSL

B. Well casing, top elevation 760.58 ft. MSL

C. Land surface elevation 758.2 ft. MSL

D. Surface seal, bottom ____.__ ft. MSL or 0.0 ft.

12. USCS classification of soil near screen:
GP ■ GM ☐ GC ☐ GW ☐ SW ■ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☐ CH ☐
Bedrock ☐

13. Sieve analysis attached? Yes ☐ No ■

14. Drilling method used: Rotary ☐ 50
Hollow Stem Auger ■ 41
_____ Other ☐

15. Drilling fluid used: Water ☐ 02 Air ☐ 01
Drilling Mud ☐ 03 None ■ 99

16. Drilling additives used? Yes ☐ No ■

Describe _____

17. Source of water (attach analysis):

E. Bentonite seal, top 758.2 ft. MSL or 0.0 ft.

F. Fine sand, top 736.2 ft. MSL or 22.0 ft.

G. Filter pack, top 734.7 ft. MSL or 23.5 ft.

H. Screen joint, top 733.7 ft. MSL or 24.5 ft.

I. Well bottom 728.7 ft. MSL or 29.5 ft.

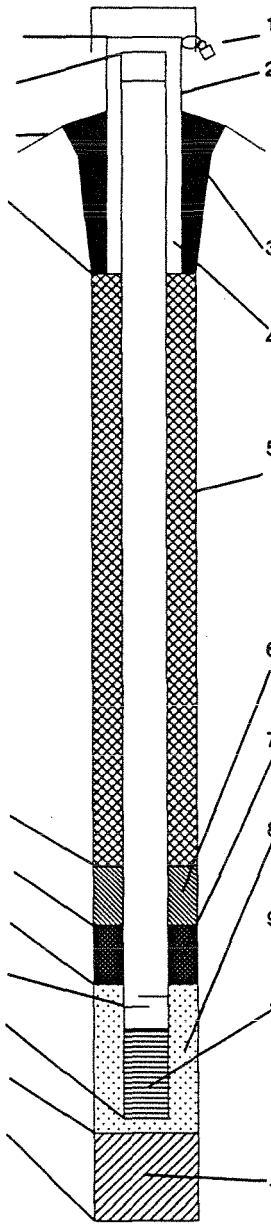
J. Filter pack, bottom 728.7 ft. MSL or 29.5 ft.

K. Borehole, bottom 728.1 ft. MSL or 30.1 ft.

L. Borehole, diameter 8.0 in.

M. O.D. well casing 2.20 in.

N. I.D. well casing 2.00 in.



1. Cap and lock? ■ Yes ☐ No

2. Protective cover pipe:
a. Inside diameter: 4.0 in.
b. Length: 7.0 ft.
c. Material: Steel ■ 04
Other ☐
d. Additional protection? ■ Yes ☐ No
If yes, describe: Bumper Posts

3. Surface seal: Bentonite ■ 30
Concrete ☐ 01
_____ Other ☐

4. Material between well casing and protective pipe:
Bentonite ☐ 30
Annular space seal ☐
Badger Mining Corp. BB#7 Other ■

5. Annular space seal: a. Granular Bentonite ☐ 33
b. ___ Lbs/gal mud weight...Bentonite-sand slurry ☐ 35
c. ___ Lbs/gal mud weight..... Bentonite slurry ☐ 31
d. ___ % Bentonite..... Bentonite-cement grout ☐ 50
e. ___ lb volume added for any of the above
f. How installed: Tremie ☐ 01
Tremie pumped ☐ 02
Gravity ☐ 08

6. Bentonite seal: a. Bentonite granules ☐ 33
b. ☐ 1/4 in. ☐3/8 in. ☐ 1/2 in. Bentonite pellets ☐ 32
c. 3/8" Bentonite Chips Other ■

7. Fine sand material: Manufacturer, product name, mesh size
a. Badger Mining Corp. BB#7
b. Volume added 50 lb

8. Filter pack material: Manufacturer, product, mesh size
a. Red Flint #30 Sand
b. Volume added 150 lb

9. Well casing: Flush threaded PVC schedule 40 ■ 23
Flush threaded PVC schedule 80 ☐ 24
_____ Other ☐

10. Screen Material: Schedule 40 PVC
a. Screen type: Factory cut ■ 11
Continuous slot ☐ 01
_____ Other ☐
b. Manufacturer Northern Air
c. Slot size: 0.010 in.
d. Slotted length: 5.0 ft.

11. Backfill material (below filter pack): None ☐14
Native soil Other ■

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature Lisa A. Iwerks | Firm RMT, Inc.

Please complete both sides of this form and return to the appropriate DNR office listed at the top of this form as required by chs. 144, 147 and 160, Wis. Stats., and ch. NR 141, Wis. Adm. Code. In accordance with ch. 144, Wis. Stats., failure to file this form may result in a forfeiture of not less than $10, nor more than $5,000 for each day of violation. In accordance with ch. 147, Wis. Stats., failure to file this form may result in a forfeiture of not more than $10,000 for each day of violation. NOTE: Shaded areas are for DNR use only. See instructions for more information including where the completed form should be sent.

State of Wisconsin
Department of Natural Resources

Route to: Solid Waste ☐ Haz. Waste ☐ Wastewater ☐
Env. Response & Repair ☐ Underground Tanks ☐ Other ☐

MONITORING WELL CONSTRUCTION

Form 4400-113A Rev. 4-90

Facility/Project Name Tecumseh Products Company 3084.02	Local Grid Location of Well ☐ N. ☐ E. ft. ☐ S. ft. ☐ W.	Well Name MW-10
Facility License, Permit or Monitoring Number	Grid Origin Location Lat. ___ ___ ___ Long. ___ ___ ___ or	Wis. Unique Well Number DNR Well Number ___ ___ ___ ___ ___ ___ ___ ___ ___
Type of Well: Water Table Observation Well ■ 11 Piezometer ☐ 12	St. Plane ft. N, ft. E.	Date Well Installed 08 / 19 / 94 M M D D Y Y
Distance Well is From Waste/Source Boundary ft.	Section Location of Waste/Source SE¼ of SW¼ of Sec.13, T10N, R21 ■ E. ☐ W.	Well Installed By: (Persons' Name and Firm) Dan Zielazowski WTD Environmental Drilling
Is Well A Point of Enforcement Std. Application? ☐ Yes ☐ No	Location of Well Relative to Waste/Source U ■ Upgradient S ☐ Sidegradient D ☐ Downgradient N ☐ Not Known	

A. Protective pipe, top elevation 772.05 ft. MSL

B. Well casing, top elevation 772.01 ft. MSL

C. Land surface elevation 769.8 ft. MSL

D. Surface seal, bottom ____. ft. MSL or 0.0 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ■ MH ☐ CL ■ CH ☐
Bedrock ☐

13. Sieve analysis attached? Yes ☐ No ■

14. Drilling method used: Rotary ☐ 50
Hollow Stem Auger ■ 41
_____ Other ☐ ▒▒

15. Drilling fluid used: Water ☐ 02 Air ☐ 01
Drilling Mud ☐ 03 None ■ 99

16. Drilling additives used? Yes ☐ No ■

Describe

17. Source of water (attach analysis):

E. Bentonite seal, top 769.8 ft. MSL or 0.0 ft.

F. Fine sand, top 766.3 ft. MSL or 3.5 ft.

G. Filter pack, top 765.8 ft. MSL or 4.0 ft.

H. Screen joint, top 765.3 ft. MSL or 4.5 ft.

I. Well bottom 755.3 ft. MSL or 14.5 ft.

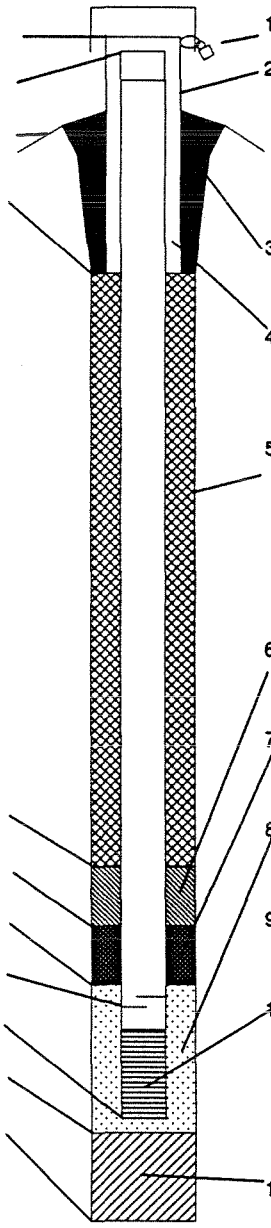
J. Filter pack, bottom 754.8 ft. MSL or 15.0 ft.

K. Borehole, bottom 754.8 ft. MSL or 15.0 ft.

L. Borehole, diameter 8.0 in.

M. O.D. well casing 2.20 in.

N. I.D. well casing 2.00 in.



1. Cap and lock? ■ Yes ☐ No

2. Protective cover pipe:
a. Inside diameter: 4.0 in.
b. Length: 5.0 ft.
c. Material: Steel ■ 04
Other ☐ ▒▒
d. Additional protection? ☐ Yes ☐ No
If yes, describe: _____

3. Surface seal: Bentonite ■ 30
Concrete ☐ 01
_____ Other ☐ ▒▒

4. Material between well casing and protective pipe:
Bentonite ☐ 30
Annular space seal ☐ ▒▒
Red Flint #30 Sand Other ■ ▒▒

5. Annular space seal: a. Granular Bentonite ☐ 33
b. ___ Lbs/gal mud weight...Bentonite-sand slurry ☐ 35
c. ___ Lbs/gal mud weight..... Bentonite slurry ☐ 31
d. ___ % Bentonite..... Bentonite-cement grout ☐ 50
e. ___ lb volume added for any of the above
f. How installed: Tremie ☐ 01
Tremie pumped ☐ 02
Gravity ☐ 08

6. Bentonite seal: a. Bentonite granules ☐ 33
b. ☐ 1/4 in. ☐ 3/8 in. ☐ 1/2 in. Bentonite pellets ☐ 32
c. 3/8" Bentonite Chips Other ■ ▒▒

7. Fine sand material: Manufacturer, product name, mesh size ▒▒
a. Badger Mining Corp. BB#7
b. Volume added 50 lb

8. Filter pack material: Manufacturer, product, mesh size ▒▒
a. Red Flint #30 Sand
b. Volume added 350 lb

9. Well casing: Flush threaded PVC schedule 40 ■ 23
Flush threaded PVC schedule 80 ☐ 24
_____ Other ☐ ▒▒

10. Screen Material: Schedule 40 PVC ▒▒
a. Screen type: Factory cut ■ 11
Continuous slot ☐ 01
_____ Other ☐ ▒▒
b. Manufacturer Northern Air
c. Slot size: 0.010 in.
d. Slotted length: 10.0 ft.

11. Backfill material (below filter pack): None ■ 14
_____ Other ☐ ▒▒

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature Lisa A. Zmuda | Firm RMT, Inc.

Please complete both sides of this form and return to the appropriate DNR office listed at the top of this form as required by chs. 144, 147 and 160, Wis. Stats., and ch. NR 141, Wis. Adm. Code. In accordance with ch. 144, Wis. Stats., failure to file this form may result in a forfeiture of not less than $10, nor more than $5,000 for each day of violation. In accordance with ch. 147, Wis. Stats., failure to file this form may result in a forfeiture of not more than $10,000 for each day of violation. NOTE: Shaded areas are for DNR use only. See instructions for more information including where the completed form should be sent.

State of Wisconsin
Department of Natural Resources

MONITORING WELL DEVELOPMENT
Form 4400-113B Rev. 4-90

Route to: Solid Waste ☐ Haz. Waste ☐ Wastewater ☐
Env. Response & Repair ☐ Underground Tanks ☐ Other ☐ _____

Facility/Project Name	County Name	Well Name
Tecumseh Products Company 3084.02	Ozaukee	MW-3D

Facility License, Permit or Monitoring Number	County Code	Wis. Unique Well Number	DNR Well Number
	46		

1. Can this well be purged dry? ☐ Yes ■ No

2. Well development method
   - surged with bailer and bailed ☐ 41
   - surged with bailer and pumped ■ 61
   - surged with block and bailed ☐ 42
   - surged with block and pumped ☐ 62
   - surged with block, bailed and pumped ☐ 70
   - compressed air ☐ 20
   - bailed only ☐ 10
   - pumped only ☐ 51
   - pumped slowly ☐ 50
   - Other _____ ☐

3. Time spent developing well 115 min.

4. Depth of well (from top of well casing) 31.7 ft.

5. Inside diameter of well 2.00 in.

6. Volume of water in filter pack and well casing 9.9 gal.

7. Volume of water removed from well 1000.0 gal.

8. Volume of water added (if any) 0.0 gal.

9. Source of water added N/A

10. Analysis performed on water added? (If yes, attach results) ☐ Yes ☐ No

	Before Development	After Development
11. Depth to Water (from top of well casing)	a. 11.27 ft.	11.29 ft.
Date	b. 08/22/94 (m m d d y y) ■ a.m.	08/22/94 (m m d d y y) ☐ a.m.
Time	c. 10:10 ☐ p.m.	12:00 ■ p.m.
12. Sediment in well bottom	0.0 inches	0.0 inches
13. Water clarity	Clear ☐ 10 / Turbid ■ 15 (Describe)	Clear ■ 20 / Turbid ☐ 25 (Describe)
	Brown	
14. Total suspended solids	____.__ mg/l	____.__ mg/l
15. COD	____.__ mg/l	____.__ mg/l

Fill in if drilling fluids were used and well is at solid waste facility:

16. Additional comments on development:

Surged with a bailer for 30 minutes
Purged with a pump for 85 minutes

Well developed by: Person's Name and Firm

Name: Bryan Holz

Firm: WTD Environmental Drilling

I hereby certify that the above information is true and correct to the best of my knowledge.

Signature: Lisa A. Zgurech

Print Initials: LSD

Firm: RMT, Inc.

NOTE: Shaded areas are for DNR use only. See instructions for more information including a list of county codes.

State of Wisconsin
Department of Natural Resources

MONITORING WELL DEVELOPMENT
Form 4400-113B Rev. 4-90

Route to: Solid Waste ☐ Haz. Waste ☐ Wastewater ☐
Env. Response & Repair ☐ Underground Tanks ☐ Other ☐ _____

Facility/Project Name	County Name	Well Name
Tecumseh Products Company 3084.02	Ozaukee	MW-8D

Facility License, Permit or Monitoring Number	County Code	Wis. Unique Well Number	DNR Well Number
_____	46	_____	_____

1. Can this well be purged dry? ☐ Yes ■ No

2. Well development method

surged with bailer and bailed	☐ 41
surged with bailer and pumped	■ 61
surged with block and bailed	☐ 42
surged with block and pumped	☐ 62
surged with block, bailed and pumped	☐ 70
compressed air	☐ 20
bailed only	☐ 10
pumped only	☐ 51
pumped slowly	☐ 50
Other _____	☐

3. Time spent developing well: 120 min.

4. Depth of well (from top of well casing): 33.2 ft.

5. Inside diameter of well: 2.00 in.

6. Volume of water in filter pack and well casing: 8.8 gal.

7. Volume of water removed from well: 900.0 gal.

8. Volume of water added (if any): 0.0 gal.

9. Source of water added: N/A

10. Analysis performed on water added? (If yes, attach results) ☐ Yes ☐ No

	Before Development	After Development
11. Depth to Water (from top of well casing)	a. 11.45 ft.	11.48 ft.
Date	b. 08/22/94 (m m d d y y) ☐ a.m.	08/22/94 (m m d d y y) ☐ a.m.
Time	c. 1:00 ■ p.m.	3:00 ■ p.m.
12. Sediment in well bottom	0.0 inches	0.0 inches
13. Water clarity	Clear ☐ 10 / Turbid ■ 15 (Describe)	Clear ■ 20 / Turbid ☐ 25 (Describe)
	Brown	
Fill in if drilling fluids were used and well is at solid waste facility:		
14. Total suspended solids	____.__ mg/l	____.__ mg/l
15. COD	____.__ mg/l	____.__ mg/l

16. Additional comments on development:

Surged with a bailer for 30 minutes
Purged with a pump for 90 minutes

Well developed by: Person's Name and Firm

Name: Bryan Holz

Firm: WTD Environmental Drilling

I hereby certify that the above information is true and correct to the best of my knowledge.

Signature: Lisa M. Bennett

Print Initials: LSD

Firm: RMT, Inc.

NOTE: Shaded areas are for DNR use only. See instructions for more information including a list of county codes.

State of Wisconsin
Department of Natural Resources

MONITORING WELL DEVELOPMENT
Form 4400-113B Rev. 4-90

Route to: Solid Waste ☐ Haz. Waste ☐ Wastewater ☐
Env. Response & Repair ☐ Underground Tanks ☐ Other ☐ _____

Facility/Project Name	County Name	Well Name
Tecumseh Products Company 3084.02	Ozaukee	MW-9

Facility License, Permit or Monitoring Number	County Code	Wis. Unique Well Number	DNR Well Number
	46		

1. Can this well be purged dry? ☐ Yes ■ No

2. Well development method

surged with bailer and bailed	☐ 41
surged with bailer and pumped	■ 61
surged with block and bailed	☐ 42
surged with block and pumped	☐ 62
surged with block, bailed and pumped	☐ 70
compressed air	☐ 20
bailed only	☐ 10
pumped only	☐ 51
pumped slowly	☐ 50
Other _____	☐

3. Time spent developing well: 60 min.

4. Depth of well (from top of well casing): 18.5 ft.

5. Inside diameter of well: 2.00 in.

6. Volume of water in filter pack and well casing: 4.5 gal.

7. Volume of water removed from well: 45.0 gal.

8. Volume of water added (if any): 0.0 gal.

9. Source of water added: N/A

10. Analysis performed on water added? (If yes, attach results) ☐ Yes ☐ No

	Before Development	After Development
11. Depth to Water (from top of well casing)	a. 13.44 ft.	13.65 ft.
Date	b. 08/22/94 (m m d d y y) ■ a.m.	08/22/94 (m m d d y y) ☐ a.m.
Time	c. 10:45 ☐ p.m.	12:30 ■ p.m.
12. Sediment in well bottom	0.0 inches	0.0 inches
13. Water clarity	Clear ☐ 10 / Turbid ■ 15 (Describe)	Clear ■ 20 / Turbid ☐ 25 (Describe)
	Brown	
14. Total suspended solids	____.__ mg/l	____.__ mg/l
15. COD	____.__ mg/l	____.__ mg/l

Fill in if drilling fluids were used and well is at solid waste facility:

16. Additional comments on development:

Surged with a bailer for 30 minutes
Purged with a pump for 30 minutes

Well developed by: Person's Name and Firm

Name: Bryan Holz

Firm: WTD Environmental Drilling

I hereby certify that the above information is true and correct to the best of my knowledge.

Signature: Lisa M. Bzdusek

Print Initials: LSD

Firm: RMT, Inc.

NOTE: Shaded areas are for DNR use only. See instructions for more information including a list of county codes.

State of Wisconsin
Department of Natural Resources

MONITORING WELL DEVELOPMENT
Form 4400-113B Rev. 4-90

Route to: Solid Waste ☐ Haz. Waste ☐ Wastewater ☐
Env. Response & Repair ☐ Underground Tanks ☐ Other ☐ _____

Facility/Project Name	County Name	Well Name
Tecumseh Products Company 3084.02	Ozaukee	MW-9D

Facility License, Permit or Monitoring Number	County Code	Wis. Unique Well Number	DNR Well Number
	46		

1. Can this well be purged dry? ☐ Yes ■ No

2. Well development method
   - surged with bailer and bailed ☐ 41
   - surged with bailer and pumped ■ 61
   - surged with block and bailed ☐ 42
   - surged with block and pumped ☐ 62
   - surged with block, bailed and pumped ☐ 70
   - compressed air ☐ 20
   - bailed only ☐ 10
   - pumped only ☐ 51
   - pumped slowly ☐ 50
   - Other _____ ☐

3. Time spent developing well 90 min.

4. Depth of well (from top of well casing) 31.8 ft.

5. Inside diameter of well 2.00 in.

6. Volume of water in filter pack and well casing 8.8 gal.

7. Volume of water removed from well 90.0 gal.

8. Volume of water added (if any) 0.0 gal.

9. Source of water added N/A

10. Analysis performed on water added? (If yes, attach results) ☐ Yes ☐ No

	Before Development	After Development
11. Depth to Water (from top of well casing)	a. 13.36 ft.	13.40 ft.
Date	b. 08/22/94 (m m d d y y) ■ a.m.	08/22/94 (m m d d y y) ☐ a.m.
Time	c. 11:50 ☐ p.m.	1:30 ■ p.m.
12. Sediment in well bottom	0.0 inches	0.0 inches
13. Water clarity	Clear ☐ 10 Turbid ■ 15 (Describe) Brown	Clear ■ 20 Turbid ☐ 25 (Describe)

Fill in if drilling fluids were used and well is at solid waste facility:

14. Total suspended solids	____.__ mg/l	____.__ mg/l
15. COD	____.__ mg/l	____.__ mg/l

16. Additional comments on development:

Surged with a bailer for 30 minutes
Purged with a pump for 60 minutes

Well developed by: Person's Name and Firm

Name: Bryan Holz

Firm: WTD Environmental Drilling

I hereby certify that the above information is true and correct to the best of my knowledge.

Signature: Lisa A. Thurnau

Print Initials: LSD

Firm: RMT, Inc.

NOTE: Shaded areas are for DNR use only. See instructions for more information including a list of county codes.

State of Wisconsin
Department of Natural Resources

MONITORING WELL DEVELOPMENT
Form 4400-113B Rev. 4-90

Route to: Solid Waste ☐ Haz. Waste ☐ Wastewater ☐
Env. Response & Repair ☐ Underground Tanks ☐ Other ☐ _____

Facility/Project Name	County Name	Well Name
Tecumseh Products Company 3084.02	Ozaukee	MW-10

Facility License, Permit or Monitoring Number	County Code	Wis. Unique Well Number	DNR Well Number
	46		

1. Can this well be purged dry? ■ Yes ☐ No

2. Well development method
   - surged with bailer and bailed ☐ 41
   - surged with bailer and pumped ☐ 61
   - surged with block and bailed ☐ 42
   - surged with block and pumped ☐ 62
   - surged with block, bailed and pumped ☐ 70
   - compressed air ☐ 20
   - bailed only ■ 10
   - pumped only ☐ 51
   - pumped slowly ☐ 50
   - Other _____ ☐ ▒

3. Time spent developing well 30 min.

4. Depth of well (from top of well casing) 16.8 ft.

5. Inside diameter of well 2.00 in.

6. Volume of water in filter pack and well casing 8.0 gal.

7. Volume of water removed from well 18.0 gal.

8. Volume of water added (if any) 0.0 gal.

9. Source of water added N/A

10. Analysis performed on water added? (If yes, attach results) ☐ Yes ☐ No

	Before Development	After Development
11. Depth to Water (from top of well casing)	a. 7.75 ft.	13.82 ft.
Date	b. 08/22/94 m m d d y y	08/22/94 m m d d y y
Time	■ a.m. c. 9:40 ☐ p.m.	☐ a.m. 3:20 ■ p.m.
12. Sediment in well bottom	0.0 inches	0.0 inches
13. Water clarity	Clear ☐ 10 Turbid ■ 15 (Describe) Brown	Clear ☐ 20 Turbid ■ 25 (Describe) Yellow brown

Fill in if drilling fluids were used and well is at solid waste facility:

14. Total suspended solids	____.__ mg/l	____.__ mg/l
15. COD	____.__ mg/l	____.__ mg/l

16. Additional comments on development:

Bailed dry 4 times

Well developed by: Person's Name and Firm

Name: Lisa Drzewiecki

Firm: RMT Inc.

I hereby certify that the above information is true and correct to the best of my knowledge.

Signature: Lisa A. Drzewiecki

Print Initials: LSD

Firm: RMT, Inc.

NOTE: Shaded areas are for DNR use only. See instructions for more information including a list of county codes.

APPENDIX C

APPENDIX C

HYDRAULIC CONDUCTIVITY DATA AND GROUNDWATER FLOW CALCULATIONS

COMPUTATION SHEET

RMT INC.

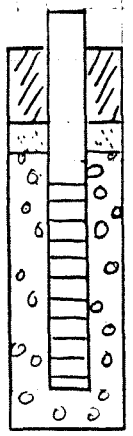
SHEET _____ OF _____

744 Heartland Trail P.O. Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX: (608) 831-3334

PROJECT / PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO.
Tecumseh Products Company	By: LSD	Date: 10-3-94	By: JM	Date: 10-5-94	308403

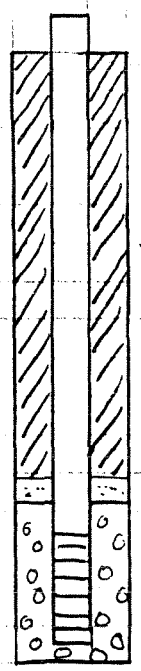
VERTICAL GRADIENT CALCULATIONS

WELL: MW-9



747.13 ✓

WELL: MW-9D



747.07 ✓

734.7 ✓

MIDPOINT OF FILTER PACK = 731.7 ✓

728.7 ✓

$$\text{VERTICAL GRADIENT} = \frac{\Delta h}{\Delta l} = \frac{747.13 - 747.07}{747.13 - 731.7}$$

VERTICAL GRADIENT = 0.0039 ✓ downward

COMPUTATION SHEET

RMT INC.

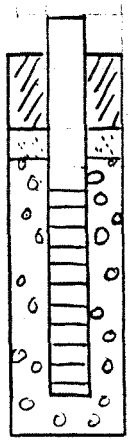
SHEET _____ OF _____

744 Heartland Trail P.O. Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX: (608) 831-3334

PROJECT / PROPOSAL NAME	PREPARED By: LSD Date: 10-3-94	CHECKED By: JAA Date: 10-5-94	PROJECT/PROPOSAL NO.
Tecumseh Products Company			308403

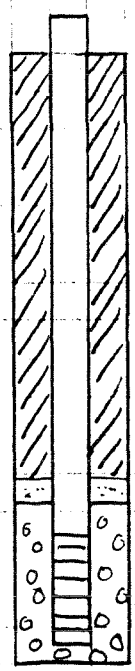
VERTICAL GRADIENT CALCULATIONS

WELL: MW-8



747.52 ✓

WELL: MW-8D



747.42 ✓

732.2 ✓

730.9 ✓

MIDPOINT OF FILTER PACK = 729.1 ✓

725.9 ✓

$$\text{VERTICAL GRADIENT} = \frac{\Delta h}{\Delta l} = \frac{747.52 - 747.42}{747.52 - 729.1}$$

Vertical gradient = 0.0054 ✓ downward

COMPUTATION SHEET

RMT INC.

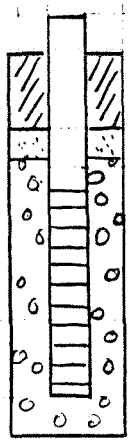
SHEET _____ OF _____

744 Heartland Trail P.O. Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX: (608) 831-3334

PROJECT / PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO.
Tecumseh Products Company	By: LSD	Date: 10-3-94	By: JMH	Date: 10-5-94	308403

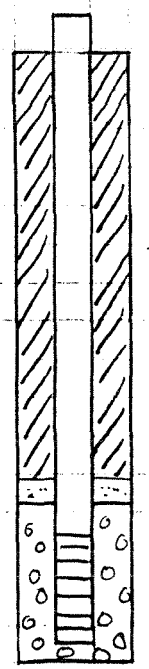
VERTICAL GRADIENT CALCULATIONS

WELL: MW-3



750.45 ✓

WELL: MW-3D



747.22 ✓

734.0 ✓
732.0 ✓

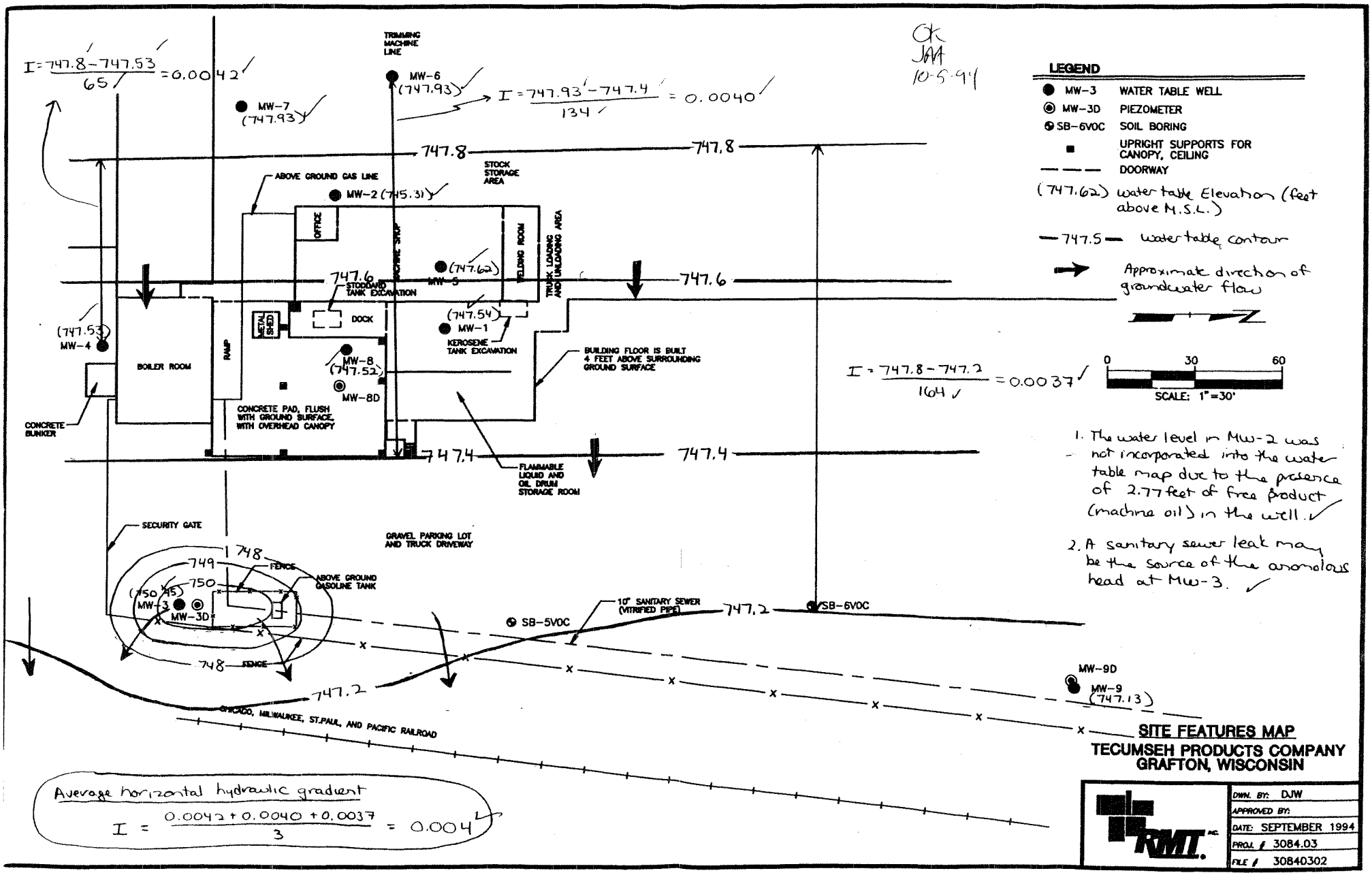
727.0 ✓
726.0 ✓

MIDPOINT OF FILTER PACK = 730.0 ✓

$$\text{VERTICAL GRADIENT} = \frac{\Delta h}{\Delta \ell} = \frac{750.45 - 747.22}{750.45 - 730.0}$$

VERTICAL GRADIENT = 0.16 ✓ downward

The sanitary sewer leak at MW-3 may be causing the high vertical gradient at this well nest



1. The water level in MW-2 was not incorporated into the water table map due to the presence of 2.77 feet of free product (machine oil) in the well.
2. A sanitary sewer leak may be the source of the anomalous head at MW-3.

Average horizontal hydraulic gradient

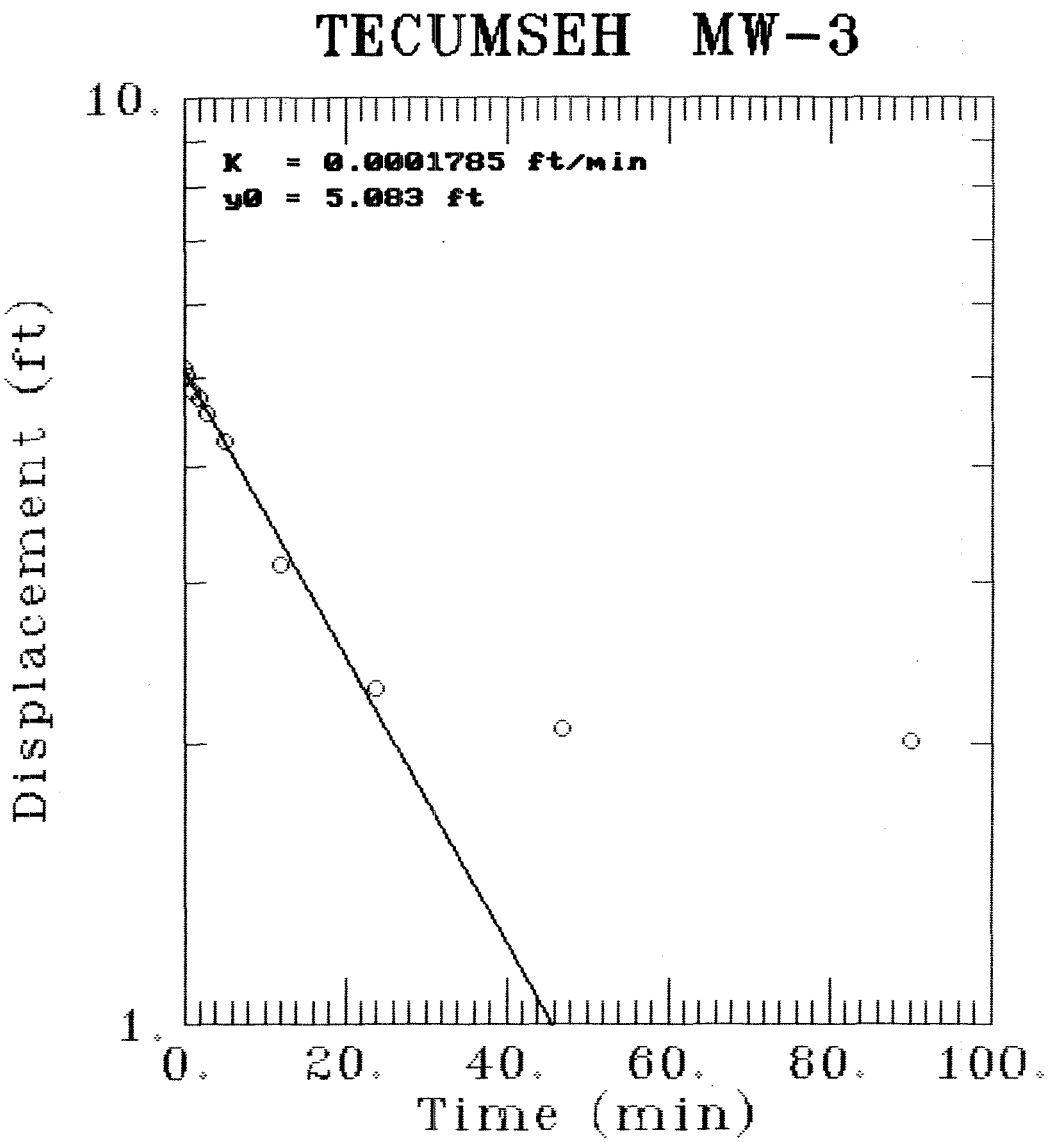
$$I = \frac{0.0042 + 0.0040 + 0.0037}{3} = 0.004$$

SITE FEATURES MAP
TECUMSEH PRODUCTS COMPANY
GRAFTON, WISCONSIN

RMT, INC.

DWN. BY:	DJW
APPROVED BY:	
DATE:	SEPTEMBER 1994
PROJ. #	3084.03
FILE #	30840302

FIGURE 3



$K = 9.0 \times 10^{-5}$ cm/s

RMT INC
744 Heartland Trail P.O. Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX. (608) 831-3334

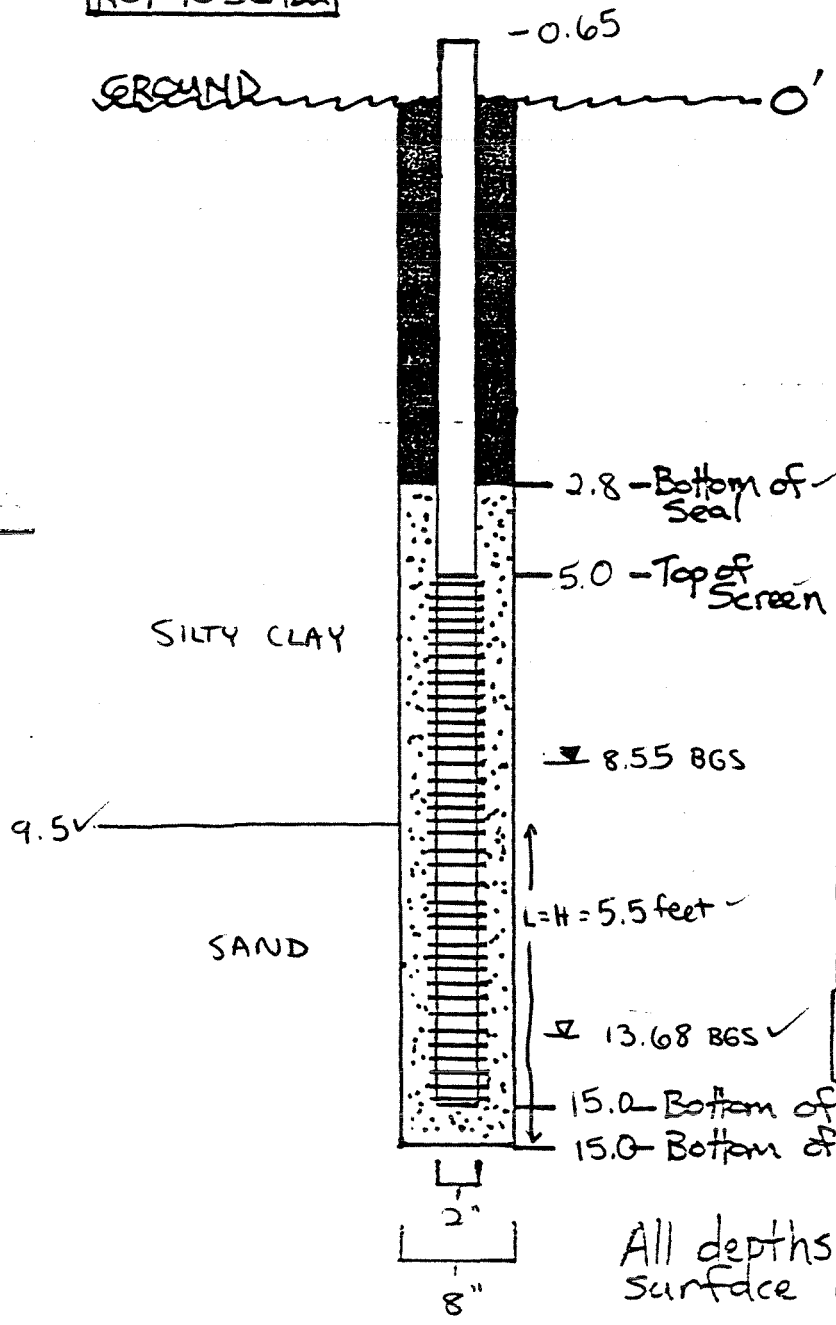
SHEET _____ OF _____

PROJECT / PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
Tecumseh Products Co.	CSD	10-3-94	MJG	10.5.94	3084.02

BOUWER and RICE SINGLE-WELL RESPONSE TEST ANALYSIS

WELL NUMBER MW-3

FIGURE IS NOT TO SCALE



"SLUG TEST DATA" for Aqtesolv

- Initial Drawdown = 5.13
- Radius of Well Casing (rc or r'c) = 0.18
- Radius of Well (rw) = 0.33
- Saturated Aquifer Thickness (D) = 22
- Effective Screen Length (L) = 5.5
- Static Height of Water in Well (H) = 5.5

Default for Aquitards D=H=L

r'c correction factor is used to adjust for sand pack de-watering effects.

$$r'_c = \sqrt{r_c^2 + n_e(r_w^2 - r_c^2)}$$

$$r_c' = \sqrt{(0.083)^2 + 0.25(0.33^2 - 0.083^2)}$$

▽ Static Water Level

All depths are in feet below ground surface unless otherwise noted.

Assumptions: Bottom of sand is at 31.5 feet based on well log MW-3D
Saturated thickness = 31.5 - 9.5 = 22 feet

<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>

A Q T E S O L V   R E S U L T S

Version 1.10

10/03/94 20:38:27

==

TEST DESCRIPTION

Data set........... c:\aqtesolv\tecum-3.dat
Data set title..... TECUMSEH MW-3

Knowns and Constants:
- No. of data points.................. 11
- Radius of well casing............... 0.18
- Radius of well...................... 0.33
- Aquifer saturated thickness......... 22
- Well screen length.................. 5.5
- Static height of water in well...... 5.5
- Log(Re/Rw)......................... 1.7
- A, B, C............................. 2.062, 0.314, 0.000

==

ANALYTICAL METHOD

Bouwer and Rice (unconfined aquifer slug test)

==

RESULTS FROM STATISTICAL CURVE MATCHING

STATISTICAL MATCH PARAMETER ESTIMATES

	Estimate		Std. Error
K =	1.7850E-004	+/-	9.0808E-006
y0 =	5.0829E+000	+/-	5.2985E-002

ANALYSIS OF MODEL RESIDUALS

residual = calculated - observed
weighted residual = residual * weight

Weighted Residual Statistics:
- Number of residuals............... 8
- Number of estimated parameters.... 2
- Degrees of freedom................ 6
- Residual mean..................... 0.002128
- Residual standard deviation....... 0.1066
- Residual variance................. 0.01137

Model Residuals:

Time	Observed	Calculated	Residual	Weight

0.25	5.13	5.0378	0.092206	1
0.5	5.02	4.9931	0.02691	1
1	4.83	4.9049	-0.07487	1
2	4.74	4.7331	0.0069215	1
3	4.57	4.5673	0.0026962	1
5	4.26	4.253	0.0070304	1
12	3.13	3.3136	-0.18364	1
24	2.3	2.1602	0.13977	1

==

RESULTS FROM VISUAL CURVE MATCHING

VISUAL MATCH PARAMETER ESTIMATES

	Estimate
K =	1.7850E-004
y0 =	5.0829E+000

<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>

RMT INC.

FIELD HYDRAULIC CONDUCTIVITY TEST

PROJECT NAME: Tecumseh DATE: 8-25-94

PROJECT NUMBER: 3084.02 SAMPLER(S): L. Drewiecki/R. Gahan

WELL NUMBER: MW-3 WELL DIAMETER: 2"

DTW: 7.90 + 0.00 T/PVC DTB: 14.17 + 0.18 T/PVC

Water Volume Removed: 2 gal (DRY) Depth to Bottom: 14.35

Type of Test: Baildown Initial Time: 1:13 End Time: 3:10
(slug/baildown)

	Time (H/M/S)	Water Level	Drawdown	Time (H/M/S)	Water Level	Drawdown
	0/0/0	(Initial)	-------			
	0/0/15	13.03	5.13			
	0/0/30	12.92	5.02			
	0/1/0	12.73	4.83			
	0/2/0	12.64	4.74			
	0/3/0	12.47	4.57			
	0/4/0					
	0/5/0	12.16	4.26			
	0/10/0					
1:25	0/12/0	11.03	3.13			
1:37	0/24/0	10.20	2.30			
2:00	0/47/0	9.98	2.08			
2:43	1/30/0	9.92	2.02			
3:10	1/57/0	9.90	2.00			

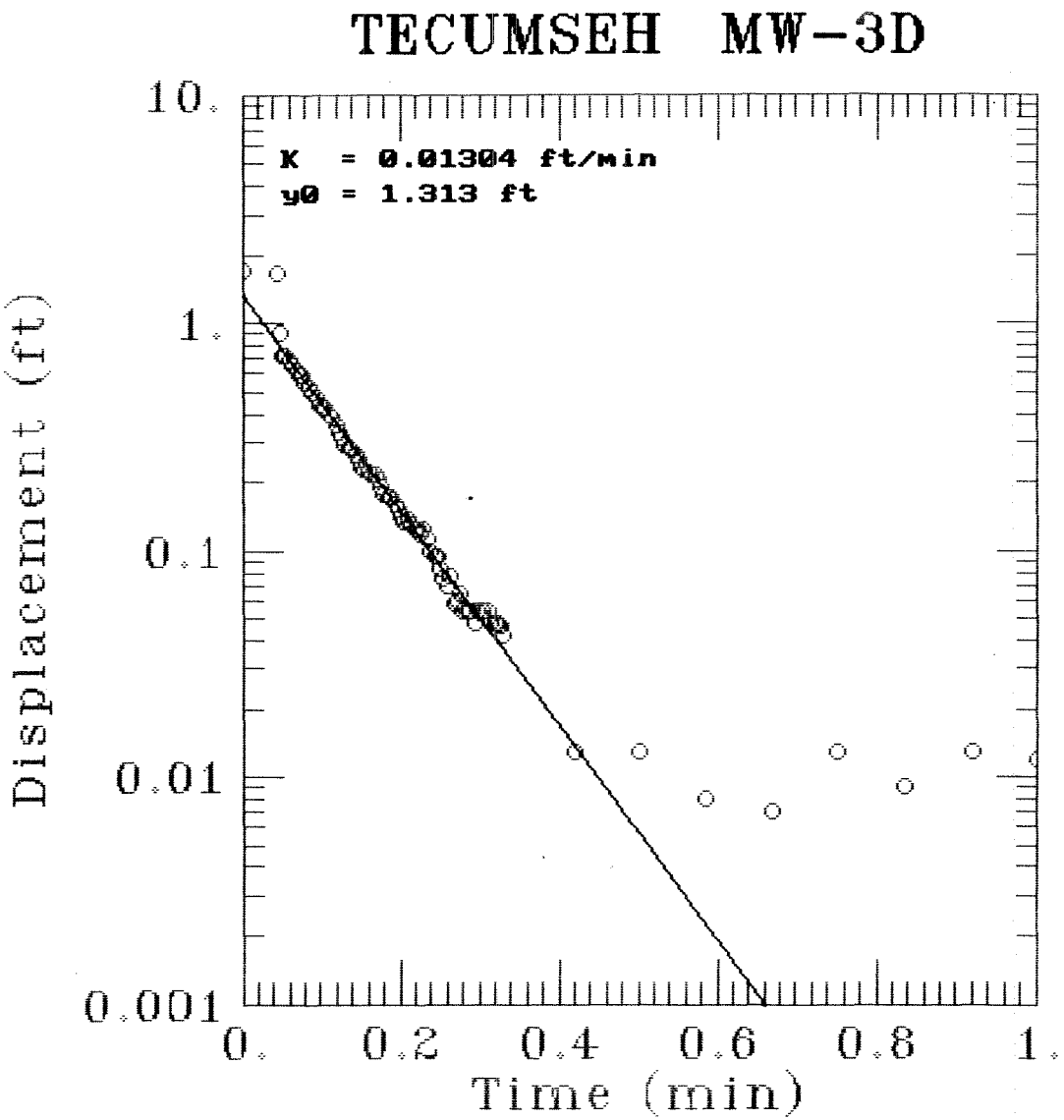
* For water table wells, remove at least one well (borehole volume):

one well/borehole volume (gallons) - $\pi\ h_{water}\ [r_w^2 + n_{sp}\ (r_b^2 - r_w^2)] \times 7.48\ gal/ft^3$

n_{sp} = porosity of sand pack = 0.25, w = well, b = borehole

* For piezometers, remove sufficient water to produce at least 1 foot of drawdown, but no not lower water level into the sandpack.

Signed 8-25-94 Date QC'd By 10-5-94 Date



$K = 6.6 \times 10^{-3}$ cm/s ✓

RMT INC
744 Heartland Trail P.O. Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX (608) 831-3334

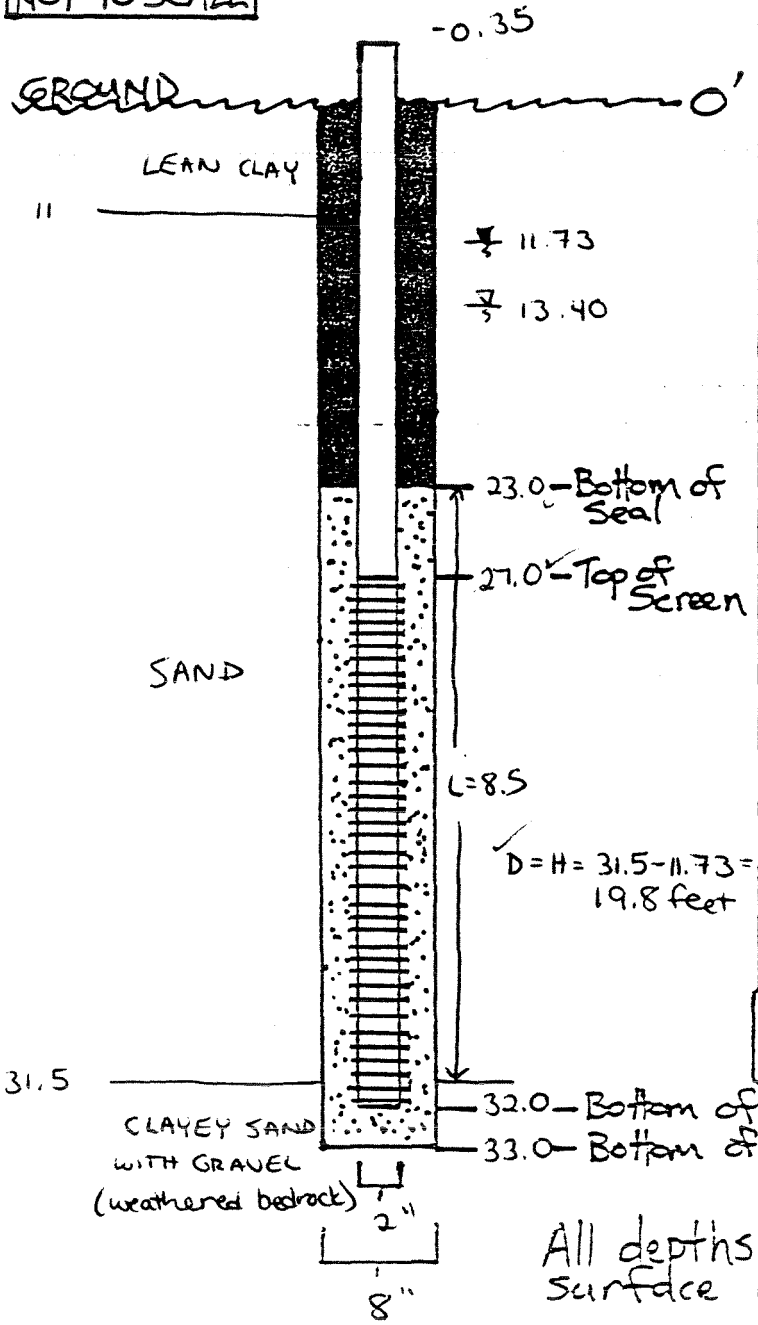
SHEET _____ OF _____

PROJECT / PROPOSAL NAME	PREPARED By	Date	CHECKED By	Date	PROJECT/PROPOSAL NO.
Tecumseh Products Co.	CSD	10-3-94	MBG	10.5.94	3084.02

BOUWER and RICE SINGLE-WELL RESPONSE TEST ANALYSIS

WELL NUMBER MW-3D

FIGURE IS NOT TO SCALE



"SLUG TEST DATA" for Aqtesolv

Initial Drawdown = 1.667 ✓

Radius of Well Casing (rc or r'c) = 0.083 ✓

Radius of Well (rw) = 0.33 ✓

Saturated Aquifer Thickness (D) = 20 ✓

Effective Screen Length (L) = 8.5 ✓

Static Height of Water in Well (H) = 20 ✓

Default ~~for~~ Aquitards D=H=L

r'c correction factor is NOT used to adjust for sand pack de-watering effects.

$$r'_c = \sqrt{r_c^2 + n_e(r_w^2 - r_c^2)}$$

▽ Static Water Level

All depths are in feet below ground surface unless otherwise noted.

Assumptions: The r_c' correction factor is not used because the water level does not rise in the screened section of the well. ✓

<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>

A Q T E S O L V   R E S U L T S
Version 1.10

10/03/94 21:52:33

==

TEST DESCRIPTION

Data set........... c:\aqtesolv\tecum-3d.dat
Data set title..... TECUMSEH MW-3D

Knowns and Constants:
- No. of data points.................. 82
- Radius of well casing............... 0.083
- Radius of well...................... 0.33
- Aquifer saturated thickness......... 20
- Well screen length.................. 8.5
- Static height of water in well...... 20
- Log(Re/Rw)......................... 2.947
- A, B, C............................. 0.000, 0.000, 1.837

==

ANALYTICAL METHOD

Bouwer and Rice (unconfined aquifer slug test)

==

RESULTS FROM STATISTICAL CURVE MATCHING

STATISTICAL MATCH PARAMETER ESTIMATES

	Estimate		Std. Error
K =	1.3042E-002	+/-	9.1926E-005
y0 =	1.3130E+000	+/-	1.0516E-002

ANALYSIS OF MODEL RESIDUALS

residual = calculated - observed
weighted residual = residual * weight

Weighted Residual Statistics:
- Number of residuals............... 69
- Number of estimated parameters.... 2
- Degrees of freedom................ 67
- Residual mean..................... 0.0006413
- Residual standard deviation....... 0.008405
- Residual variance................. 7.064E-005

Model Residuals:

Time	Observed	Calculated	Residual	Weight

0.052	0.727	0.74411	-0.017112	1
0.056	0.716	0.71231	0.0036919	1
0.06	0.681	0.68186	-0.00086342	1
0.065	0.657	0.64563	0.011369	1
0.069	0.616	0.61804	-0.002036	1
0.073	0.594	0.59162	0.0023794	1
0.077	0.593	0.56633	0.026666	1
0.081	0.546	0.54213	0.0038714	1
0.085	0.517	0.51896	-0.0019575	1
0.09	0.5	0.49138	0.0086187	1
0.094	0.476	0.47038	0.0056207	1
0.098	0.441	0.45027	-0.0092748	1
0.102	0.428	0.43103	-0.0030297	1
0.106	0.422	0.41261	0.0093929	1
0.11	0.393	0.39497	-0.0019719	1
0.115	0.382	0.37398	0.008016	1
0.119	0.358	0.358	3.8122E-007	1
0.123	0.334	0.3427	-0.0086984	1
0.127	0.318	0.32805	-0.010051	1
0.131	0.294	0.31403	-0.02003	1
0.135	0.283	0.30061	-0.017608	1
0.14	0.277	0.28463	-0.0076344	1
0.144	0.264	0.27247	-0.0084689	1
0.148	0.253	0.26082	-0.0078233	1
0.152	0.236	0.24968	-0.013676	1
0.156	0.23	0.239	-0.0090042	1
0.16	0.224	0.22879	-0.0047889	1
0.165	0.217	0.21663	0.00036838	1
0.169	0.218	0.20737	0.010627	1
0.173	0.206	0.19851	0.0074907	1
0.177	0.189	0.19002	-0.0010248	1
0.181	0.177	0.1819	-0.004903	1
0.185	0.171	0.17413	-0.0031283	1
0.19	0.171	0.16488	0.0061245	1
0.194	0.16	0.15783	0.0021714	1
0.198	0.153	0.15108	0.0019171	1
0.202	0.142	0.14463	-0.0026255	1
0.206	0.135	0.13844	-0.003444	1
0.21	0.136	0.13253	0.0034732	1
0.215	0.13	0.12548	0.0045153	1
0.219	0.123	0.12012	0.0028787	1
0.223	0.124	0.11499	0.0090128	1
0.227	0.118	0.11007	0.0079274	1
0.231	0.123	0.10537	0.017632	1
0.235	0.113	0.10086	0.012136	1
0.24	0.1	0.095505	0.0044952	1
0.244	0.095	0.091423	0.0035772	1
0.248	0.094	0.087515	0.0064847	1
0.252	0.083	0.083775	-0.00077483	1
0.256	0.076	0.080194	-0.0041942	1
0.26	0.07	0.076767	-0.0067666	1
0.265	0.077	0.072687	0.0043125	1
0.269	0.059	0.069581	-0.010581	1
0.273	0.06	0.066607	-0.0066068	1
0.277	0.065	0.06376	0.0012401	1
0.281	0.054	0.061035	-0.0070348	1
0.285	0.054	0.058426	-0.0044261	1
0.29	0.054	0.055321	-0.0013215	1
0.294	0.048	0.052957	-0.004957	1

0.298	0.054	0.050694	0.0033064	1
0.302	0.053	0.048527	0.0044731	1
0.306	0.054	0.046453	0.0075472	1
0.31	0.054	0.044467	0.0095326	1
0.315	0.048	0.042104	0.0058955	1
0.319	0.048	0.040305	0.0076951	1
0.323	0.048	0.038582	0.0094178	1
0.327	0.047	0.036933	0.010067	1
0.331	0.042	0.035355	0.0066454	1
0.419	0.013	0.013524	-0.00052369	1

==

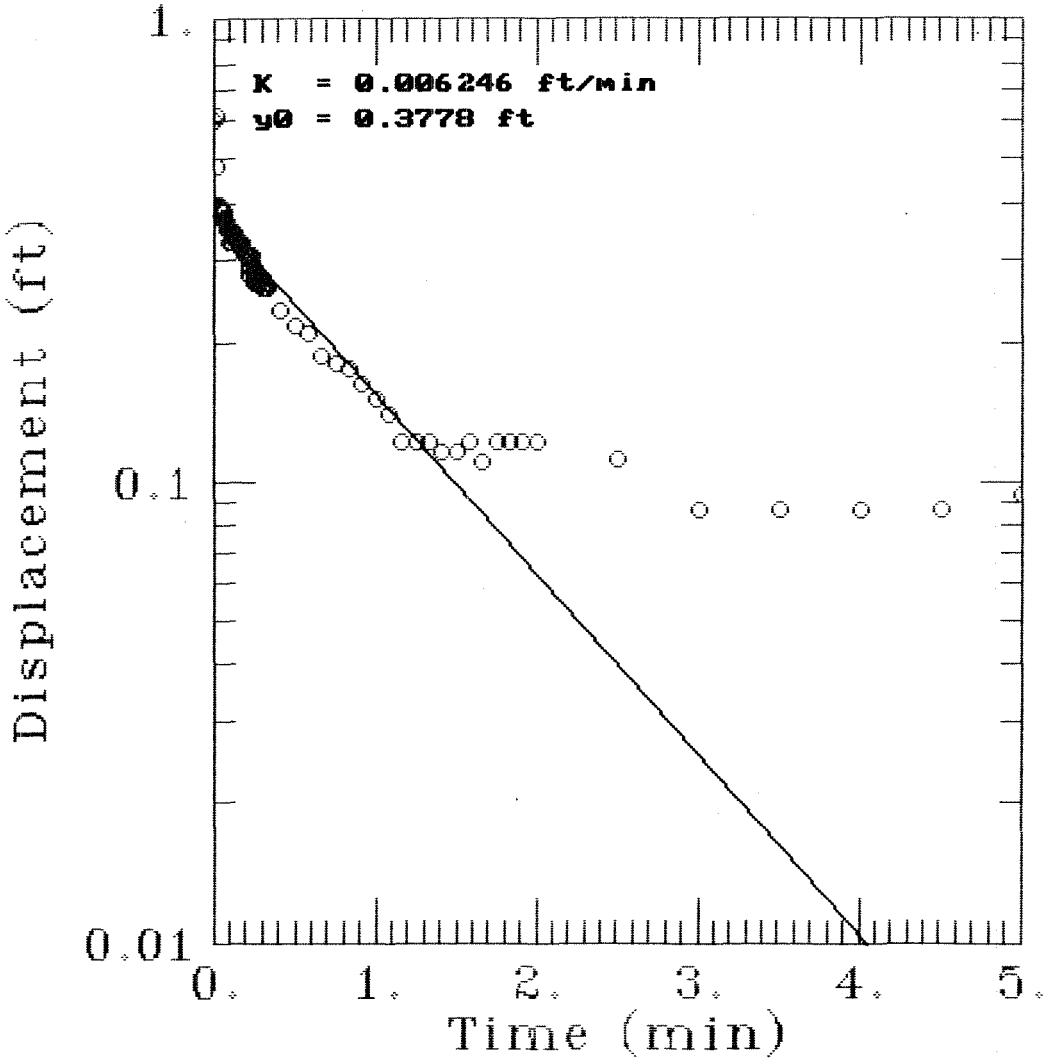
RESULTS FROM VISUAL CURVE MATCHING

VISUAL MATCH PARAMETER ESTIMATES

```
          Estimate
   K  =   1.3042E-002
   y0 =   1.3130E+000
```

<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>

TECUMSEH MW-4



$K = 3.2 \times 10^{-3}$ cm/s

3×10^{-3}

RMT INC

SHEET _____ OF _____

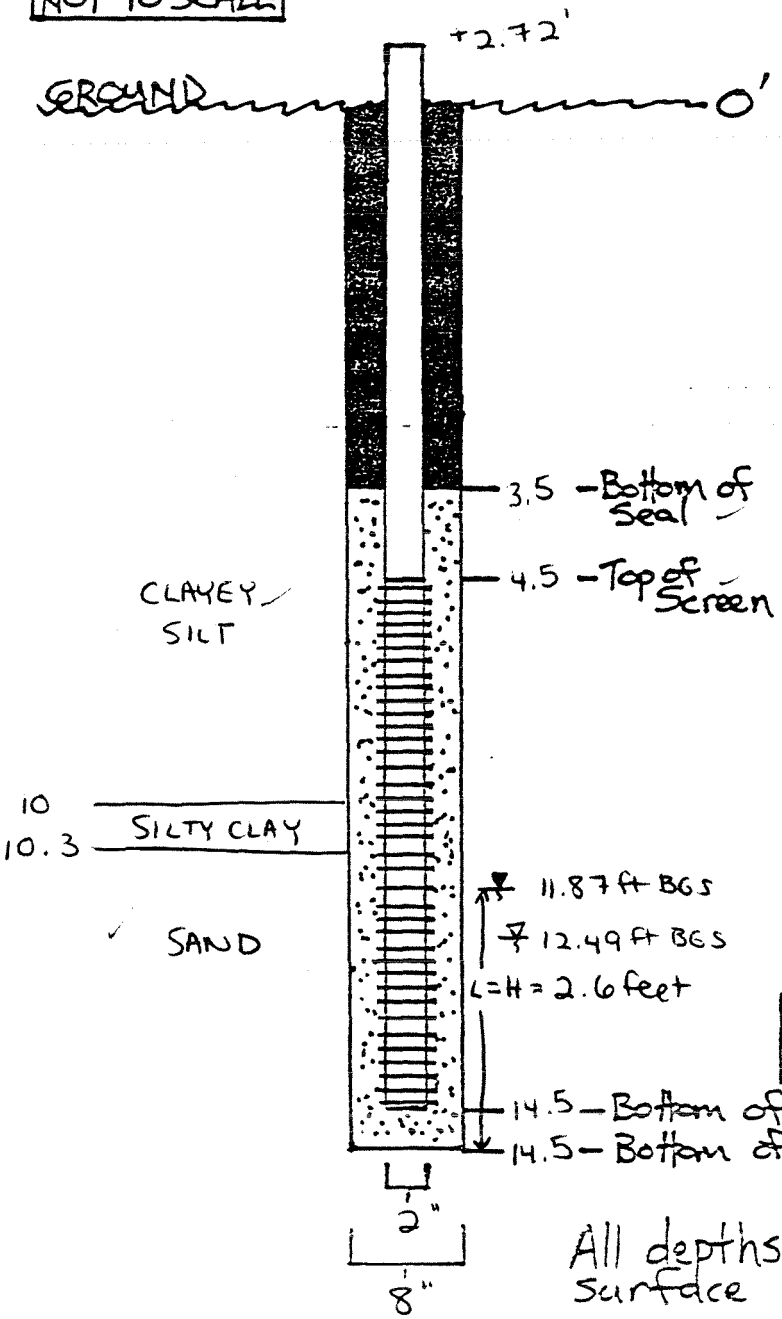
744 Heartland Trail P.O. Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX (608) 831-3334

PROJECT / PROPOSAL NAME	PREPARED		CHECKED		PROJECT/PROPOSAL NO.
Tecumseh Products Co.	By: LSD	Date: 10-3-94	By: MBG	Date: 10-5-94	3084.02

BOUWER and RICE SINGLE-WELL RESPONSE TEST ANALYSIS

WELL NUMBER MW-4

FIGURE IS NOT TO SCALE



"SLUG TEST DATA" for Aqtesolv

Initial Drawdown = 0.619 ✓

Radius of Well Casing (rc or r'c) = 0.18 ✓

Radius of Well (rw) = 0.33 ✓

Saturated Aquifer Thickness (D) = 22 ✓

Effective Screen Length (L) = 2.6 ft ✓

Static Height of Water in Well (H) = 2.6 ft ✓

Default for Aquitards D=H=L

r'c correction factor is used to adjust for sand pack de-watering effects.

$$r'_c = \sqrt{r_c^2 + n_e(r_w^2 - r_c^2)}$$

$$r_c' = \sqrt{(0.083)^2 + 0.25(0.33^2 - 0.083^2)}$$

▽ Static Water Level

All depths are in feet below ground surface unless otherwise noted.

Assumptions: Bottom of sand at MW-8D is 34 feet BGS. Assume a similar depth for MW-4.
Saturated thickness = 34 − 11.87 = 22.1 (assume ~22 feet)

<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>

A Q T E S O L V   R E S U L T S

Version 1.10

10/03/94 21:15:17

TEST DESCRIPTION

Data set........... c:\aqtesolv\tecum-4.dat
Data set title..... TECUMSEH MW-4

Knowns and Constants:
- No. of data points.................. 129
- Radius of well casing............... 0.18
- Radius of well...................... 0.33
- Aquifer saturated thickness......... 22
- Well screen length.................. 2.6
- Static height of water in well...... 2.6
- Log(Re/Rw).......................... 1.116
- A, B, C............................. 1.842, 0.250, 0.000

ANALYTICAL METHOD

Bouwer and Rice (unconfined aquifer slug test)

RESULTS FROM STATISTICAL CURVE MATCHING

STATISTICAL MATCH PARAMETER ESTIMATES

	Estimate		Std. Error
K =	6.2462E-003	+/-	2.8128E-004
y0 =	3.7784E-001	+/-	4.4246E-003

ANALYSIS OF MODEL RESIDUALS

residual = calculated - observed
weighted residual = residual * weight

Weighted Residual Statistics:
- Number of residuals............... 94
- Number of estimated parameters.... 2
- Degrees of freedom................ 92
- Residual mean..................... 0.001723
- Residual standard deviation....... 0.02337
- Residual variance................. 0.0005462

Model Residuals:

Time	Observed	Calculated	Residual	Weight

0.031	0.482	0.36747	0.11453	1
0.035	0.399	0.36615	0.032848	1
0.04	0.393	0.36451	0.028488	1
0.044	0.387	0.36321	0.023795	1
0.048	0.387	0.3619	0.025097	1
0.052	0.369	0.36061	0.0083948	1
0.056	0.381	0.35931	0.021688	1
0.06	0.369	0.35802	0.010976	1
0.065	0.375	0.35642	0.01858	1
0.069	0.381	0.35514	0.025858	1
0.073	0.363	0.35387	0.0091314	1
0.077	0.375	0.3526	0.0224	1
0.081	0.363	0.35134	0.011664	1
0.085	0.363	0.35008	0.012924	1
0.09	0.351	0.34851	0.0024925	1
0.094	0.328	0.34726	-0.019258	1
0.098	0.345	0.34601	-0.0010128	1
0.102	0.345	0.34477	0.00022783	1
0.106	0.345	0.34354	0.001464	1
0.11	0.345	0.3423	0.0026958	1
0.115	0.339	0.34077	-0.0017707	1
0.119	0.345	0.33955	0.0054511	1
0.123	0.328	0.33833	-0.010331	1
0.127	0.345	0.33712	0.0078817	1
0.131	0.345	0.33591	0.0090905	1
0.135	0.345	0.33471	0.010295	1
0.14	0.334	0.33321	0.00079435	1
0.144	0.334	0.33201	0.0019891	1
0.148	0.328	0.33082	-0.0028205	1
0.152	0.339	0.32963	0.0093657	1
0.156	0.328	0.32845	-0.00045239	1
0.16	0.334	0.32727	0.0067253	1
0.165	0.322	0.32581	-0.0038085	1
0.169	0.328	0.32464	0.0033597	1
0.173	0.328	0.32348	0.0045237	1
0.177	0.322	0.32232	-0.00031649	1
0.181	0.328	0.32116	0.0068392	1
0.185	0.322	0.32001	0.0019907	1
0.19	0.31	0.31858	-0.0085756	1
0.194	0.31	0.31743	-0.0074334	1
0.198	0.316	0.3163	-0.0002952	1
0.202	0.31	0.31516	-0.0051611	1
0.206	0.31	0.31403	-0.0040311	1
0.21	0.31	0.31291	-0.0029051	1
0.215	0.31	0.3115	-0.0015033	1
0.219	0.304	0.31039	-0.0063864	1
0.223	0.31	0.30927	0.0007265	1
0.227	0.292	0.30816	-0.016165	1
0.231	0.28	0.30706	-0.02706	1
0.235	0.31	0.30596	0.0040413	1
0.24	0.304	0.30459	-0.000588	1
0.244	0.304	0.3035	0.00050412	1
0.248	0.298	0.30241	-0.0044077	1
0.252	0.286	0.30132	-0.015323	1
0.256	0.292	0.30024	-0.008243	1
0.26	0.274	0.29917	-0.025166	1
0.265	0.268	0.29783	-0.029826	1
0.269	0.28	0.29676	-0.016758	1
0.273	0.269	0.29569	-0.026694	1

0.277	0.268	0.29463	-0.026634	1
0.281	0.274	0.29358	-0.019578	1
0.285	0.274	0.29252	-0.018525	1
0.29	0.269	0.29121	-0.022215	1
0.294	0.269	0.29017	-0.02117	1
0.298	0.263	0.28913	-0.02613	1
0.302	0.263	0.28809	-0.025093	1
0.306	0.263	0.28706	-0.02406	1
0.31	0.275	0.28603	-0.011031	1
0.315	0.263	0.28475	-0.02175	1
0.319	0.263	0.28373	-0.020729	1
0.323	0.268	0.28271	-0.014711	1
0.327	0.262	0.2817	-0.019698	1
0.331	0.263	0.28069	-0.017688	1
0.419	0.234	0.25936	-0.02536	1
0.502	0.216	0.24073	-0.024732	1
0.585	0.21	0.22344	-0.013442	1
0.669	0.186	0.20721	-0.021207	1
0.752	0.18	0.19232	-0.012325	1
0.835	0.175	0.17851	-0.0035111	1
0.919	0.163	0.16554	-0.002541	1
1.002	0.151	0.15365	-0.0026512	1
1.085	0.139	0.14262	-0.0036154	1
1.169	0.122	0.13225	-0.010253	1
1.252	0.122	0.12275	-0.00075441	1
1.335	0.122	0.11394	0.0080623	1
1.419	0.116	0.10566	0.010341	1
1.502	0.116	0.09807	0.01793	1
1.585	0.122	0.091027	0.030973	1
1.669	0.11	0.084413	0.025587	1
1.752	0.122	0.07835	0.04365	1
1.835	0.122	0.072723	0.049277	1
1.919	0.122	0.067439	0.054561	1
2.002	0.122	0.062595	0.059405	1
2.502	0.111	0.039952	0.071048	1

==

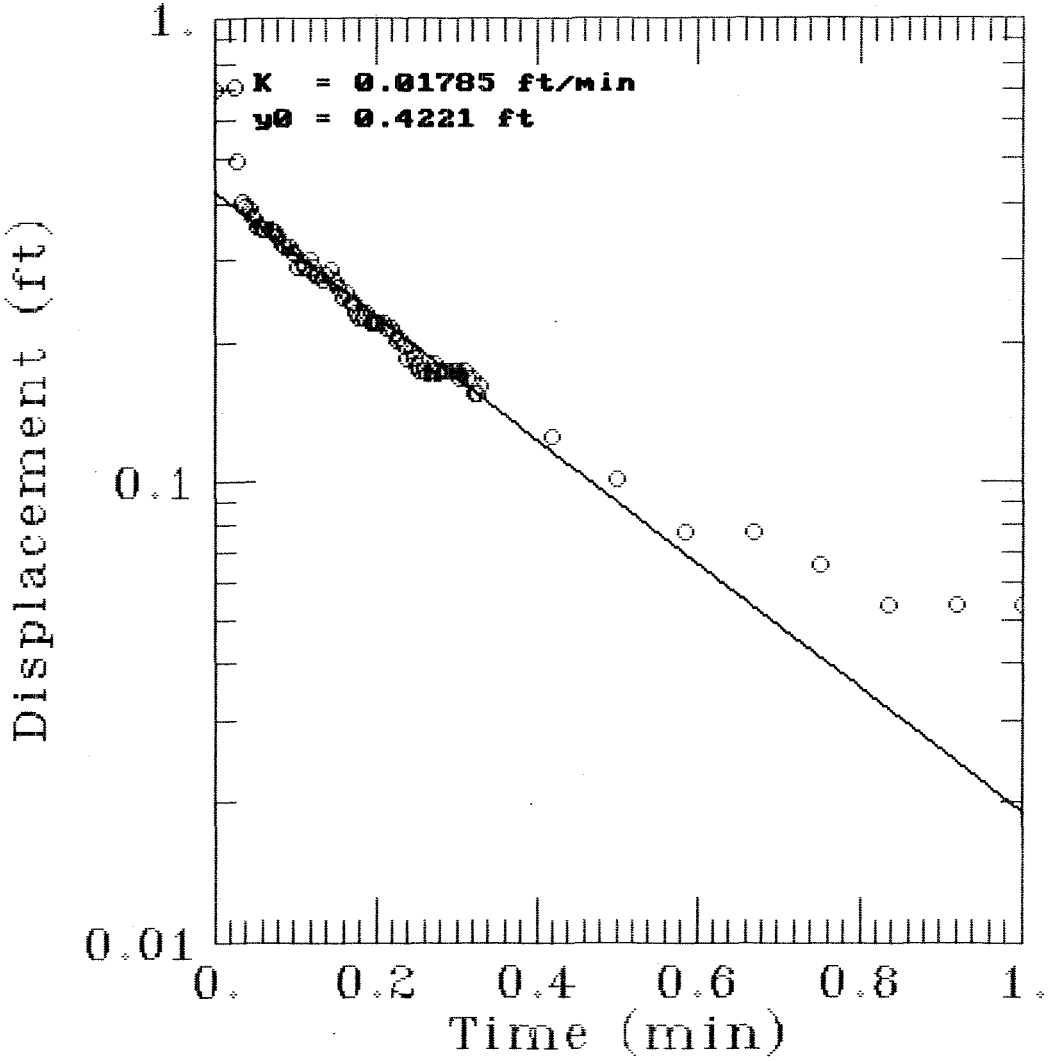
RESULTS FROM VISUAL CURVE MATCHING

VISUAL MATCH PARAMETER ESTIMATES

	Estimate
K =	6.2462E-003
y0 =	3.7784E-001

<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>

TECUMSEH MW-7



$K = 9.1 \times 10^{-3}$ cm/s
9×10^{-3}

RMT INC
744 Heartland Trail P.O. Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX (608) 831-3334

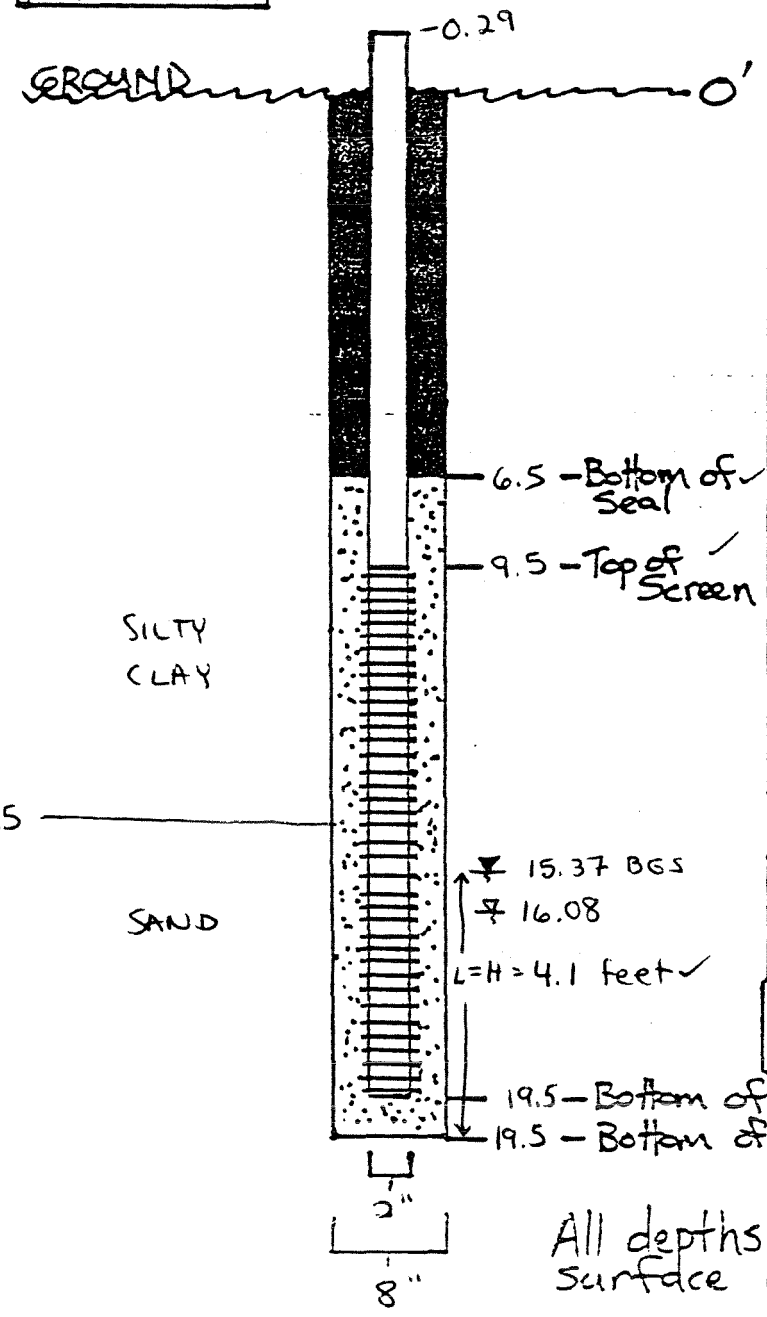
SHEET ____ OF ____

PROJECT / PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
Tecumseh Products Co.	LSD	10-3-94	MDG	10-5-94	3084.03

BOUWER and RICE SINGLE-WELL RESPONSE TEST ANALYSIS

WELL NUMBER MW-7

FIGURE IS NOT TO SCALE



"SLUG TEST DATA" for Aqtesolv

Initial Drawdown = 0.714

Radius of Well Casing (rc or r'c) = 0.18

Radius of Well (rw) = 0.33

Saturated Aquifer Thickness (D) = 23

Effective Screen Length (L) = 4.1

Static Height of Water in Well (H) = 4.1

Default for Aquitards D=H=L

r'c correction factor is used to adjust for sand pack de-watering effects.

$$r'_c = \sqrt{r_c^2 + n_e(r_w^2 - r_c^2)}$$

$$r'_c = \sqrt{(0.083)^2 + 0.25(0.33^2 - 0.083^2)}$$

▽ Static Water Level

All depths are in feet below ground surface unless otherwise noted.

Assumptions: Bottom of sand at MW-8D is 34 feet BGS. Well MW-7 is approximately 4 feet higher than MW-8D so assume bottom of sand at MW-7 is approximately 38 feet BGS.

Saturated thickness = 38 - 15.37 = 22.6 (assume ~23 feet)

<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>

A Q T E S O L V   R E S U L T S
Version 1.10

10/03/94 21:02:20

==

TEST DESCRIPTION

Data set........... tecum-7.dat
Data set title..... TECUMSEH MW-7

Knowns and Constants:
- No. of data points.................. 82
- Radius of well casing............... 0.18
- Radius of well...................... 0.33
- Aquifer saturated thickness......... 23
- Well screen length.................. 4.1
- Static height of water in well...... 4.1
- Log(Re/Rw).......................... 1.458
- A, B, C............................. 1.959, 0.281, 0.000

==

ANALYTICAL METHOD

Bouwer and Rice (unconfined aquifer slug test)

==

RESULTS FROM STATISTICAL CURVE MATCHING

STATISTICAL MATCH PARAMETER ESTIMATES

	Estimate		Std. Error
K =	1.7849E-002	+/-	3.6258E-004
y0 =	4.2207E-001	+/-	4.6604E-003

ANALYSIS OF MODEL RESIDUALS

residual = calculated - observed
weighted residual = residual * weight

Weighted Residual Statistics:
- Number of residuals............... 76
- Number of estimated parameters.... 2
- Degrees of freedom................ 74
- Residual mean..................... 0.001262
- Residual standard deviation....... 0.01072
- Residual variance................. 0.0001149

Model Residuals:

Time	Observed	Calculated	Residual	Weight

0.052	0.369	0.35927	0.0097303	1
0.056	0.357	0.35485	0.0021549	1
0.06	0.351	0.35047	0.00052504	1
0.065	0.351	0.34509	0.0059121	1
0.069	0.351	0.34084	0.010162	1
0.073	0.345	0.33664	0.0083597	1
0.077	0.345	0.33249	0.012506	1
0.081	0.339	0.3284	0.0106	1
0.085	0.327	0.32436	0.0026449	1
0.09	0.322	0.31937	0.0026304	1
0.094	0.321	0.31544	0.0055637	1
0.098	0.315	0.31155	0.0034484	1
0.102	0.309	0.30771	0.0012854	1
0.106	0.292	0.30392	-0.011925	1
0.11	0.298	0.30018	-0.0021819	1
0.115	0.292	0.29557	-0.0035679	1
0.119	0.303	0.29193	0.011072	1
0.123	0.292	0.28833	0.0036674	1
0.127	0.28	0.28478	-0.0047816	1
0.131	0.28	0.28127	-0.0012743	1
0.135	0.274	0.27781	-0.0038103	1
0.14	0.28	0.27354	0.0064599	1
0.144	0.286	0.27017	0.015829	1
0.148	0.274	0.26684	0.007156	1
0.152	0.268	0.26356	0.0044423	1
0.156	0.262	0.26031	0.0016882	1
0.16	0.25	0.25711	-0.0071059	1
0.165	0.256	0.25315	0.002846	1
0.169	0.244	0.25004	-0.0060363	1
0.173	0.244	0.24696	-0.0029569	1
0.177	0.232	0.24392	-0.011916	1
0.181	0.226	0.24091	-0.014912	1
0.185	0.226	0.23794	-0.011945	1
0.19	0.232	0.23429	-0.0022872	1
0.194	0.22	0.2314	-0.011402	1
0.198	0.22	0.22855	-0.008552	1
0.202	0.22	0.22574	-0.0057372	1
0.206	0.22	0.22296	-0.0029571	1
0.21	0.22	0.22021	-0.00021129	1
0.215	0.214	0.21683	-0.0028265	1
0.219	0.214	0.21416	-0.00015615	1
0.223	0.208	0.21152	-0.0035187	1
0.227	0.202	0.20891	-0.0069137	1
0.231	0.203	0.20634	-0.0033408	1
0.235	0.196	0.2038	-0.0077996	1
0.24	0.185	0.20067	-0.015667	1
0.244	0.191	0.1982	-0.0071957	1
0.248	0.185	0.19575	-0.010755	1
0.252	0.178	0.19334	-0.015344	1
0.256	0.173	0.19096	-0.017963	1
0.26	0.173	0.18861	-0.015611	1
0.265	0.172	0.18571	-0.013712	1
0.269	0.173	0.18342	-0.010425	1
0.273	0.179	0.18117	-0.0021658	1
0.277	0.172	0.17893	-0.0069347	1
0.281	0.173	0.17673	-0.003731	1
0.285	0.173	0.17455	-0.0015544	1
0.29	0.173	0.17187	0.0011286	1
0.294	0.173	0.16975	0.0032453	1

0.298	0.173	0.16766	0.0053359	1
0.302	0.173	0.1656	0.0074008	1
0.306	0.167	0.16356	0.0034402	1
0.31	0.173	0.16155	0.011455	1
0.315	0.167	0.15906	0.0079376	1
0.319	0.167	0.1571	0.0098966	1
0.323	0.155	0.15517	-0.00016859	1
0.327	0.155	0.15326	0.0017424	1
0.331	0.161	0.15137	0.0096299	1
0.419	0.125	0.11525	0.0097501	1
0.502	0.101	0.089119	0.011881	1
0.585	0.077	0.068912	0.0080878	1
0.669	0.077	0.053122	0.023878	1
0.752	0.066	0.041078	0.024922	1
0.835	0.054	0.031764	0.022236	1
0.919	0.054	0.024486	0.029514	1
1.002	0.054	0.018934	0.035066	1

==

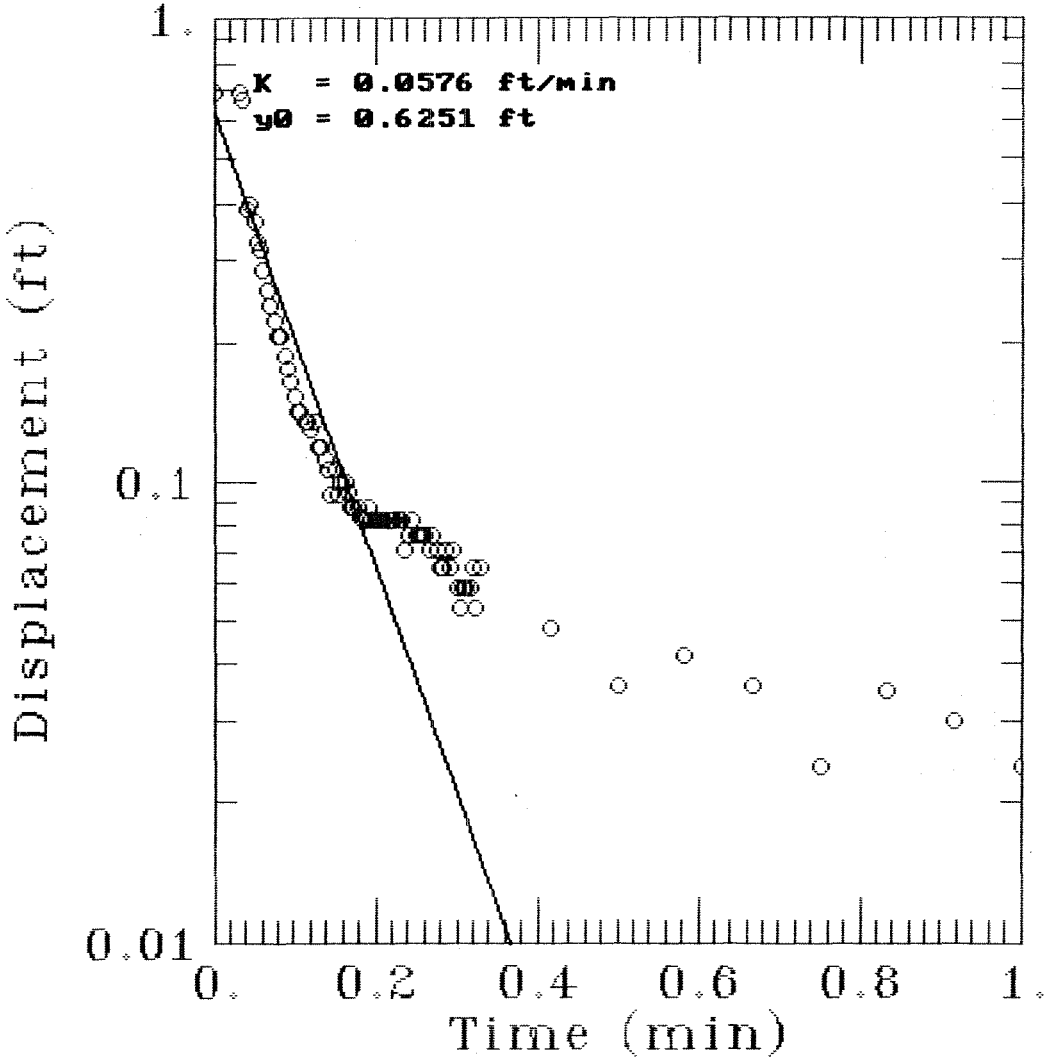
RESULTS FROM VISUAL CURVE MATCHING

VISUAL MATCH PARAMETER ESTIMATES

	Estimate
K =	1.6677E-002
y0 =	4.2258E-001

<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>

TECUMEH MW-9



$K = 2.9 \times 10^{-2}$ cm/s
3×10^{-2}

RMT INC
744 Heartland Trail P.O. Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX (608) 831-3334

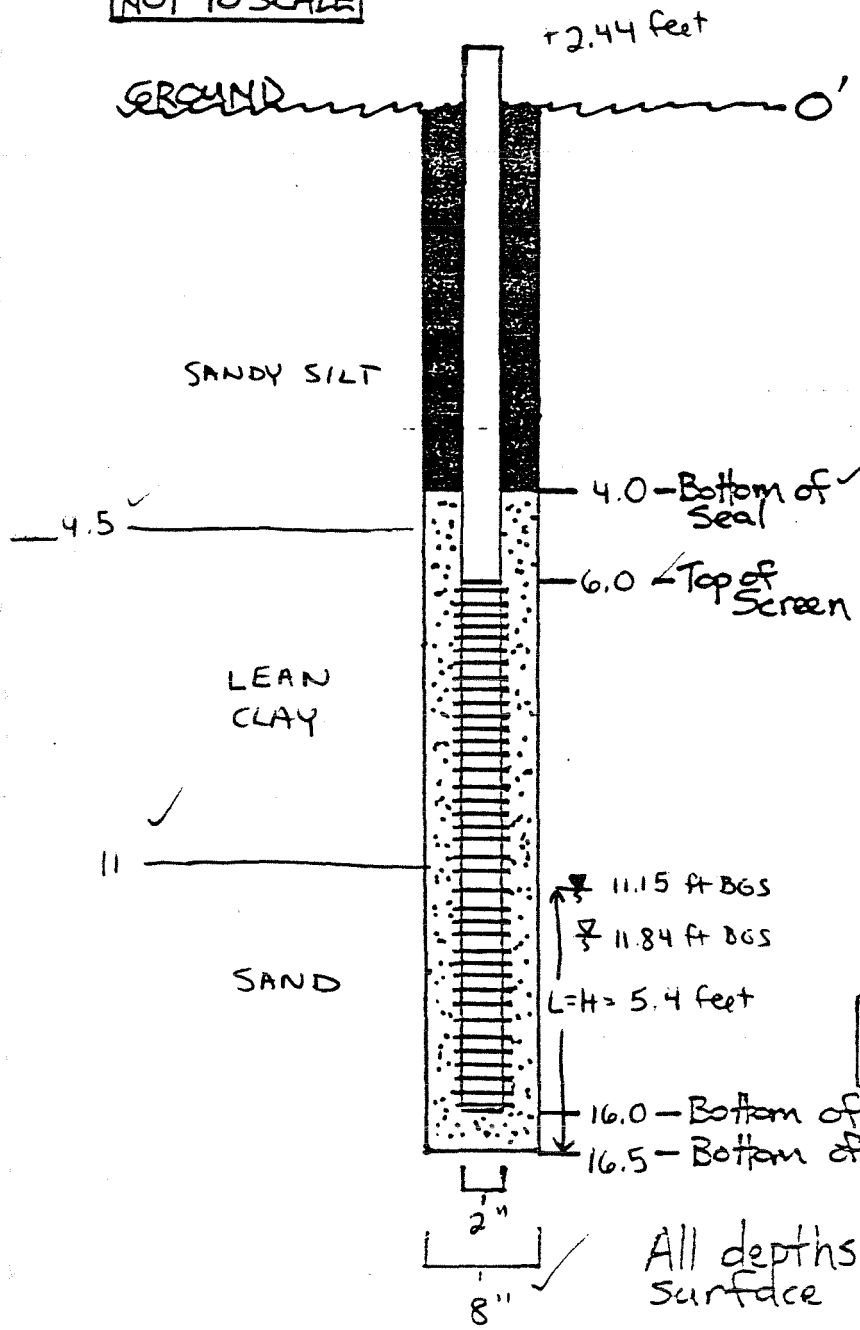
SHEET ____ OF ____

PROJECT / PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
Tecumseh Products Co.	LSD	10-3-94	MJBG	10-5-94	3084.02

BOUWER and RICE SINGLE-WELL RESPONSE TEST ANALYSIS

WELL NUMBER MW-9

FIGURE IS NOT TO SCALE



"SLUG TEST DATA" for Aqtesolv

Initial Drawdown = 0.694

Radius of Well Casing (rc or r'c) = 0.18

Radius of Well (rw) = 0.33

Saturated Aquifer Thickness (D) = 19

Effective Screen Length (L) = 5.4

Static Height of Water in Well (H) = 5.4

Default for Aquitards D=H=L

r'c correction factor is used to adjust for sand pack de-watering effects.

$$r'_c = \sqrt{r_c^2 + n_e(r_w^2 - r_c^2)}$$

▽ Static Water Level

All depths are in feet below ground surface unless otherwise noted.

Assumptions: Bottom of sand is approximately 30 feet BGS based on boring log for MW-9D. Saturated thickness = 30 – 11.15 = 18.9 (assume thickness = 19 feet)

<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>

A Q T E S O L V   R E S U L T S

Version 1.10

10/03/94 22:49:29

==

TEST DESCRIPTION

Data set........... c:\aqtesolv\tecum-9.dat
Data set title..... TECUMEH MW-9

Knowns and Constants:
- No. of data points.................. 82
- Radius of well casing............... 0.18
- Radius of well...................... 0.33
- Aquifer saturated thickness......... 19
- Well screen length.................. 5.4
- Static height of water in well...... 5.4
- Log(Re/Rw).......................... 1.695
- A, B, C............................. 2.055, 0.311, 0.000

==

ANALYTICAL METHOD

Bouwer and Rice (unconfined aquifer slug test)

==

RESULTS FROM STATISTICAL CURVE MATCHING

STATISTICAL MATCH PARAMETER ESTIMATES

	Estimate		Std. Error
K =	5.7599E-002	+/-	3.9412E-003
y0 =	6.2514E-001	+/-	4.3316E-002

ANALYSIS OF MODEL RESIDUALS

residual = calculated - observed
weighted residual = residual * weight

Weighted Residual Statistics:
- Number of residuals............... 81
- Number of estimated parameters.... 2
- Degrees of freedom................ 79
- Residual mean..................... 0.01422
- Residual standard deviation....... 0.04475
- Residual variance................. 0.002002

Model Residuals:

Time	Observed	Calculated	Residual	Weight

0.037	0.665	0.41115	0.25385	1
0.042	0.388	0.38851	-0.00051254	1
0.046	0.4	0.37131	0.028694	1
0.05	0.365	0.35486	0.010139	1
0.054	0.33	0.33914	-0.0091445	1
0.058	0.318	0.32412	-0.0061241	1
0.062	0.288	0.30977	-0.021769	1
0.067	0.259	0.29272	-0.033716	1
0.071	0.241	0.27975	-0.038752	1
0.075	0.223	0.26736	-0.044362	1
0.079	0.206	0.25552	-0.049521	1
0.083	0.206	0.2442	-0.038204	1
0.088	0.188	0.23076	-0.04276	1
0.092	0.176	0.22054	-0.04454	1
0.096	0.165	0.21077	-0.045772	1
0.1	0.153	0.20144	-0.048438	1
0.104	0.141	0.19252	-0.051516	1
0.108	0.141	0.18399	-0.04299	1
0.113	0.135	0.17386	-0.038861	1
0.117	0.135	0.16616	-0.031161	1
0.121	0.129	0.1588	-0.029802	1
0.125	0.135	0.15177	-0.016768	1
0.129	0.118	0.14505	-0.027047	1
0.133	0.118	0.13862	-0.020623	1
0.138	0.112	0.13099	-0.018991	1
0.142	0.106	0.12519	-0.01919	1
0.146	0.094	0.11965	-0.025645	1
0.15	0.106	0.11435	-0.0083464	1
0.154	0.094	0.10928	-0.015282	1
0.158	0.1	0.10444	-0.0044421	1
0.163	0.1	0.098692	0.0013076	1
0.167	0.095	0.094321	0.00067856	1
0.171	0.088	0.090144	-0.002144	1
0.175	0.088	0.086152	0.0018484	1
0.179	0.088	0.082336	0.0056639	1
0.183	0.083	0.078689	0.0043105	1
0.187	0.082	0.075204	0.0067956	1
0.192	0.088	0.071064	0.016936	1
0.196	0.082	0.067917	0.014083	1
0.2	0.082	0.064909	0.017091	1
0.204	0.082	0.062034	0.019966	1
0.208	0.082	0.059287	0.022713	1
0.212	0.082	0.056661	0.025339	1
0.217	0.082	0.053542	0.028458	1
0.221	0.082	0.05117	0.03083	1
0.225	0.082	0.048904	0.033096	1
0.229	0.082	0.046738	0.035262	1
0.233	0.082	0.044668	0.037332	1
0.237	0.071	0.04269	0.02831	1
0.242	0.076	0.04034	0.03566	1
0.246	0.082	0.038553	0.043447	1
0.25	0.076	0.036846	0.039154	1
0.254	0.076	0.035214	0.040786	1
0.258	0.076	0.033654	0.042346	1
0.262	0.076	0.032164	0.043836	1
0.267	0.071	0.030393	0.040607	1
0.271	0.076	0.029047	0.046953	1
0.275	0.071	0.027761	0.043239	1
0.279	0.065	0.026531	0.038469	1

0.283	0.065	0.025356	0.039644	1
0.287	0.071	0.024233	0.046767	1
0.292	0.065	0.022899	0.042101	1
0.296	0.071	0.021885	0.049115	1
0.3	0.059	0.020916	0.038084	1
0.304	0.053	0.019989	0.033011	1
0.308	0.059	0.019104	0.039896	1
0.312	0.059	0.018258	0.040742	1
0.317	0.059	0.017253	0.041747	1
0.321	0.065	0.016489	0.048511	1
0.325	0.053	0.015758	0.037242	1
0.329	0.065	0.01506	0.04994	1
0.417	0.048	0.0055593	0.042441	1
0.5	0.036	0.0021717	0.033828	1
0.583	0.042	0.00084835	0.041152	1
0.667	0.036	0.00032767	0.035672	1
0.75	0.024	0.000128	0.023872	1
0.833	0.035	5.0002E-005	0.03495	1
0.917	0.03	1.9313E-005	0.029981	1
1	0.024	7.5443E-006	0.023992	1
1.083	0.076	2.9471E-006	0.075997	1
1.167	0.042	1.1383E-006	0.041999	1

==

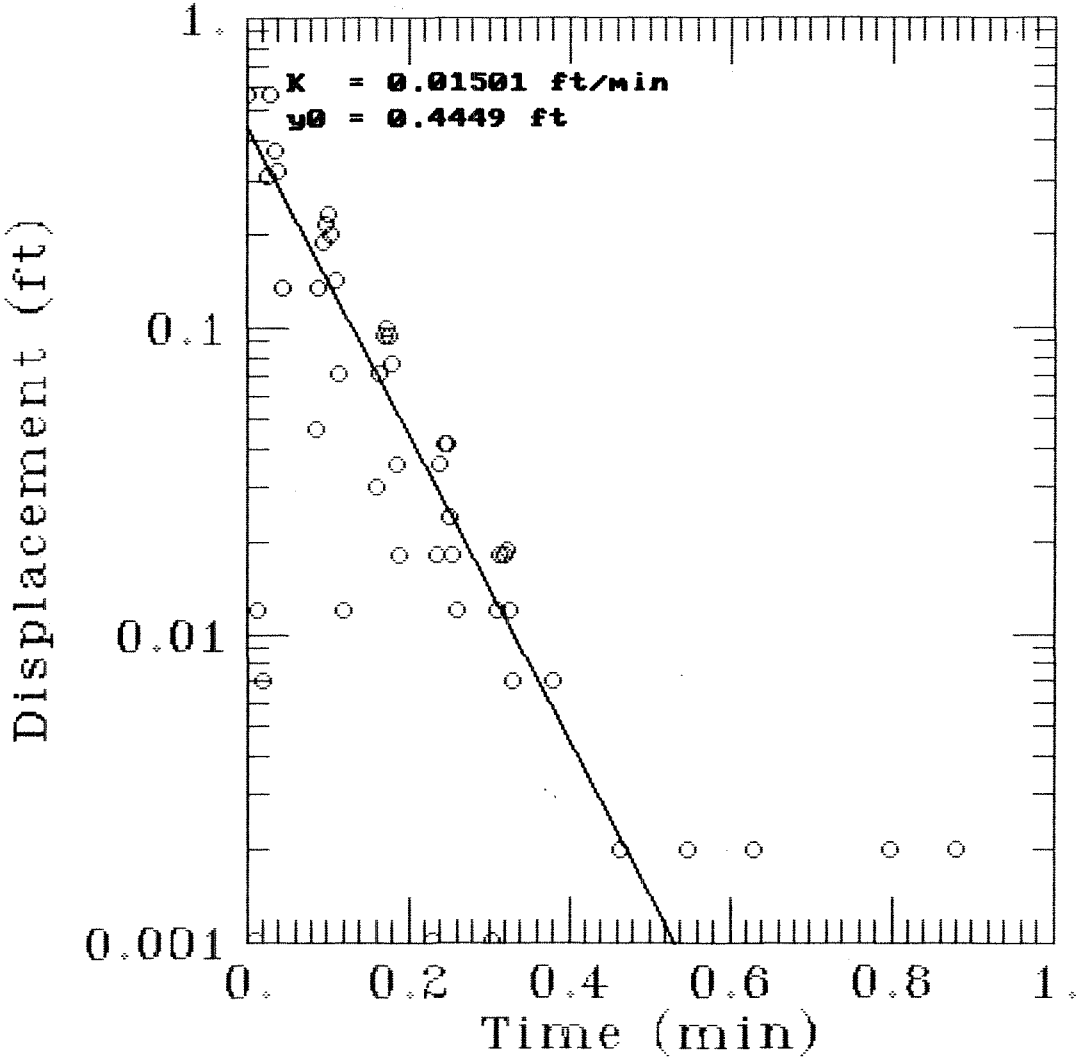
RESULTS FROM VISUAL CURVE MATCHING

VISUAL MATCH PARAMETER ESTIMATES

	Estimate
K =	5.7599E-002
y0 =	6.2514E-001

<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>

TECUMSEH MW-9D



$k = 7.6 \times 10^{-3}$ cm/s

RMT INC
744 Heartland Trail P.O. Box 8923 Madison, WI 53708-8923 (608) 831-4444 FAX (608) 831-3334

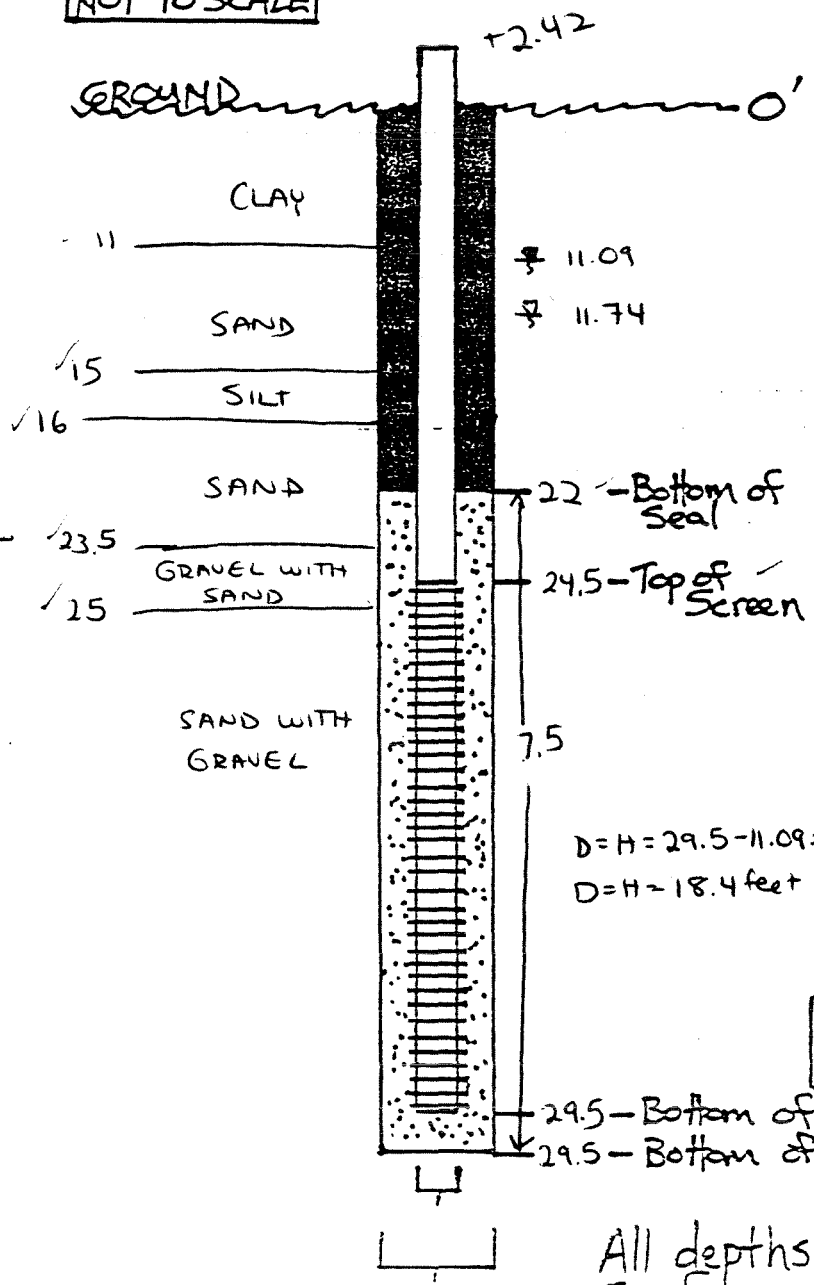
SHEET ____ OF ____

PROJECT / PROPOSAL NAME	PREPARED By:	Date:	CHECKED By:	Date:	PROJECT/PROPOSAL NO.
Tecumseh Products Co.	LSD	10-3-94	MBG	10-5-94	3084.02

BOUWER and RICE SINGLE-WELL RESPONSE TEST ANALYSIS

WELL NUMBER MW-9D

FIGURE IS NOT TO SCALE



"SLUG TEST DATA" for Aqtesolv

Initial Drawdown = 0.563

Radius of Well Casing (rc or r'c) = 0.083

Radius of Well (rw) = ~~0.18~~ 0.33

Saturated Aquifer Thickness (D) = 18

Effective Screen Length (L) = 7.5

Static Height of Water in Well (H) = 18

Default for Aquitards D=H=L

r'c correction factor used to adjust for sand pack de-watering effects.

$$r'_c = \sqrt{r_c^2 + n_e(r_w^2 - r_c^2)}$$

▽ Static Water Level

All depths are in feet below ground surface unless otherwise noted.

Assumptions: The r'c correction factor is not used because the water level does not rise in the screened section of the well

<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>

A Q T E S O L V   R E S U L T S
Version 1.10

10/05/94 14:21:10

==

TEST DESCRIPTION

Data set........... c:\aqtesolv\tp-9d.dat
Data set title..... TECUMSEH MW-9D

Knowns and Constants:
- No. of data points.................. 46
- Radius of well casing............... 0.083
- Radius of well...................... 0.33
- Aquifer saturated thickness......... 18
- Well screen length.................. 7.5
- Static height of water in well...... 18
- Log(Re/Rw).......................... 2.843
- A, B, C............................. 0.000, 0.000, 1.744

==

ANALYTICAL METHOD

Bouwer and Rice (unconfined aquifer slug test)

==

RESULTS FROM STATISTICAL CURVE MATCHING

STATISTICAL MATCH PARAMETER ESTIMATES

	Estimate		Std. Error
K =	1.5005E-002	+/-	2.1049E-003
y0 =	4.4493E-001	+/-	6.2196E-002

ANALYSIS OF MODEL RESIDUALS

residual = calculated - observed
weighted residual = residual * weight

Weighted Residual Statistics:
- Number of residuals............... 37
- Number of estimated parameters.... 2
- Degrees of freedom................ 35
- Residual mean..................... 0.000291
- Residual standard deviation....... 0.04868
- Residual variance................. 0.002369

Model Residuals:

Time	Observed	Calculated	Residual	Weight

0.035	0.375	0.29757	0.077435	1
0.04	0.323	0.28095	0.042053	1
0.044	0.135	0.26832	-0.13332	1
0.085	0.047	0.16749	-0.12049	1
0.09	0.135	0.15814	-0.023139	1
0.094	0.188	0.15103	0.036967	1
0.098	0.216	0.14425	0.071754	1
0.102	0.234	0.13776	0.096235	1
0.106	0.199	0.13157	0.067426	1
0.11	0.141	0.12566	0.015338	1
0.115	0.071	0.11864	-0.047644	1
0.119	0.012	0.11331	-0.10131	1
0.16	0.03	0.070732	-0.040732	1
0.165	0.071	0.066782	0.004218	1
0.169	0.094	0.063781	0.030219	1
0.173	0.1	0.060915	0.039085	1
0.177	0.094	0.058178	0.035822	1
0.181	0.077	0.055564	0.021436	1
0.185	0.036	0.053067	-0.017067	1
0.19	0.018	0.050103	-0.032103	1
0.231	0.001	0.031276	-0.030276	1
0.235	0.018	0.02987	-0.01187	1
0.24	0.036	0.028202	0.0077979	1
0.244	0.042	0.026935	0.015065	1
0.248	0.042	0.025725	0.016275	1
0.252	0.024	0.024569	-0.00056861	1
0.256	0.018	0.023465	-0.0054646	1
0.26	0.012	0.02241	-0.01041	1
0.306	0.001	0.013208	-0.012208	1
0.31	0.012	0.012614	-0.00061424	1
0.315	0.018	0.01191	0.0060903	1
0.319	0.018	0.011375	0.0066254	1
0.323	0.019	0.010863	0.0081365	1
0.327	0.012	0.010375	0.0016247	1
0.331	0.007	0.0099091	-0.0029091	1
0.381	0.007	0.0055776	0.0014224	1
0.465	0.002	0.002124	-0.00012396	1

===

RESULTS FROM VISUAL CURVE MATCHING

VISUAL MATCH PARAMETER ESTIMATES

	Estimate
K =	1.5005E-002
y0 =	4.4493E-001

<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<>>

APPENDIX D

APPENDIX D

RESULTS OF LABORATORY ANALYSIS OF SOIL

RMT LABORATORIES - 744 HEARTLAND TRAIL - MADISON, WI - 53717-1934 - P.O. BOX 8923 - MADISON, WI - 53708-8923 - 608/831-4444 - 608/831-7530 FAX

CLIENT: TECUMSEH
SAMPLE #: 5484-003
PROJECT #: 03084.02
WORK ORDER #: 5484
WI DNR LAB ID: 113138520

REPORT DATE: 10/03/94
COLLECTION DATE: 09/13/94
STATION ID: COMPOSITE SAMP

TOXICITY CHARACTERISTIC LEACHING PROCEDURE
VOLATILES (mg/L)

PARAMETER	PQL	SPIKE RECOVERY	THRESHOLD LIMIT	RESULT
Vinyl chloride	0.050	82%	0.2	<0.050
1,1-Dichloroethene	0.10	92%	0.7	<0.10
Chloroform	0.10	93%	6.0	<0.10
1,2-Dichloroethane	0.10	103%	0.5	<0.10
2-Butanone	0.20	111%	200.0	<0.20
Carbon tetrachloride	0.10	88%	0.5	<0.10
Trichloroethene	0.10	86%	0.5	<0.10
Benzene	0.10	92%	0.5	<0.10
Tetrachloroethene	0.10	79%	0.7	<0.10
Chlorobenzene	0.10	87%	100.0	<0.10
1,4-Dichlorobenzene	0.10	66%	7.5	<0.10

Kevin P. Moser 10.4-94
Approval Signature

Methods from USEPA SW846, 3rd Edition, 8260 (method 1311).
PQL : practical quantitation limit

RMT LABORATORIES - 744 HEARTLAND TRAIL - MADISON, WI - 53717-1934 - P.O. BOX 8923 - MADISON, WI - 53708-8923 - 608/831-4444 - 608/831-7530 FAX

PROJECT NAME: TECUMSEH
PROJECT NO: 03084.02
WORK ORDER NO: 5484
WI DNR LAB ID: 113138520

REPORT DATE: 10/06/94
PAGE NO: 1

SAMPLE NO.	STATION ID	COLL. DATE	SAMPLE NO.	STATION ID	COLL. DATE
5484-003	COMPOSITE SAMP	09/13/94			

I certify that the data contained in this Final Report has been generated and reviewed in accordance with approved methods and RMT Laboratory Standard Operating Procedure. Exceptions, if any, are discussed in the accompanying sample narrative. Release of this Final Report is authorized by RMT Laboratory management, as is verified by the following signature.

Approval Signature

10/6/94
Date

RMT LABORATORIES - 744 HEARTLAND TRAIL - MADISON, WI - 53717-1934 - P.O. BOX 8923 - MADISON, WI - 53708-8923 - 608/831-4444 - 608/831-7530 FAX

SAMPLE NARRATIVE
VOLATILE ORGANIC GC ANALYSIS

PROJECT NAME: TECUMSEH
PROJECT NUMBER: 3084.02
WORKORDER NUMBER: 5368
DATE: 09/07/94

Sample numbers 5368-001 and 5368-003 had surrogate* recoveries that were outside acceptable limits. The recoveries achieved in the analyses were as follows:

Sample Number	Surrogate	Recovery Analysis 1 (%)	Recovery Analysis 2 (%)	Acceptable Recovery (%)	Analysis Reported
5368-001	Bromochlorobenzene (PID)	57	57	61-115	1st
	Toluene-d	85	99	68-115	1st
5368-001	Bromochlorobenzene (ECLD)	50	75	53-116	1st
	3-Chloro-1-Propene	67	63	50-150	1st

Sample number 5368-003 also had surrogate recoveries that were outside the established limits. The sample was analyzed at a dilution due to the presence of a significant hydrocarbon pattern. The surrogate failure was not duplicated at this dilution, however, it was duplicated in a previous undiluted analysis.

*Surrogates are organic compounds that are similar to analytes of interest in chemical composition, extraction, and chromatography, but that are not normally found in environmental samples. These compounds are spiked into all blanks, standards, samples, and spiked samples before analysis (USEPA SW846 9/86 3rd edition).

RMT LABORATORIES - 744 HEARTLAND TRAIL - MADISON, WI - 53717-1934 - P.O. BOX 8923 - MADISON, WI - 53708-8923 - 608/831-4444 - 608/831-7530 FAX

CLIENT: TECUMSEH
SAMPLE #: 5484-003
PROJECT #: 03084.02
WORK ORDER #: 5484
WI DNR LAB ID: 113138520

REPORT DATE: 09/30/94
COLLECTION DATE: 09/13/94
STATION ID: COMPOSITE SAMP

TOXICITY CHARACTERISTIC LEACHING PROCEDURE
SEMIVOLATILES (mg/L)

PARAMETER	PQL	SPIKE RECOVERY	THRESHOLD LIMIT	RESULT
Pyridine	0.12	39%	5.0	<0.12
Cresol, total	0.075	53%	200	<0.075
Hexachloroethane	0.025	40%	3.0	<0.025
Nitrobenzene	0.025	67%	2.0	<0.025
Hexachlorobutadiene	0.025	46%	0.5	<0.025
2,4,6-Trichlorophenol	0.025	78%	2.0	<0.025
2,4,5-Trichlorophenol	0.12	78%	400	<0.12
2,4-Dinitrotoluene	0.025	90%	0.13	<0.025
Hexachlorobenzene	0.025	134%	0.13	<0.025
Pentachlorophenol	0.12	104%	100	<0.12

Joseph Kubal 9/30/94
Approval Signature

Methods from USEPA SW846, 3rd Edition, 8270A (method 1311).
PQL : practical quantitation limit

RMT LABORATORIES 744 HEARTLAND TRAIL MADISON, WI 53717-1934 P.O. BOX 8923 MADISON, WI 53708-8923 608/831-4444 608/831-7530 FAX

CLIENT: TECUMSEH
SAMPLE #: 5484-003
PROJECT #: 03084.02
WORK ORDER #: 5484
WI DNR LAB ID: 113138520

REPORT DATE: 10/07/94
COLLECTION DATE: 09/13/94
STATION ID: COMPOSITE SAMP

TOXICITY CHARACTERISTIC LEACHING PROCEDURE
METALS (mg/L)

PARAMETER	METHOD	PQL	SPIKE RECOVERY	THRESHOLD LIMIT	RESULT
Arsenic	6010	0.70	103%	5.0	<0.70
Barium	6010	0.050	92%	100.0	0.30
Cadmium	6010	0.010	95%	1.0	<0.010
Chromium	6010	0.010	91%	5.0	<0.010
Copper	6010	0.020	94%	---	<0.020
Lead	6010	0.20	92%	5.0	<0.20
Mercury	7470	0.0004	MSA 0.9998	0.2	<0.00040
Nickel	6010	0.040	90%	---	<0.040
Selenium	6010	0.70	113%	1.0	<0.70
Silver	6010	0.010	97%	5.0	<0.010
Zinc	6010	0.020	94%	---	0.095

Jeff Hearhart 10-7-94

Approval Signature

Methods from USEPA SW846, 3rd Edition.
PQL : practical quantitation limit
MSA : Method of Standard Addition, acceptable correlation coefficient value (r) greater than 0.995.

RMT LABORATORIES - 744 HEARTLAND TRAIL - MADISON, WI - 53717-1934 - P.O. BOX 8923 - MADISON, WI - 53708-8923 - 608/831-4444 - 608/831-7530 FAX

CLIENT: TECUMSEH
SAMPLE #: 5368-001
PROJECT #: 03084.02
WORK ORDER #: 5368
WI DNR LAB ID: 113138520

REPORT DATE: 09/07/94
COLLECTION DATE: 08/17/94
STATION ID: MW-3D-M 38

VOLATILE ORGANICS ANALYSIS REPORT

COMPOUND	RESULT	UNITS
Bromobenzene	<1.1	ug/kg dry wt.
1,3,5-Trimethylbenzene	<1.1	ug/kg dry wt.
2-Chlorotoluene	<1.1	ug/kg dry wt.
4-Chlorotoluene	<1.1	ug/kg dry wt.
tert-Butylbenzene	<2.2	ug/kg dry wt.
1,2,4-Trimethylbenzene	<1.1	ug/kg dry wt.
sec-Butylbenzene	<1.1	ug/kg dry wt.
p-Isopropyltoluene	<1.1	ug/kg dry wt.
1,3-Dichlorobenzene	<1.1	ug/kg dry wt.
1,4-Dichlorobenzene	<1.1	ug/kg dry wt.
1,2-Dichlorobenzene	<1.1	ug/kg dry wt.
n-Butylbenzene	<1.1	ug/kg dry wt.
1,2-Dibromo-3-chloropropane	<1.1	ug/kg dry wt.
1,2,4-Trichlorobenzene	<1.1	ug/kg dry wt.
Hexachlorobutadiene	<1.1	ug/kg dry wt.
Naphthalene	<5.4	ug/kg dry wt.
1,2,3-Trichlorobenzene	<1.1	ug/kg dry wt.

Repeated surrogate failure (see Sample Narrative).

Kevin P. Meek 9-7-94
Approval Signature

S-F ANALYTICAL LABORATORIES, INC.
A Subsidiary of Sommer-Frey Laboratories, Inc.

RMT, Inc.
P.O. Box 8923
Madison, Wisconsin 53708

September 19, 1994
Project #94002514
P.O. #43232

Attn: Kevin Hinckley

CHEMICAL ANALYSIS

Sample labelled: #5484-003 Composite Sample
RMT Project No.: 3084.02

Parameter Name	Units	Result	Detection Limit	Date Analyzed	Method	Analyst
Total Chlorine as Cl	% wt.	0.02	0.01	9-16-94	D808* 325.2**	rb

references: * ASTM
**Methods for Chemical Analysis of Water & Wastes, EPA

Gary G. Geipel
Senior Analyst

6125 West National Avenue, P.O. Box 14513, Milwaukee, Wisconsin 53214
(414) 475-6700 FAX: (414) 475-7216
Toll-Free: 800-300-6700

RMT LABORATORIES 744 HEARTLAND TRAIL MADISON, WI 53717-1934 P.O. BOX 8923 MADISON, WI 53708-8923 608/831-4444 608/831-7530 FAX

CLIENT: TECUMSEH
PROJECT #: 03084.02
WORK ORDER #: 5484

REPORT DATE: 10/07/94

TOXICITY CHARACTERISTIC LEACHING PROCEDURE WET CHEMISTRY

SAMPLE	DATE	STATION ID	Phenolics, total recoverable	UNITS
5484-003	09/13/94	COMPOSITE SAMP	<0.10 P,M	mg/L
5484-004	09/13/94	LEACH BLK	<0.10 M	mg/L

Jeff Hearhart 10-7-94

Approval Signature

RMT LABORATORIES 744 HEARTLAND TRAIL MADISON, WI 53717-1934 P.O. BOX 8923 MADISON, WI 53708-8923 608/831-4444 608/831-7530 FAX

CLIENT: TECUMSEH
SAMPLE #: 5484-003
PROJECT #: 03084.02
WORK ORDER #: 5484
WI DNR LAB ID: 113138520

REPORT DATE: 10/07/94
COLLECTION DATE: 09/13/94
STATION ID: COMPOSITE SAMP

INORGANIC ANALYSIS REPORT

PARAMETER	RESULT	UNITS
Acidity as CaCO3, soluble	32	mg/L
Alkalinity as CaCO3, soluble	36	mg/kg dry wt.
Cyanide, free	<2.9	mg/Kg dry wt.
Flashpoint	>210	F
Free liquids	NFLP	%
Gravity, specific	2.05	
Solids, total	86.3	%
Sulfide, reactive	<10	mg/k
pH, laboratory (in CaCl2)	8.0	su

NFLP = No free liqiuds present.

Jeff Gearhart 10-7-94

Approval Signature

RMT LABORATORIES 744 HEARTLAND TRAIL MADISON, WI 53717-1934 P.O. BOX 8923 MADISON, WI 53708-8923 608/831-4444 608/831-7530 FAX

CLIENT: TECUMSEH
SAMPLE #: 5484-003
PROJECT #: 03084.02
WORK ORDER #: 5484
WI DNR LAB ID: 113138520

REPORT DATE: 10/07/94
COLLECTION DATE: 09/13/94
STATION ID: COMPOSITE SAMP

TOXICITY CHARACTERISTIC LEACHING PROCEDURE

EXTRACTION 1311

PARAMETER	RESULT	UNITS
Sample weight, total	100.0	gm
pH, after 5 minutes	9.8	su
pH, after heating	7.8	su
Extraction solution	2	
Final pH	5.4	su
Extraction pH	2.9	su
Leaching date	09/16/94	

Jeff Gearhart 10-7-94

Approval Signature

METHOD 1311, AS PUBLISHED IN FED. REGISTER; JUNE 29,1990;
40 CFR PARTS 261, 264, 265, 268, 271, AND 302.

RMT LABORATORIES - 744 HEARTLAND TRAIL - MADISON, WI - 53717-1934 - P.O. BOX 8923 - MADISON, WI - 53708-8923 - 608/831-4444 - 608/831-7530 FAX

PROJECT NAME: TECUMSEH
PROJECT NUMBER: 03084.02
LAB SAMPLE NUMBER: 5484-003
STATION ID: COMPOSITE SAMP
WI DNR LAB ID: 113138520

REPORT DATE: 10/06/94
COLLECTION DATE: 09/13/94
EXTRACTION DATE: 09/26/94
ANALYSIS DATE: 10/04/94
METHOD: 8080

PESTICIDE/PCB ANALYSIS REPORT

COMPOUND	RESULT	EQL	CODE	UNITS
Aroclor-1016	<39	39		ug/kg dry wt.
Aroclor-1221	<78	78		ug/kg dry wt.
Aroclor-1232	<39	39		ug/kg dry wt.
Aroclor-1242	<39	39		ug/kg dry wt.
Aroclor-1248	<39	39		ug/kg dry wt.
Aroclor-1254	<39	39		ug/kg dry wt.
Aroclor-1260	<39	39		ug/kg dry wt.

Aroclor 1254 was identified in the sample at a level below quantifiable limits.

APPENDIX E

APPENDIX E

RESULTS OF LABORATORY ANALYSIS OF GROUNDWATER

RMT LABORATORIES - 744 HEARTLAND TRAIL - MADISON, WI - 53717-1934 - P.O. BOX 8923 - MADISON, WI - 53708-8923 - 608/831-4444 - 608/831-7530 FAX

CLIENT: TECUMSEH
SAMPLE #: 5368-001
PROJECT #: 03084.02
WORK ORDER #: 5368
WI DNR LAB ID: 113138520

REPORT DATE: 09/07/94
COLLECTION DATE: 08/17/94
STATION ID: MW-3D-M 38

VOLATILE ORGANICS ANALYSIS REPORT

COMPOUND	RESULT	UNITS
Dichlorodifluoromethane	<2.2	ug/kg dry wt.
Chloromethane	<1.1	ug/kg dry wt.
Vinyl chloride	<1.1	ug/kg dry wt.
Bromomethane	<5.4	ug/kg dry wt.
Chloroethane	<1.1	ug/kg dry wt.
Fluorotrichloromethane	<1.1	ug/kg dry wt.
1,1-Dichloroethene	<1.1	ug/kg dry wt.
Methylene chloride	<1.1	ug/kg dry wt.
trans-1,2-Dichloroethene	<1.1	ug/kg dry wt.
1,1-Dichloroethane	<1.1	ug/kg dry wt.
2,2-Dichloropropane	<2.2	ug/kg dry wt.
cis-1,2-Dichloroethene	<1.1	ug/kg dry wt.
Chloroform	<1.1	ug/kg dry wt.
Bromochloromethane	<1.1	ug/kg dry wt.
1,1,1-Trichloroethane	<1.1	ug/kg dry wt.
1,1-Dichloropropene	<1.1	ug/kg dry wt.
Carbon tetrachloride	<1.1	ug/kg dry wt.
1,2-Dichloroethane	<1.1	ug/kg dry wt.
Benzene	<1.1	ug/kg dry wt.
Trichloroethene	<1.1	ug/kg dry wt.
1,2-Dichloropropane	<1.1	ug/kg dry wt.
Bromodichloromethane	<1.1	ug/kg dry wt.
Dibromomethane	<1.1	ug/kg dry wt.
cis-1,3-Dichloropropene	<1.1	ug/kg dry wt.
Toluene	<1.1	ug/kg dry wt.
trans-1,3-Dichloropropene	<1.1	ug/kg dry wt.
1,1,2-Trichloroethane	<1.1	ug/kg dry wt.
Tetrachloroethene	<2.2	ug/kg dry wt.
1,3-Dichloropropane	<2.2	ug/kg dry wt.
Chlorodibromomethane	<1.1	ug/kg dry wt.
1,2-Dibromoethane	<1.1	ug/kg dry wt.
Chlorobenzene	<1.1	ug/kg dry wt.
1,1,1,2-Tetrachloroethane	<2.2	ug/kg dry wt.
Ethylbenzene	<1.1	ug/kg dry wt.
Xylene, total	<3.3	ug/kg dry wt.
Styrene	<1.1	ug/kg dry wt.
Isopropylbenzene	<1.1	ug/kg dry wt.
Bromoform	<2.2	ug/kg dry wt.
1,1,2,2-Tetrachloroethane	<1.1	ug/kg dry wt.
1,2,3-Trichloropropane	<1.1	ug/kg dry wt.
n-Propylbenzene	<1.1	ug/kg dry wt.

RMT LABORATORIES - 744 HEARTLAND TRAIL - MADISON, WI - 53717-1934 - P.O. BOX 8923 - MADISON, WI - 53708-8923 - 608/831-4444 - 608/831-7530 FAX

CLIENT: TECUMSEH
SAMPLE #: 5368-003
PROJECT #: 03084.02
WORK ORDER #: 5368
WI DNR LAB ID: 113138520

REPORT DATE: 09/07/94
COLLECTION DATE: 08/18/94
STATION ID: MW-8D-B 5-7

VOLATILE ORGANICS ANALYSIS REPORT

COMPOUND	RESULT	UNITS
Bromobenzene	<600	ug/kg dry wt.
1,3,5-Trimethylbenzene	6200	ug/kg dry wt.
2-Chlorotoluene	<600	ug/kg dry wt.
4-Chlorotoluene	<600	ug/kg dry wt.
tert-Butylbenzene	<1200	ug/kg dry wt.
1,2,4-Trimethylbenzene	20000	ug/kg dry wt.
sec-Butylbenzene	880	ug/kg dry wt.
p-Isopropyltoluene	1000	ug/kg dry wt.
1,3-Dichlorobenzene	<600	ug/kg dry wt.
1,4-Dichlorobenzene	<600	ug/kg dry wt.
1,2-Dichlorobenzene	<600	ug/kg dry wt.
n-Butylbenzene	12000	ug/kg dry wt.
1,2-Dibromo-3-chloropropane	<600	ug/kg dry wt.
1,2,4-Trichlorobenzene	<600	ug/kg dry wt.
Hexachlorobutadiene	<600	ug/kg dry wt.
Naphthalene	5900	ug/kg dry wt.
1,2,3-Trichlorobenzene	<600	ug/kg dry wt.

Repeated surrogate failure (see Sample Narrative).

Ken P. Meer 9-7-94
Approval Signature

RMT LABORATORIES - 744 HEARTLAND TRAIL - MADISON, WI - 53717-1934 - P.O. BOX 8923 - MADISON, WI - 53708-8923 - 608/831-4444 - 608/831-7530 FAX

CLIENT: TECUMSEH
SAMPLE #: 5368-003
PROJECT #: 03084.02
WORK ORDER #: 5368
WI DNR LAB ID: 113138520

REPORT DATE: 09/07/94
COLLECTION DATE: 08/18/94
STATION ID: MW-8D-B 5-7

VOLATILE ORGANICS ANALYSIS REPORT

COMPOUND	RESULT	UNITS
Dichlorodifluoromethane	<1200	ug/kg dry wt.
Chloromethane	<600	ug/kg dry wt.
Vinyl chloride	<600	ug/kg dry wt.
Bromomethane	<3000	ug/kg dry wt.
Chloroethane	<600	ug/kg dry wt.
Fluorotrichloromethane	<600	ug/kg dry wt.
1,1-Dichloroethene	<600	ug/kg dry wt.
Methylene chloride	1200	ug/kg dry wt.
trans-1,2-Dichloroethene	<600	ug/kg dry wt.
1,1-Dichloroethane	1500	ug/kg dry wt.
2,2-Dichloropropane	<1200	ug/kg dry wt.
cis-1,2-Dichloroethene	1000	ug/kg dry wt.
Chloroform	<600	ug/kg dry wt.
Bromochloromethane	<600	ug/kg dry wt.
1,1,1-Trichloroethane	9800	ug/kg dry wt.
1,1-Dichloropropene	<600	ug/kg dry wt.
Carbon tetrachloride	<600	ug/kg dry wt.
1,2-Dichloroethane	<600	ug/kg dry wt.
Benzene	<600	ug/kg dry wt.
Trichloroethene	1800	ug/kg dry wt.
1,2-Dichloropropane	760	ug/kg dry wt.
Bromodichloromethane	<600	ug/kg dry wt.
Dibromomethane	<600	ug/kg dry wt.
cis-1,3-Dichloropropene	<600	ug/kg dry wt.
Toluene	4300	ug/kg dry wt.
trans-1,3-Dichloropropene	<600	ug/kg dry wt.
1,1,2-Trichloroethane	<600	ug/kg dry wt.
Tetrachloroethene	<1200	ug/kg dry wt.
1,3-Dichloropropane	<1200	ug/kg dry wt.
Chlorodibromomethane	<600	ug/kg dry wt.
1,2-Dibromoethane	<600	ug/kg dry wt.
Chlorobenzene	<600	ug/kg dry wt.
1,1,1,2-Tetrachloroethane	<1200	ug/kg dry wt.
Ethylbenzene	3500	ug/kg dry wt.
Xylene, total	24000	ug/kg dry wt.
Styrene	<600	ug/kg dry wt.
Isopropylbenzene	1200	ug/kg dry wt.
Bromoform	<1200	ug/kg dry wt.
1,1,2,2-Tetrachloroethane	<600	ug/kg dry wt.
1,2,3-Trichloropropane	<600	ug/kg dry wt.
n-Propylbenzene	2100	ug/kg dry wt.

RMT LABORATORIES - 744 HEARTLAND TRAIL - MADISON, WI - 53717-1934 - P.O. BOX 8923 - MADISON, WI - 53708-8923 - 608/831-4444 - 608/831-7530 FAX

PROJECT NAME: TECUMSEH
PROJECT NO: 03084.02
WORK ORDER NO: 5389
WI DNR LAB ID: 113138520

REPORT DATE:09/12/94
PAGE NO: 1

SAMPLE NO.	STATION ID	SAMPLING DATE	SAMPLE NO.	STATION ID	SAMPLING DATE
5389-002	TRIP BLANK	08/25/94			
5389-003	MW-9	08/25/94			
5389-004	MW-9D	08/25/94			
5389-005	MW-3	08/25/94			
5389-006	MW-3D	08/25/94			
5389-007	MW-8	08/25/94			
5389-008	MW-8D	08/25/94			
5389-009	FB-1	08/25/94			

I certify that the data contained in this Final Report has been generated and reviewed in accordance with approved methods and RMT Laboratory Standard Operating Procedure. Exceptions, if any, are discussed in the accompanying sample narrative. Release of this Final Report is authorized by RMT Laboratory management, as is verified by the following signature.

Kevin P. Mack
Approval Signature

9-12-94
Date

RMT LABORATORIES - 744 HEARTLAND TRAIL - MADISON, WI - 53717-1934 - P.O. BOX 8923 - MADISON, WI 53708-8923 - 608/831-4444 - 608/831-7530 FAX

SAMPLE NARRATIVE
VOLATILE GC ORGANIC ANALYSIS

PROJECT NAME:	TECUMSEH
PROJECT NUMBER:	3084.02
WORKORDER NUMBER:	5389
DATE:	9/12/94

Sample numbers 5389-005, 5389-006, 5389-007, and 5389-008 were initially analyzed within the 14 day holding time for volatile organics analysis. These samples all required reanalysis due to either the presence of requested analytes at concentrations that exceeded the instrument calibration range or to failure to meet established quality control criteria. The samples were reloaded on a closed system auto-sampler on the last day of holding time. However, they did not inject onto the gas chromatograph (GC) until after midnight. The last sample analyzed was injected onto the GC at 2:26 a.m.; 2 hours and 26 minutes after the 14 day holding time had expired.

RMT LABORATORIES - 744 HEARTLAND TRAIL - MADISON, WI - 53717-1934 - P.O. BOX 8923 - MADISON, WI 53708-8923 - 608/831-4444 - 608/831-7530 FAX

PROJECT NAME: TECUMSEH
PROJECT NUMBER: 03084.02
LAB SAMPLE NUMBER: 5389-002
STATION ID: TRIP BLANK
WI DNR LAB ID: 113138520

REPORT DATE: 09/12/94
COLLECTION DATE:
ANALYSIS DATE: 09/06/94
METHOD: 8021

VOLATILE ORGANICS ANALYSIS REPORT

COMPOUND	RESULT	EQL	CODE	UNITS
Dichlorodifluoromethane	<2.0	2.0		ug/L
Chloromethane	<1.0	1.0		ug/L
Vinyl chloride	<1.0	1.0		ug/L
Bromomethane	<5.0	5.0		ug/L
Chloroethane	<1.0	1.0		ug/L
Fluorotrichloromethane	<1.0	1.0		ug/L
1,1-Dichloroethene	<1.0	1.0		ug/L
Methylene chloride	<1.0	1.0		ug/L
trans-1,2-Dichloroethene	<1.0	1.0		ug/L
1,1-Dichloroethane	<1.0	1.0		ug/L
2,2-Dichloropropane	<2.0	2.0		ug/L
cis-1,2-Dichloroethene	<1.0	1.0		ug/L
Chloroform	<1.0	1.0		ug/L
Bromochloromethane	<1.0	1.0		ug/L
1,1,1-Trichloroethane	<1.0	1.0		ug/L
1,1-Dichloropropene	<1.0	1.0		ug/L
Carbon tetrachloride	<1.0	1.0		ug/L
1,2-Dichloroethane	<1.0	1.0		ug/L
Benzene	<1.0	1.0		ug/L
Trichloroethene	<1.0	1.0		ug/L
1,2-Dichloropropane	<1.0	1.0		ug/L
Bromodichloromethane	<1.0	1.0		ug/L
Dibromomethane	<1.0	1.0		ug/L
cis-1,3-Dichloropropene	<1.0	1.0		ug/L
Toluene	<1.0	1.0		ug/L
trans-1,3-Dichloropropene	<1.0	1.0		ug/L
1,1,2-Trichloroethane	<1.0	1.0		ug/L
Tetrachloroethene	<2.0	2.0		ug/L
1,3-Dichloropropane	<2.0	2.0		ug/L
Chlorodibromomethane	<1.0	1.0		ug/L
1,2-Dibromoethane	<1.0	1.0		ug/L
Chlorobenzene	<1.0	1.0		ug/L
1,1,1,2-Tetrachloroethane	<2.0	2.0		ug/L
Ethylbenzene	<1.0	1.0		ug/L
Xylene, total	<3.0	3.0		ug/L
Styrene	<1.0	1.0		ug/L
Isopropylbenzene	<1.0	1.0		ug/L
Bromoform	<2.0	2.0		ug/L
1,1,2,2-Tetrachloroethane	<1.0	1.0		ug/L
1,2,3-Trichloropropane	<1.0	1.0		ug/L
n-Propylbenzene	<1.0	1.0		ug/L

RMT LABORATORIES - 744 HEARTLAND TRAIL - MADISON, WI 53717-1934 - P.O. BOX 8923 - MADISON, WI 53708-8923 - 608/831-4444 - 608/831-7530 FAX

PROJECT NAME: TECUMSEH
PROJECT NUMBER: 03084.02
LAB SAMPLE NUMBER: 5389-002
STATION ID: TRIP BLANK
WI DNR LAB ID: 113138520

REPORT DATE: 09/12/94
COLLECTION DATE:
ANALYSIS DATE: 09/06/94
METHOD: 8021

VOLATILE ORGANICS ANALYSIS REPORT

COMPOUND	RESULT	EQL	CODE	UNITS
Bromobenzene	<1.0	1.0		ug/L
1,3,5-Trimethylbenzene	<1.0	1.0		ug/L
2-Chlorotoluene	<1.0	1.0		ug/L
4-Chlorotoluene	<1.0	1.0		ug/L
tert-Butylbenzene	<2.0	2.0		ug/L
1,2,4-Trimethylbenzene	<1.0	1.0		ug/L
sec-Butylbenzene	<1.0	1.0		ug/L
p-Isopropyltoluene	<1.0	1.0		ug/L
1,3-Dichlorobenzene	<1.0	1.0		ug/L
1,4-Dichlorobenzene	<1.0	1.0		ug/L
n-Butylbenzene	<1.0	1.0		ug/L
1,2-Dichlorobenzene	<1.0	1.0		ug/L
1,2-Dibromo-3-chloropropane	<1.0	1.0		ug/L
1,2,4-Trichlorobenzene	<1.0	1.0		ug/L
Hexachlorobutadiene	<1.0	1.0		ug/L
Naphthalene	<5.0	5.0		ug/L
1,2,3-Trichlorobenzene	<1.0	1.0		ug/L

RMT LABORATORIES - 744 HEARTLAND TRAIL - MADISON, WI - 53717-1934 - P.O. BOX 8923 - MADISON, WI 53708-8923 - 608/831-4444 - 608/831-7530 FAX

PROJECT NAME: TECUMSEH
PROJECT NUMBER: 03084.02
LAB SAMPLE NUMBER: 5389-003
STATION ID: MW-9
WI DNR LAB ID: 113138520

REPORT DATE: 09/12/94
COLLECTION DATE: 08/25/94
ANALYSIS DATE: 09/08/94
METHOD: 8021

VOLATILE ORGANICS ANALYSIS REPORT

COMPOUND	RESULT	EQL	CODE	UNITS
Dichlorodifluoromethane	<200	200		ug/L
Chloromethane	<100	100		ug/L
Vinyl chloride	<100	100		ug/L
Bromomethane	<500	500		ug/L
Chloroethane	<100	100		ug/L
Fluorotrichloromethane	<100	100		ug/L
1,1-Dichloroethene	<100	100		ug/L
Methylene chloride	<100	100		ug/L
trans-1,2-Dichloroethene	<100	100		ug/L
1,1-Dichloroethane	100	100		ug/L
2,2-Dichloropropane	<200	200		ug/L
cis-1,2-Dichloroethene	1500	100		ug/L
Chloroform	<100	100		ug/L
Bromochloromethane	<100	100		ug/L
1,1,1-Trichloroethane	530	100		ug/L
1,1-Dichloropropene	<100	100		ug/L
Carbon tetrachloride	<100	100		ug/L
1,2-Dichloroethane	<100	100		ug/L
Benzene	<100	100		ug/L
Trichloroethene	3000	100		ug/L
1,2-Dichloropropane	<100	100		ug/L
Bromodichloromethane	<100	100		ug/L
Dibromomethane	<100	100		ug/L
cis-1,3-Dichloropropene	<100	100		ug/L
Toluene	<100	100		ug/L
trans-1,3-Dichloropropene	<100	100		ug/L
1,1,2-Trichloroethane	<100	100		ug/L
Tetrachloroethene	<200	200		ug/L
1,3-Dichloropropane	<200	200		ug/L
Chlorodibromomethane	<100	100		ug/L
1,2-Dibromoethane	<100	100		ug/L
Chlorobenzene	<100	100		ug/L
1,1,1,2-Tetrachloroethane	<200	200		ug/L
Ethylbenzene	<100	100		ug/L
Xylene, total	<300	300		ug/L
Styrene	<100	100		ug/L
Isopropylbenzene	<100	100		ug/L
Bromoform	<200	200		ug/L
1,1,2,2-Tetrachloroethane	<100	100		ug/L
1,2,3-Trichloropropane	<100	100		ug/L
n-Propylbenzene	<100	100		ug/L

RMT LABORATORIES 744 HEARTLAND TRAIL MADISON, WI 53717-1934 P.O. BOX 8923 MADISON, WI 53708-8923 608/831-4444 608/831-7530 FAX

PROJECT NAME: TECUMSEH
PROJECT NUMBER: 03084.02
LAB SAMPLE NUMBER: 5389-003
STATION ID: MW-9
WI DNR LAB ID: 113138520

REPORT DATE: 09/12/94
COLLECTION DATE: 08/25/94
ANALYSIS DATE: 09/08/94
METHOD: 8021

VOLATILE ORGANICS ANALYSIS REPORT

COMPOUND	RESULT	EQL	CODE	UNITS
Bromobenzene	<100	100		ug/L
1,3,5-Trimethylbenzene	<100	100		ug/L
2-Chlorotoluene	<100	100		ug/L
4-Chlorotoluene	<100	100		ug/L
tert-Butylbenzene	<200	200		ug/L
1,2,4-Trimethylbenzene	<100	100		ug/L
sec-Butylbenzene	<100	100		ug/L
p-Isopropyltoluene	<100	100		ug/L
1,3-Dichlorobenzene	<100	100		ug/L
1,4-Dichlorobenzene	<100	100		ug/L
n-Butylbenzene	<100	100		ug/L
1,2-Dichlorobenzene	<100	100		ug/L
1,2-Dibromo-3-chloropropane	<100	100		ug/L
1,2,4-Trichlorobenzene	<100	100		ug/L
Hexachlorobutadiene	<100	100		ug/L
Naphthalene	<500	500		ug/L
1,2,3-Trichlorobenzene	<100	100		ug/L

RMT LABORATORIES 744 HEARTLAND TRAIL MADISON, WI 53717-1934 P.O. BOX 8923 MADISON, WI 53708-8923 608/831-4444 608/831-7530 FAX

PROJECT NAME: TECUMSEH
PROJECT NUMBER: 03084.02
LAB SAMPLE NUMBER: 5389-004
STATION ID: MW-9D
WI DNR LAB ID: 113138520

REPORT DATE: 09/12/94
COLLECTION DATE: 08/25/94
ANALYSIS DATE: 09/08/94
METHOD: 8021

VOLATILE ORGANICS ANALYSIS REPORT

COMPOUND	RESULT	EQL	CODE	UNITS
Dichlorodifluoromethane	<200	200		ug/L
Chloromethane	<100	100		ug/L
Vinyl chloride	<100	100		ug/L
Bromomethane	<500	500		ug/L
Chloroethane	<100	100		ug/L
Fluorotrichloromethane	<100	100		ug/L
1,1-Dichloroethene	<100	100		ug/L
Methylene chloride	<100	100		ug/L
trans-1,2-Dichloroethene	<100	100		ug/L
1,1-Dichloroethane	290	100		ug/L
2,2-Dichloropropane	<200	200		ug/L
cis-1,2-Dichloroethene	330	100		ug/L
Chloroform	<100	100		ug/L
Bromochloromethane	<100	100		ug/L
1,1,1-Trichloroethane	700	100		ug/L
1,1-Dichloropropene	<100	100		ug/L
Carbon tetrachloride	<100	100		ug/L
1,2-Dichloroethane	<100	100		ug/L
Benzene	<100	100		ug/L
Trichloroethene	1200	100		ug/L
1,2-Dichloropropane	<100	100		ug/L
Bromodichloromethane	<100	100		ug/L
Dibromomethane	<100	100		ug/L
cis-1,3-Dichloropropene	<100	100		ug/L
Toluene	<100	100		ug/L
trans-1,3-Dichloropropene	<100	100		ug/L
1,1,2-Trichloroethane	<100	100		ug/L
Tetrachloroethene	<200	200		ug/L
1,3-Dichloropropane	<200	200		ug/L
Chlorodibromomethane	<100	100		ug/L
1,2-Dibromoethane	<100	100		ug/L
Chlorobenzene	<100	100		ug/L
1,1,1,2-Tetrachloroethane	<200	200		ug/L
Ethylbenzene	<100	100		ug/L
Xylene, total	<300	300		ug/L
Styrene	<100	100		ug/L
Isopropylbenzene	<100	100		ug/L
Bromoform	<200	200		ug/L
1,1,2,2-Tetrachloroethane	<100	100		ug/L
1,2,3-Trichloropropane	<100	100		ug/L
n-Propylbenzene	<100	100		ug/L

RMT LABORATORIES - 744 HEARTLAND TRAIL - MADISON, WI - 53717-1934 - P.O. BOX 8923 - MADISON, WI 53708-8923 - 608/831-4444 - 608/831-7530 FAX

PROJECT NAME: TECUMSEH
PROJECT NUMBER: 03084.02
LAB SAMPLE NUMBER: 5389-004
STATION ID: MW-9D
WI DNR LAB ID: 113138520

REPORT DATE: 09/12/94
COLLECTION DATE: 08/25/94
ANALYSIS DATE: 09/08/94
METHOD: 8021

VOLATILE ORGANICS ANALYSIS REPORT

COMPOUND	RESULT	EQL	CODE	UNITS
Bromobenzene	<100	100		ug/L
1,3,5-Trimethylbenzene	<100	100		ug/L
2-Chlorotoluene	<100	100		ug/L
4-Chlorotoluene	<100	100		ug/L
tert-Butylbenzene	<200	200		ug/L
1,2,4-Trimethylbenzene	<100	100		ug/L
sec-Butylbenzene	<100	100		ug/L
p-Isopropyltoluene	<100	100		ug/L
1,3-Dichlorobenzene	<100	100		ug/L
1,4-Dichlorobenzene	<100	100		ug/L
n-Butylbenzene	<100	100		ug/L
1,2-Dichlorobenzene	<100	100		ug/L
1,2-Dibromo-3-chloropropane	<100	100		ug/L
1,2,4-Trichlorobenzene	<100	100		ug/L
Hexachlorobutadiene	<100	100		ug/L
Naphthalene	<500	500		ug/L
1,2,3-Trichlorobenzene	<100	100		ug/L

RMT LABORATORIES - 744 HEARTLAND TRAIL - MADISON, WI - 53717-1934 - P.O. BOX 8923 - MADISON, WI 53708-8923 - 608/831-4444 - 608/831-7530 FAX

PROJECT NAME: TECUMSEH
PROJECT NUMBER: 03084.02
LAB SAMPLE NUMBER: 5389-005
STATION ID: MW-3
WI DNR LAB ID: 113138520

REPORT DATE: 09/12/94
COLLECTION DATE: 08/25/94
ANALYSIS DATE: 09/09/94
METHOD: 8021

VOLATILE ORGANICS ANALYSIS REPORT

COMPOUND	RESULT	EQL	CODE	UNITS
Dichlorodifluoromethane	<2.0	2.0		ug/L
Chloromethane	<1.0	1.0		ug/L
Vinyl chloride	<1.0	1.0		ug/L
Bromomethane	<5.0	5.0		ug/L
Chloroethane	<1.0	1.0		ug/L
Fluorotrichloromethane	<1.0	1.0		ug/L
1,1-Dichloroethene	<1.0	1.0		ug/L
Methylene chloride	<1.0	1.0		ug/L
trans-1,2-Dichloroethene	<1.0	1.0		ug/L
1,1-Dichloroethane	<1.0	1.0		ug/L
2,2-Dichloropropane	<2.0	2.0		ug/L
cis-1,2-Dichloroethene	<1.0	1.0		ug/L
Chloroform	<1.0	1.0		ug/L
Bromochloromethane	<1.0	1.0		ug/L
1,1,1-Trichloroethane	<1.0	1.0		ug/L
1,1-Dichloropropene	<1.0	1.0		ug/L
Carbon tetrachloride	<1.0	1.0		ug/L
1,2-Dichloroethane	<1.0	1.0		ug/L
Benzene	<1.0	1.0		ug/L
Trichloroethene	39	1.0		ug/L
1,2-Dichloropropane	<1.0	1.0		ug/L
Bromodichloromethane	<1.0	1.0		ug/L
Dibromomethane	<1.0	1.0		ug/L
cis-1,3-Dichloropropene	<1.0	1.0		ug/L
Toluene	<1.0	1.0		ug/L
trans-1,3-Dichloropropene	<1.0	1.0		ug/L
1,1,2-Trichloroethane	<1.0	1.0		ug/L
Tetrachloroethene	<2.0	2.0		ug/L
1,3-Dichloropropane	<2.0	2.0		ug/L
Chlorodibromomethane	<1.0	1.0		ug/L
1,2-Dibromoethane	<1.0	1.0		ug/L
Chlorobenzene	<1.0	1.0		ug/L
1,1,1,2-Tetrachloroethane	<2.0	2.0		ug/L
Ethylbenzene	<1.0	1.0		ug/L
Xylene, total	<3.0	3.0		ug/L
Styrene	<1.0	1.0		ug/L
Isopropylbenzene	<1.0	1.0		ug/L
Bromoform	<2.0	2.0		ug/L
1,1,2,2-Tetrachloroethane	<1.0	1.0		ug/L
1,2,3-Trichloropropane	<1.0	1.0		ug/L
n-Propylbenzene	<1.0	1.0		ug/L

RMT LABORATORIES - 744 HEARTLAND TRAIL - MADISON, WI - 53717-1934 - P.O. BOX 8923 - MADISON, WI 53708-8923 - 608/831-4444 - 608/831-7530 FAX

PROJECT NAME: TECUMSEH
PROJECT NUMBER: 03084.02
LAB SAMPLE NUMBER: 5389-005
STATION ID: MW-3
WI DNR LAB ID: 113138520

REPORT DATE: 09/12/94
COLLECTION DATE: 08/25/94
ANALYSIS DATE: 09/09/94
METHOD: 8021

VOLATILE ORGANICS ANALYSIS REPORT

COMPOUND	RESULT	EQL	CODE	UNITS
Bromobenzene	<1.0	1.0		ug/L
1,3,5-Trimethylbenzene	<1.0	1.0		ug/L
2-Chlorotoluene	<1.0	1.0		ug/L
4-Chlorotoluene	<1.0	1.0		ug/L
tert-Butylbenzene	<2.0	2.0		ug/L
1,2,4-Trimethylbenzene	<1.0	1.0		ug/L
sec-Butylbenzene	<1.0	1.0		ug/L
p-Isopropyltoluene	<1.0	1.0		ug/L
1,3-Dichlorobenzene	<1.0	1.0		ug/L
1,4-Dichlorobenzene	<1.0	1.0		ug/L
n-Butylbenzene	<1.0	1.0		ug/L
1,2-Dichlorobenzene	<1.0	1.0		ug/L
1,2-Dibromo-3-chloropropane	<1.0	1.0		ug/L
1,2,4-Trichlorobenzene	<1.0	1.0		ug/L
Hexachlorobutadiene	<1.0	1.0		ug/L
Naphthalene	<5.0	5.0		ug/L
1,2,3-Trichlorobenzene	<1.0	1.0		ug/L

Analysis performed 1 day past holding time.

RMT LABORATORIES - 744 HEARTLAND TRAIL - MADISON, WI - 53717-1934 - P.O. BOX 8923 - MADISON, WI 53708-8923 - 608/831-4444 - 608/831-7530 FAX

PROJECT NAME: TECUMSEH
PROJECT NUMBER: 03084.02
LAB SAMPLE NUMBER: 5389-006
STATION ID: MW-3D
WI DNR LAB ID: 113138520

REPORT DATE: 09/12/94
COLLECTION DATE: 08/25/94
ANALYSIS DATE: 09/09/94
METHOD: 8021

VOLATILE ORGANICS ANALYSIS REPORT

COMPOUND	RESULT	EQL	CODE	UNITS
Dichlorodifluoromethane	<10	10		ug/L
Chloromethane	<5.0	5.0		ug/L
Vinyl chloride	6.1	5.0		ug/L
Bromomethane	<25	25		ug/L
Chloroethane	<5.0	5.0		ug/L
Fluorotrichloromethane	<5.0	5.0		ug/L
1,1-Dichloroethene	24	5.0		ug/L
Methylene chloride	<5.0	5.0		ug/L
trans-1,2-Dichloroethene	<5.0	5.0		ug/L
1,1-Dichloroethane	7.2	5.0		ug/L
2,2-Dichloropropane	<10	10		ug/L
cis-1,2-Dichloroethene	6.8	5.0		ug/L
Chloroform	<5.0	5.0		ug/L
Bromochloromethane	<5.0	5.0		ug/L
1,1,1-Trichloroethane	21	5.0		ug/L
1,1-Dichloropropene	<5.0	5.0		ug/L
Carbon tetrachloride	<5.0	5.0		ug/L
1,2-Dichloroethane	<5.0	5.0		ug/L
Benzene	<5.0	5.0		ug/L
Trichloroethene	88	5.0		ug/L
1,2-Dichloropropane	<5.0	5.0		ug/L
Bromodichloromethane	<5.0	5.0		ug/L
Dibromomethane	<5.0	5.0		ug/L
cis-1,3-Dichloropropene	<5.0	5.0		ug/L
Toluene	<5.0	5.0		ug/L
trans-1,3-Dichloropropene	<5.0	5.0		ug/L
1,1,2-Trichloroethane	<5.0	5.0		ug/L
Tetrachloroethene	<10	10		ug/L
1,3-Dichloropropane	<10	10		ug/L
Chlorodibromomethane	<5.0	5.0		ug/L
1,2-Dibromoethane	<5.0	5.0		ug/L
Chlorobenzene	<5.0	5.0		ug/L
1,1,1,2-Tetrachloroethane	<10	10		ug/L
Ethylbenzene	54	5.0		ug/L
Xylene, total	18	15		ug/L
Styrene	<5.0	5.0		ug/L
Isopropylbenzene	<5.0	5.0		ug/L
Bromoform	<10	10		ug/L
1,1,2,2-Tetrachloroethane	<5.0	5.0		ug/L
1,2,3-Trichloropropane	<5.0	5.0		ug/L
n-Propylbenzene	<5.0	5.0		ug/L

RMT LABORATORIES - 744 HEARTLAND TRAIL - MADISON, WI - 53717-1934 - P.O. BOX 8923 - MADISON, WI 53708-8923 - 608/831-4444 - 608/831-7530 FAX

PROJECT NAME: TECUMSEH
PROJECT NUMBER: 03084.02
LAB SAMPLE NUMBER: 5389-006
STATION ID: MW-3D
WI DNR LAB ID: 113138520

REPORT DATE: 09/12/94
COLLECTION DATE: 08/25/94
ANALYSIS DATE: 09/09/94
METHOD: 8021

VOLATILE ORGANICS ANALYSIS REPORT

COMPOUND	RESULT	EQL	CODE	UNITS
Bromobenzene	<5.0	5.0		ug/L
1,3,5-Trimethylbenzene	<5.0	5.0		ug/L
2-Chlorotoluene	<5.0	5.0		ug/L
4-Chlorotoluene	<5.0	5.0		ug/L
tert-Butylbenzene	<10	10		ug/L
1,2,4-Trimethylbenzene	30	5.0		ug/L
sec-Butylbenzene	<5.0	5.0		ug/L
p-Isopropyltoluene	<5.0	5.0		ug/L
1,3-Dichlorobenzene	<5.0	5.0		ug/L
1,4-Dichlorobenzene	<5.0	5.0		ug/L
n-Butylbenzene	<5.0	5.0		ug/L
1,2-Dichlorobenzene	<5.0	5.0		ug/L
1,2-Dibromo-3-chloropropane	<5.0	5.0		ug/L
1,2,4-Trichlorobenzene	<5.0	5.0		ug/L
Hexachlorobutadiene	<5.0	5.0		ug/L
Naphthalene	<25	25		ug/L
1,2,3-Trichlorobenzene	<5.0	5.0		ug/L

Analysis performed 1 day past holding time.

RMT LABORATORIES - 744 HEARTLAND TRAIL - MADISON, WI - 53717-1934 - P.O. BOX 8923 - MADISON, WI - 53708-8923 - 608/831-4444 - 608/831-7530 FAX

PROJECT NAME: TECUMSEH
PROJECT NUMBER: 03084.02
LAB SAMPLE NUMBER: 5389-007
STATION ID: MW-8
WI DNR LAB ID: 113138520

REPORT DATE: 09/12/94
COLLECTION DATE: 08/25/94
ANALYSIS DATE: 09/09/94
METHOD: 8021

VOLATILE ORGANICS ANALYSIS REPORT

COMPOUND	RESULT	EQL	CODE	UNITS
Dichlorodifluoromethane	<100	100		ug/L
Chloromethane	<50	50		ug/L
Vinyl chloride	77	50		ug/L
Bromomethane	<250	250		ug/L
Chloroethane	<50	50		ug/L
Fluorotrichloromethane	<50	50		ug/L
1,1-Dichloroethene	<50	50		ug/L
Methylene chloride	<50	50		ug/L
trans-1,2-Dichloroethene	<50	50		ug/L
1,1-Dichloroethane	360	50		ug/L
2,2-Dichloropropane	<100	100		ug/L
cis-1,2-Dichloroethene	130	50		ug/L
Chloroform	<50	50		ug/L
Bromochloromethane	<50	50		ug/L
1,1,1-Trichloroethane	670	50		ug/L
1,1-Dichloropropene	<50	50		ug/L
Carbon tetrachloride	<50	50		ug/L
1,2-Dichloroethane	<50	50		ug/L
Benzene	<50	50		ug/L
Trichloroethene	<50	50		ug/L
1,2-Dichloropropane	<50	50		ug/L
Bromodichloromethane	<50	50		ug/L
Dibromomethane	<50	50		ug/L
cis-1,3-Dichloropropene	<50	50		ug/L
Toluene	160	50		ug/L
trans-1,3-Dichloropropene	<50	50		ug/L
1,1,2-Trichloroethane	<50	50		ug/L
Tetrachloroethene	<100	100		ug/L
1,3-Dichloropropane	<100	100		ug/L
Chlorodibromomethane	<50	50		ug/L
1,2-Dibromoethane	<50	50		ug/L
Chlorobenzene	<50	50		ug/L
1,1,1,2-Tetrachloroethane	<100	100		ug/L
Ethylbenzene	<50	50		ug/L
Xylene, total	160	150		ug/L
Styrene	<50	50		ug/L
Isopropylbenzene	<50	50		ug/L
Bromoform	<100	100		ug/L
1,1,2,2-Tetrachloroethane	<50	50		ug/L
1,2,3-Trichloropropane	<50	50		ug/L
n-Propylbenzene	<50	50		ug/L

RMT LABORATORIES ~ 744 HEARTLAND TRAIL ~ MADISON, WI ~ 53717-1934 ~ P.O. BOX 8923 ~ MADISON, WI ~ 53708-8923 ~ 608/831-4444 ~ 608/831-7530 FAX

PROJECT NAME: TECUMSEH
PROJECT NUMBER: 03084.02
LAB SAMPLE NUMBER: 5389-007
STATION ID: MW-8
WI DNR LAB ID: 113138520

REPORT DATE: 09/12/94
COLLECTION DATE: 08/25/94
ANALYSIS DATE: 09/09/94
METHOD: 8021

VOLATILE ORGANICS ANALYSIS REPORT

COMPOUND	RESULT	EQL	CODE	UNITS
Bromobenzene	<50	50		ug/L
1,3,5-Trimethylbenzene	<50	50		ug/L
2-Chlorotoluene	<50	50		ug/L
4-Chlorotoluene	<50	50		ug/L
tert-Butylbenzene	<100	100		ug/L
1,2,4-Trimethylbenzene	110	50		ug/L
sec-Butylbenzene	<50	50		ug/L
p-Isopropyltoluene	<50	50		ug/L
1,3-Dichlorobenzene	<50	50		ug/L
1,4-Dichlorobenzene	<50	50		ug/L
n-Butylbenzene	<50	50		ug/L
1,2-Dichlorobenzene	<50	50		ug/L
1,2-Dibromo-3-chloropropane	<50	50		ug/L
1,2,4-Trichlorobenzene	<50	50		ug/L
Hexachlorobutadiene	<50	50		ug/L
Naphthalene	280	250		ug/L
1,2,3-Trichlorobenzene	<50	50		ug/L

Analysis performed 1 day past holding time.

RMT LABORATORIES - 744 HEARTLAND TRAIL - MADISON, WI - 53717-1934 - P.O. BOX 8923 - MADISON, WI - 53708-8923 - 608/831-4444 - 608/831-7530 FAX

PROJECT NAME: TECUMSEH
PROJECT NUMBER: 03084.02
LAB SAMPLE NUMBER: 5389-008
STATION ID: MW-8D
WI DNR LAB ID: 113138520

REPORT DATE: 09/12/94
COLLECTION DATE: 08/25/94
ANALYSIS DATE: 09/09/94
METHOD: 8021

VOLATILE ORGANICS ANALYSIS REPORT

COMPOUND	RESULT	EQL	CODE	UNITS
Dichlorodifluoromethane	<2.0	2.0		ug/L
Chloromethane	<1.0	1.0		ug/L
Vinyl chloride	<1.0	1.0		ug/L
Bromomethane	<5.0	5.0		ug/L
Chloroethane	<1.0	1.0		ug/L
Fluorotrichloromethane	<1.0	1.0		ug/L
1,1-Dichloroethene	<1.0	1.0		ug/L
Methylene chloride	<1.0	1.0		ug/L
trans-1,2-Dichloroethene	<1.0	1.0		ug/L
1,1-Dichloroethane	3.8	1.0		ug/L
2,2-Dichloropropane	<2.0	2.0		ug/L
cis-1,2-Dichloroethene	1.3	1.0		ug/L
Chloroform	<1.0	1.0		ug/L
Bromochloromethane	<1.0	1.0		ug/L
1,1,1-Trichloroethane	7.4	1.0		ug/L
1,1-Dichloropropene	<1.0	1.0		ug/L
Carbon tetrachloride	<1.0	1.0		ug/L
1,2-Dichloroethane	<1.0	1.0		ug/L
Benzene	<1.0	1.0		ug/L
Trichloroethene	7.0	1.0		ug/L
1,2-Dichloropropane	<1.0	1.0		ug/L
Bromodichloromethane	<1.0	1.0		ug/L
Dibromomethane	<1.0	1.0		ug/L
cis-1,3-Dichloropropene	<1.0	1.0		ug/L
Toluene	2.0	1.0		ug/L
trans-1,3-Dichloropropene	<1.0	1.0		ug/L
1,1,2-Trichloroethane	<1.0	1.0		ug/L
Tetrachloroethene	<2.0	2.0		ug/L
1,3-Dichloropropane	<2.0	2.0		ug/L
Chlorodibromomethane	<1.0	1.0		ug/L
1,2-Dibromoethane	<1.0	1.0		ug/L
Chlorobenzene	<1.0	1.0		ug/L
1,1,1,2-Tetrachloroethane	<2.0	2.0		ug/L
Ethylbenzene	<1.0	1.0		ug/L
Xylene, total	3.6	3.0		ug/L
Styrene	<1.0	1.0		ug/L
Isopropylbenzene	<1.0	1.0		ug/L
Bromoform	<2.0	2.0		ug/L
1,1,2,2-Tetrachloroethane	<1.0	1.0		ug/L
1,2,3-Trichloropropane	<1.0	1.0		ug/L
n-Propylbenzene	<1.0	1.0		ug/L

RMT LABORATORIES - 744 HEARTLAND TRAIL - MADISON, WI - 53717-1934 - P.O. BOX 8923 - MADISON, WI - 53708-8923 - 608/831-4444 - 608/831-7530 FAX

PROJECT NAME: TECUMSEH
PROJECT NUMBER: 03084.02
LAB SAMPLE NUMBER: 5389-008
STATION ID: MW-8D
WI DNR LAB ID: 113138520

REPORT DATE: 09/12/94
COLLECTION DATE: 08/25/94
ANALYSIS DATE: 09/09/94
METHOD: 8021

VOLATILE ORGANICS ANALYSIS REPORT

COMPOUND	RESULT	EQL	CODE	UNITS
Bromobenzene	<1.0	1.0		ug/L
1,3,5-Trimethylbenzene	1.6	1.0		ug/L
2-Chlorotoluene	<1.0	1.0		ug/L
4-Chlorotoluene	<1.0	1.0		ug/L
tert-Butylbenzene	<2.0	2.0		ug/L
1,2,4-Trimethylbenzene	4.6	1.0		ug/L
sec-Butylbenzene	1.3	1.0		ug/L
p-Isopropyltoluene	1.4	1.0		ug/L
1,3-Dichlorobenzene	<1.0	1.0		ug/L
1,4-Dichlorobenzene	<1.0	1.0		ug/L
n-Butylbenzene	4.5	1.0		ug/L
1,2-Dichlorobenzene	<1.0	1.0		ug/L
1,2-Dibromo-3-chloropropane	<1.0	1.0		ug/L
1,2,4-Trichlorobenzene	<1.0	1.0		ug/L
Hexachlorobutadiene	<1.0	1.0		ug/L
Naphthalene	5.0	5.0		ug/L
1,2,3-Trichlorobenzene	<1.0	1.0		ug/L

Analysis performed 1 day past holding time.

RMT LABORATORIES - 744 HEARTLAND TRAIL - MADISON, WI - 53717-1934 - P.O. BOX 8923 - MADISON, WI - 53708-8923 - 608/831-4444 - 608/831-7530 FAX

PROJECT NAME: TECUMSEH
PROJECT NUMBER: 03084.02
LAB SAMPLE NUMBER: 5389-009
STATION ID: FB-1
WI DNR LAB ID: 113138520

REPORT DATE: 09/12/94
COLLECTION DATE: 08/25/94
ANALYSIS DATE: 09/07/94
METHOD: 8021

VOLATILE ORGANICS ANALYSIS REPORT

COMPOUND	RESULT	EQL	CODE	UNITS
Dichlorodifluoromethane	<2.0	2.0		ug/L
Chloromethane	<1.0	1.0		ug/L
Vinyl chloride	<1.0	1.0		ug/L
Bromomethane	<5.0	5.0		ug/L
Chloroethane	<1.0	1.0		ug/L
Fluorotrichloromethane	<1.0	1.0		ug/L
1,1-Dichloroethene	<1.0	1.0		ug/L
Methylene chloride	<1.0	1.0		ug/L
trans-1,2-Dichloroethene	<1.0	1.0		ug/L
1,1-Dichloroethane	<1.0	1.0		ug/L
2,2-Dichloropropane	<2.0	2.0		ug/L
cis-1,2-Dichloroethene	<1.0	1.0		ug/L
Chloroform	<1.0	1.0		ug/L
Bromochloromethane	<1.0	1.0		ug/L
1,1,1-Trichloroethane	<1.0	1.0		ug/L
1,1-Dichloropropene	<1.0	1.0		ug/L
Carbon tetrachloride	<1.0	1.0		ug/L
1,2-Dichloroethane	<1.0	1.0		ug/L
Benzene	<1.0	1.0		ug/L
Trichloroethene	<1.0	1.0		ug/L
1,2-Dichloropropane	<1.0	1.0		ug/L
Bromodichloromethane	<1.0	1.0		ug/L
Dibromomethane	<1.0	1.0		ug/L
cis-1,3-Dichloropropene	<1.0	1.0		ug/L
Toluene	<1.0	1.0		ug/L
trans-1,3-Dichloropropene	<1.0	1.0		ug/L
1,1,2-Trichloroethane	<1.0	1.0		ug/L
Tetrachloroethene	<2.0	2.0		ug/L
1,3-Dichloropropane	<2.0	2.0		ug/L
Chlorodibromomethane	<1.0	1.0		ug/L
1,2-Dibromoethane	<1.0	1.0		ug/L
Chlorobenzene	<1.0	1.0		ug/L
1,1,1,2-Tetrachloroethane	<2.0	2.0		ug/L
Ethylbenzene	<1.0	1.0		ug/L
Xylene, total	<3.0	3.0		ug/L
Styrene	<1.0	1.0		ug/L
Isopropylbenzene	<1.0	1.0		ug/L
Bromoform	<2.0	2.0		ug/L
1,1,2,2-Tetrachloroethane	<1.0	1.0		ug/L
1,2,3-Trichloropropane	<1.0	1.0		ug/L
n-Propylbenzene	<1.0	1.0		ug/L

RMT LABORATORIES - 744 HEARTLAND TRAIL - MADISON, WI - 53717-1934 - P.O. BOX 8923 - MADISON, WI - 53708-8923 - 608/831-4444 - 608/831-7530 FAX

PROJECT NAME: TECUMSEH
PROJECT NUMBER: 03084.02
LAB SAMPLE NUMBER: 5389-009
STATION ID: FB-1
WI DNR LAB ID: 113138520

REPORT DATE: 09/12/94
COLLECTION DATE: 08/25/94
ANALYSIS DATE: 09/07/94
METHOD: 8021

VOLATILE ORGANICS ANALYSIS REPORT

COMPOUND	RESULT	EQL	CODE	UNITS
Bromobenzene	<1.0	1.0		ug/L
1,3,5-Trimethylbenzene	<1.0	1.0		ug/L
2-Chlorotoluene	<1.0	1.0		ug/L
4-Chlorotoluene	<1.0	1.0		ug/L
tert-Butylbenzene	<2.0	2.0		ug/L
1,2,4-Trimethylbenzene	<1.0	1.0		ug/L
sec-Butylbenzene	<1.0	1.0		ug/L
p-Isopropyltoluene	<1.0	1.0		ug/L
1,3-Dichlorobenzene	<1.0	1.0		ug/L
1,4-Dichlorobenzene	<1.0	1.0		ug/L
n-Butylbenzene	<1.0	1.0		ug/L
1,2-Dichlorobenzene	<1.0	1.0		ug/L
1,2-Dibromo-3-chloropropane	<1.0	1.0		ug/L
1,2,4-Trichlorobenzene	<1.0	1.0		ug/L
Hexachlorobutadiene	<1.0	1.0		ug/L
Naphthalene	<5.0	5.0		ug/L
1,2,3-Trichlorobenzene	<1.0	1.0		ug/L

RMT LABORATORIES - 744 HEARTLAND TRAIL - MADISON, WI - 53717-1934 - P.O. BOX 8923 - MADISON, WI - 53708-8923 - 608/831-4444 - 608/831-7530 FAX

PROJECT NAME: TECUMSEH
PROJECT NO: 03084.02
WORK ORDER NO: 5389
WI DNR LAB ID: 113138520

REPORT DATE: 09/13/94

SAMPLE NO.	STATION ID	SAMPLING DATE	SAMPLE NO.	STATION ID	SAMPLING DATE
5389-005	MW-3	08/25/94			

I certify that the data contained in this Final Report has been generated and reviewed in accordance with approved methods and RMT Laboratory Standard Operating Procedure. Exceptions, if any, are discussed in the accompanying sample narrative. Release of this Final Report is authorized by RMT Laboratory management, as is verified by the following signature.

Jeff Gearhart — Approval Signature

9-13-94 — Date

RMT LABORATORIES - 744 HEARTLAND TRAIL - MADISON, WI - 53717-1934 - P.O. BOX 8923 - MADISON, WI 53708-8923 - 608/831-4444 - 608/831-7530 FAX

PROJECT NAME: TECUMSEH
PROJECT NUMBER: 03084.02
LAB SAMPLE NUMBER: 5389-005
STATION ID: MW-3
WI DNR LAB ID: 113138520

REPORT DATE: 09/13/94
COLLECTION DATE: 08/25/94
MATRIX TYPE: GW

INORGANIC ANALYSIS REPORT

COMPOUND	RESULT	EQL	CODE	UNITS
Chloride	100	2.0		mg/L
Nitrogen, total Kjeldahl	0.29	0.10		mg/L
Phosphorus, total	< 0.10	0.10		mg/L
Sulfate	36	10		mg/L

APPENDIX F

SOLINST WATERLOO MULTILEVEL MONITORING SYSTEM

Solinst

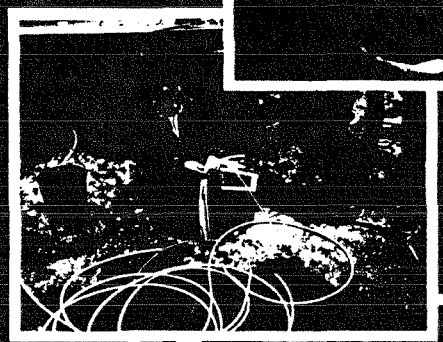
Waterloo System

Model 401 Data Sheet

Model: 401
Waterloo Multilevel Groundwater Monitoring System*

For obtaining groundwater samples, hydraulic head and permeability measurements from many isolated zones in a single borehole.

Uses a simple modular system which is customized for each application. The System installs easily in standard borehole sizes.



Features

- **Positive engineered seals**
  - Waterloo packers for rock holes
  - Dry -injected seals for overburden
- **Flexible monitoring options**
- **Dedicated samplers and transducers**
- **Cost savings**

* Manufactured under exclusive licence from the University of Waterloo Canadian Patent #1232836. US #504805, and international patents.

Solinst

Why Multilevels

Groundwater flow is complex, especially in fractured bedrock. Without multilevel monitoring the actual or potential pathways for contaminant migration are difficult to identify.

● Accurate Assessment

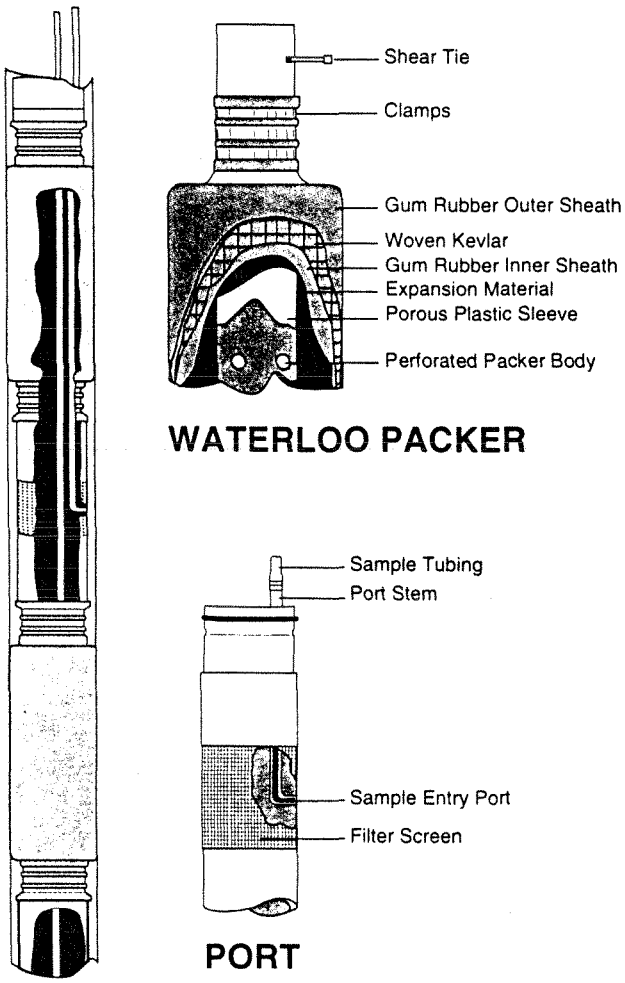
Multilevel monitoring in a number of boreholes at a site gives detailed three-dimensional data.

● Detailed Data

Multilevel monitoring maximizes the information available and reduces disturbance to the sub-surface. The Waterloo System provides for dedicated sampling to avoid cross-contamination.

● Economical

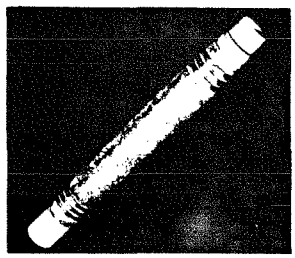
Multilevel systems also provide cost advantages over multiple piezometers. The Waterloo System maximizes these advantages. Drilling and installation costs are reduced. Little time is required to obtain each data set. Handling and disposal costs of purge water are minimized.

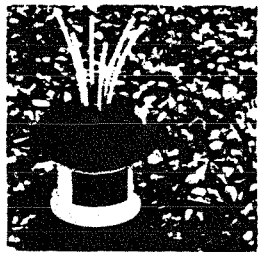


The System

The System uses modular components with specially designed joints held firmly together with nylon shear ties*. This forms a sealed casing string so that water can neither get out, nor get in. The casing string is made up of packers, ports, various casing lengths, a base plug and surface manifold. This allows accurate placement of ports at the zones to be monitored.

A monitoring tube is attached to the stem of each port. It individually connects that packed zone to the surface. The monitoring tubes are like miniature wells (piezometers). They are contained and protected within the sealed casing string.





The Waterloo Packer

The Waterloo packer is a permanent packer for use in bedrock or screened holes. It uses a water activated expansion sleeve fitted over the perforated packer body. A layer of porous plastic distributes water evenly to the packer expansion material. A Rubber/Kevlar/Rubber sheath envelops the expansion material. The Kevlar layer provides strength to bridge across large fissures. The pliant gum rubber forms an effective seal against the borehole wall.

Water is added to the inside of the sealed casing string after installation. The water passes through the packer body into the expansion sleeve, causing the material to expand. Thus an engineered seal is permanently formed against the borehole wall.

Port Modules

Port modules are manufactured in PVC or entirely of stainless steel. Formation water enters the port, passes into the stem, up into the monitoring tube attached to the stem to its static level. If a dedicated sampling pump or pressure transducer is chosen, it is attached to the port in place of the monitoring tube.

* U.S. Patents # 5255945

Monitoring Options

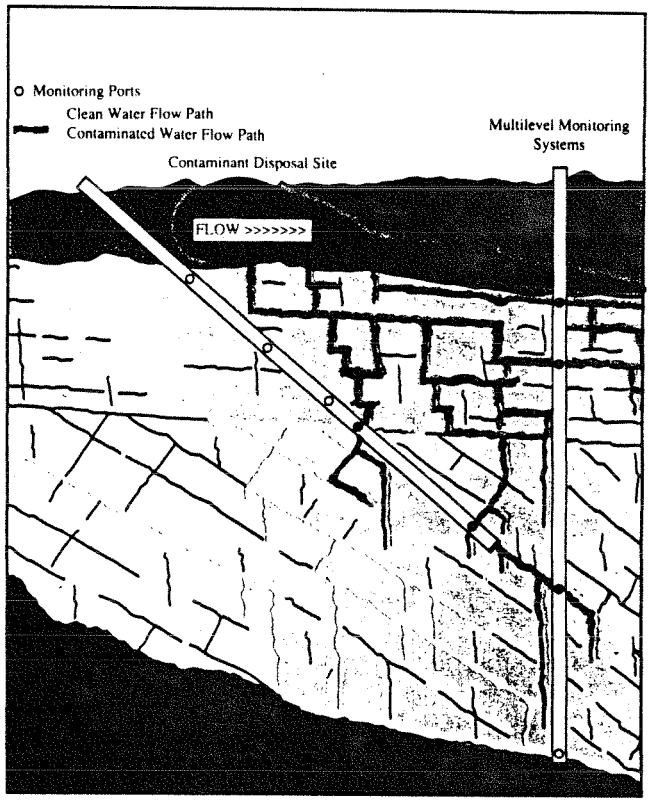
Each monitoring port may be fitted with a dedicated sampling pump or pressure transducer. This maximizes the speed with which each data set can be obtained, and avoids the need to lower portable devices. The sampling pumps are suitable for sampling many types of contaminants, including VOCs.

Purge volumes are very small and with dedicated pumps all zones can be purged simultaneously. Ports with two stems allows a dedicated pump and a transducer to be placed at exactly the same level.

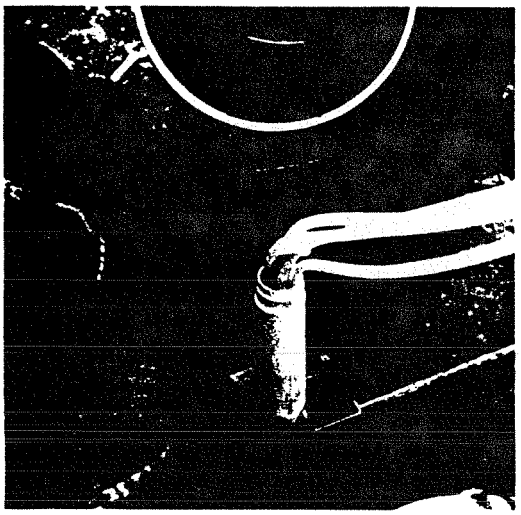
The most basic version includes open tubes attached to each port. This option allows monitoring with portable sampling and level measurement devices. This provides a very economical and flexible multilevel monitoring device.

A third option is to choose a mix of open tubes and dedicated equipment in different zones. This combines some of the advantages of each type and maintains future flexibility.

If water sampling is not needed, the System can comprise numerous pressure transducers for multilevel pressure monitoring.



Schematic showing the benefits of using the Waterloo System in complex fractured bedrock which has vertical and inclined boreholes.



Overburden Applications

In overburden the Waterloo packers are omitted. The highest quality bentonite seals and sand filters are achieved by using the Sand/Bentonite Injector.*

Precise and reliable placement of seals and filters is achieved using compressed air, sand, dry granular bentonite and a narrow diameter tube that delivers material to the point of placement, below water.

The Injector is also suitable for use in poor quality bedrock applications.

Bedrock Applications

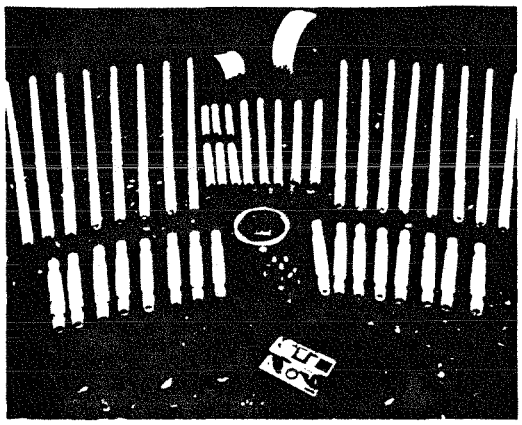
The unique Waterloo packer was designed for use in bedrock, or cased and screened holes. It provides a permanently engineered seal in either vertical or angled boreholes. It is important that the hole be of good quality, preferably diamond drilled.

The packer does not deflate over time. This removes concerns about seal integrity, and avoids the need for periodic reinflation and the presence of permanent inflation lines.

* Patents issued and pending. Injector concept licensed exclusively to Solinst by the Geological Survey of Canada, Energy, Mines and Resources.

Solinst

Solinst

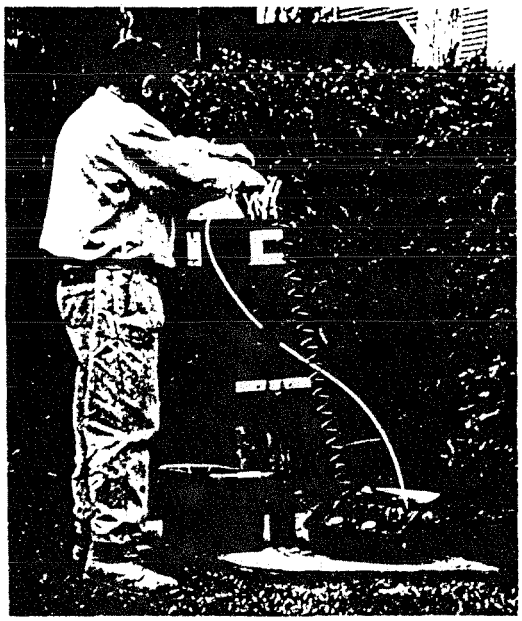


Installs Quickly

Installation of the Waterloo System is quick and easy. A complete System can be installed by one technician and an assistant, in a few hours, without the use of a drilling rig.

Starting with the base plug and lowermost sections, the components are joined together in the order required. As each new port is put into position a new monitoring tube is connected to it. Successive components are threaded over these tubes, building the casing string, until the System is complete.

All joints in the System, including the base plug are fitted with an O-ring and held together with a nylon shear tie. This joint provides a water-tight seal and prevents contact between packer inflation water inside the casing and the formation water outside the casing.



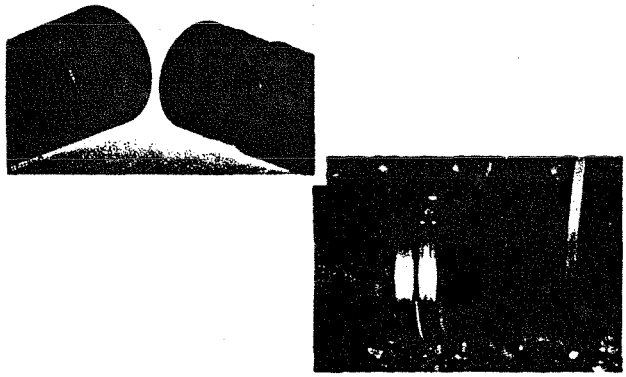
System Flexibility

The Waterloo System is extremely flexible. Each System is customized to fit:

- monitoring needs.
- site conditions.
- budget constraints.

Packers and ports can be accurately placed to monitor the zones of interest.

The maximum number of monitoring zones for a System is determined by the number of tubes and/or cables that will fit inside the casing string. This number is dependent on the monitoring options chosen. Systems can be designed to monitor from 2 to as many as 30 distinct zones.



Dedicated Instruments

As equipment is not lowered down the borehole, dedicated equipment vastly reduces the time and effort required to obtain data. This gives significant cost savings, and avoids cross contamination. A pressure transducer or gas-drive sampler is connected directly to the stem of each port . Ports can be fitted with two stems, one for a transducer and one for a pump.

Pressure measurements and permeability tests are most accurate and convenient when transducers are used. Measurements can be recorded automatically, and remotely. Different levels can also be measured simultaneously.

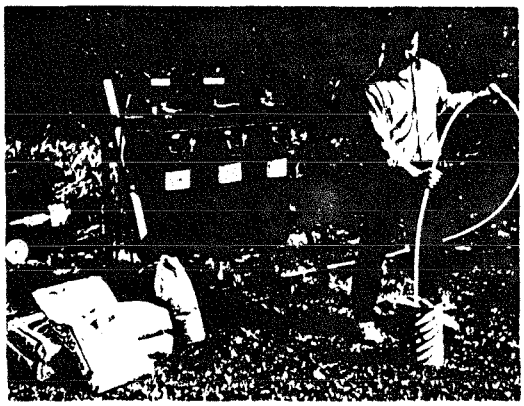
The System and control units are simple to use. Automatic control units and readouts have quick-connect couplings. Only a single connection to the manifold is required for each unit. Results and samples are easily and rapidly obtained.

The multi-purge manifold allows purging from many levels simultaneously.

Designing Your System

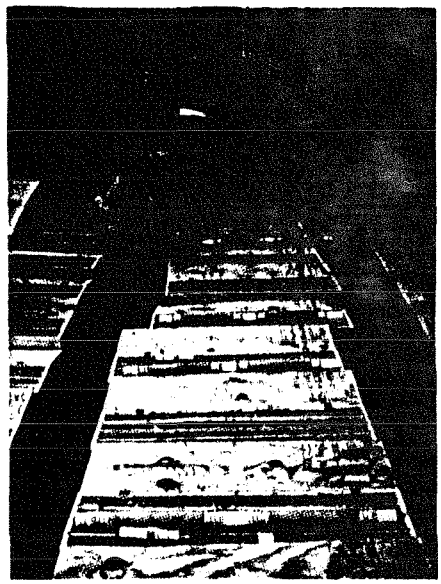
The options eventually chosen for each System will be site and application specific. The design is dependent on:

- zones of interest
- monitoring methods preferred
- cost considerations
- borehole depth and diameter



Seal Length

Generally it is desireable to seal off as much of the borehole as possible. A greater seal length can be achieved by using multiple packers.



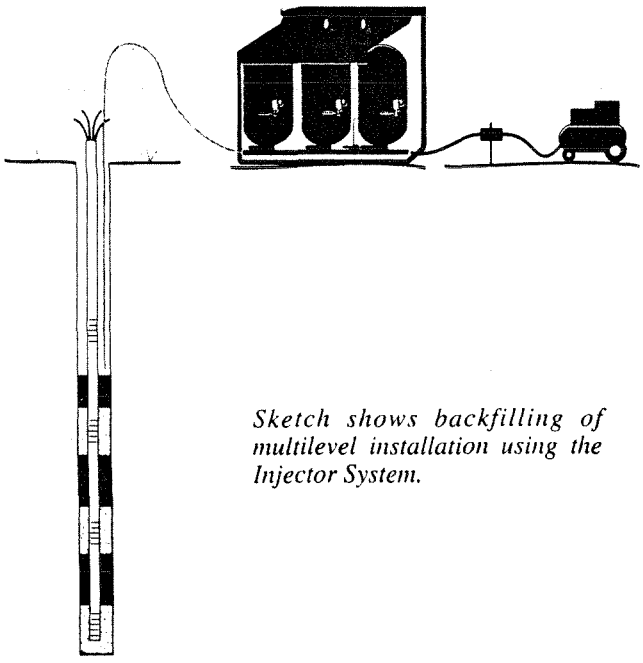
Borehole Size

Waterloo Packers are designed for use in 3" (75 mm) or 4" (100 mm) boreholes. Systems can also be installed in larger boreholes using the Sand/Bentonite Injector.

Materials

For particular applications specific materials may be chosen. These may include stainless steel casing and packer bodies, and stainless steel, nylon or Teflon* tubing.

* Teflon is a registered trademark of Dupont.



Sketch shows backfilling of multilevel installation using the Injector System.

Solinst

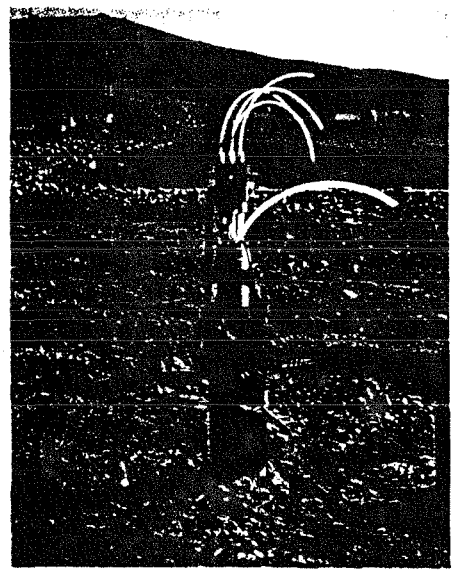
750ft. (230m) installation for a deep tunnel assessment study. Three zones monitored with dedicated Double-Valve Pumps and pressure transducers. Installed by two technicians in two days. Picture shows technician obtaining pressure measurements and groundwater samples with portable readout and control unit.

Applications

The Waterloo System has been specified by various industries and consulting professionals for numerous sites across the United States, Canada and overseas. Several sites have Superfund or RCRA designations. The System has been used for:

- o defining groundwater flow patterns
- o determination of aquitard leakiness
- o pumping test monitoring
- o performance monitoring of pump and treat systems
- o identification and determination of spatial distribution of contaminants
- o early warning system/detection of migrating contaminants

A large Midwestern USA research project studying agricultural effects on water quality. 22 multilevel installations with 3-4 zones each were installed to depths of 24-60 ft. (7.3-18.3 m) in overburden. Samples were obtained using dedicated Double Valve Pumps and Peristaltic Pumps.



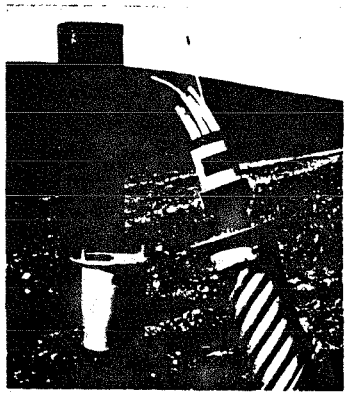
Landfill site over fractured granite, monitored with five Waterloo Systems. Each System comprised of dedicated Double Valve Pumps and Pressure Transducers in 4-6 intervals to depths of 275 feet (84m). The multipurge manifold allowed the monitoring of 21 zones to be completed in less than 2 days.

Projects

Waterloo Systems have been used on:

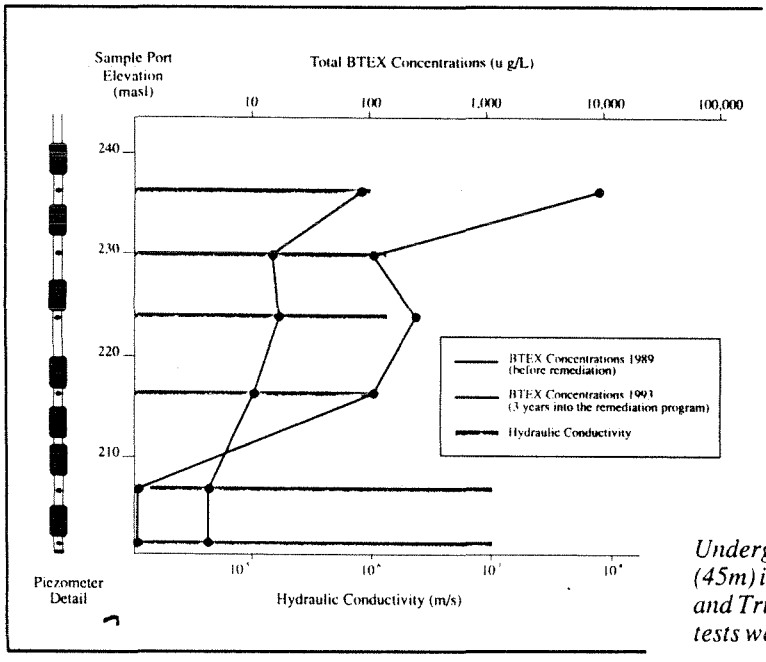
- o Salt water intrusion
- o Tunnels
- o Tailings storage
- o Pipeline leaks
- o Soil gas surveys
- o Industrial cleanups
- o Contaminant identification/cleanup
- o DNAPL & LNAPL spill sites
- o Waste disposals/landfills
- o Dam leakage/rehabilitation
- o Underground storage tanks
- o Deep well injection impacts
- o Organics plume delineation

Detailed investigation of PCE delineation in carbonate bedrock was completed in two phases. 5 systems were installed where the PCE was suspected to have been released for phase I. Phase II required 9 Systems installed around the fringe of the plume to track future contaminant migration. A cost comparison of the 14 multilevel Systems compared with nested piezometers saw savings both on original outlay and on the on-going monitoring costs.



An investigation of hydraulic properties beneath a large waste site. Multilevel systems were chosen to allow water quality sampling and to help determine the zones of highest permeability within the aquifer.

Data set shows decrease in Total BTEX contamination due to ongoing pump and treat operation at oil pipeline leak.



Underground oil pipeline leak assessment. Three 150 ft. (45m) installations, monitored with portable Water Level Meter and Triple Tube Sampler. Two point rising head permeability tests were conducted in each interval of the Multilevel System.

Ordering Information

Waterloo System

Each System will be site and application specific.

The professional staff at Solinst will be pleased to help develop a more detailed evaluation, customized to each project.

Also available are qualified field staff with extensive installation experience in the United States, Canada and overseas.

Printed in Canada
06/94

For further information Contact:
Solinst Canada Ltd. *35 Todd Road, ON, Canada L7G 4R8*
Fax: (905) 873-1992 Tel: (905)873-2255 or (800) 661-2023

Solinst

Multilevel Monitoring News

Spring 1994

Hydrologic Consultants Save $80 K with the Waterloo System!

A cost comparison of Waterloo System installations versus numerous single well installations helped Hydrologic Consultants Inc. of Colorado save $ 80,000 in capital costs for their client on a recent groundwater monitoring project.

The Project

The project involved a detailed investigation of PCE delineation in carbonate bedrock and was to be completed in two phases.

Fourteen Waterloo Systems each with 4 monitoring zones were installed around the plume to track PCE delineation.

The first phase was to install 5 Systems in the area where PCE was suspected to have been released into the ground. This provided information as to the vertical delineation.

Phase 2 saw 9 Systems installed around the fringe of the plume to track future contaminant migration.

A total of 14 Systems were installed to depths of 180 ft with 4 monitoring zones per System.

Hydrologic Consultants Inc.
Installation Cost Comparison – Project Phase 1

	Nested Piezos	Waterloo System	Savings
Drilling	$ 92,000	$ 29,000	$ 63,000
Material	24,000	25,000	(1,000)
Misc	29,000	11,000	18,000
Total	**145,000**	**65,000**	**$ 80,000**

A 55% Saving!

Compare and Save

The cost comparison convinced Hydrologic Consultants that the Waterloo Systems were the right decision for the site characterization.

Ongoing Monitoring Savings

Monitoring will be an ongoing saving for the client. Field technicians only need to visit 14 Waterloo System sites to obtain the data they require, instead of 56 individual piezometers that they would have needed to visit with nested piezometers. Dedicated sampling and monitoring equipment will also save time in set up and decontamination procedures.

The installation savings of $ 80,000 has convinced Hydrologic Consultants of the efficiency of the Waterloo System.

A Monitoring Cost Comparison[1]

	5x6-zone Waterloo Systems[2]	5x6-bundle Bundle Piezometers[2]	30 Nested Piezometers[3]
Purge time (volume)	6 hr (345 *l*)	13 hr (810 *l*)	7 hr (3,235 *l*)
Sample time (volume)	5 hr (30 *l*)	5 hr (30 *l*)	5 hr (30 *l*)
Transducer Reading Time	0.1 hr	0.25 hr	0.25 hr
Monitoring mobilization & demobilization time	1.5 hr	3.5 hr	10 hr
Time/monitoring round	12.6 hr	21.75 hr	22.25 hr
Wages/round *($ 25/hr)*	$ 315	$ 544	$ 557
Labor Cost for the 2 yr Monitoring Program	**$ 7,560**	**$ 13,050**	**$ 13,350**

Waterloo Systems save over 55% in labor costs!

[1] *Monitoring Requirements: purge 3 volumes, sample 1 litre and obtain pressure readings. Monitor from 30 zones, 1 sample round/month for a 2 year program.*
[2] *dedicated 5/8" DVP (purge rate = 0.95 l/min) and dedicated pressure transducers*
[3] *dedicated 1-1/2" DVP (purge rate = 7.57 l/min) and dedicated pressure transducers*

Multilevel Monitoring

In fractured rock the complex network of fractures can make locating the true groundwater flow paths extremely difficult.

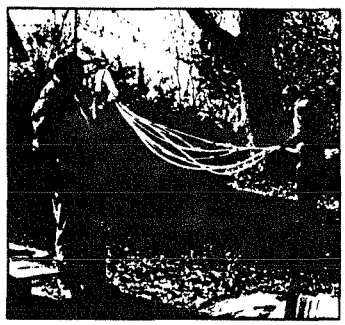
When individual piezometers are installed to various depths, it is easy to miss the contamination.

More accurate results can be obtained by installing a single system to give information from multiple levels in one borehole. A few multilevel systems at a site provides very detailed three dimensional data.

Multilevel systems also save on drilling costs, and create less disturbance to the subsurface.

How the Waterloo System Works

The Waterloo System is cost efficient and effective. Each System is designed with monitoring ports exactly where appropriate.



Packer with open tubes and DVP lines connect each zone to surface.

Dedicated or portable equipment can be chosen. Lower capital costs must be weighed against savings on operating expenses over the long term. A mix of dedicated and portable equipment can also be chosen.

A dependable and permanent seal is created between each zone with engineered packers to avoid any chance of cross-contamination.

Dedicated sample lines separately link each zone to the surface.

Each System is customized to provide the hydraulic parameters that the client requires from the site.

Any combination of groundwater samples, hydraulic conductivity measurements and water level measurements can be chosen from each zone.

Waterloo System -- Re-Engineered from Top to Bottom

Well Head Manifold

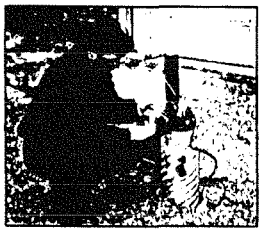
The new design makes sampling and pressure readings from dedicated equipment much easier and faster.

Dedicated Sampling

Only a single, quick connection of the Control Unit to the manifold is needed. All zones can be purged or sampled simultaneously. This saves a great deal of time for the field technician.

Transducer Readings

Only a single connection is needed between the read-out unit and all transducers. Up to 65,000 data points can be stored or the transducer cables can connect directly to a data-logger for automatic or remote readings.



Sampling and pressure readings are faster and easier.

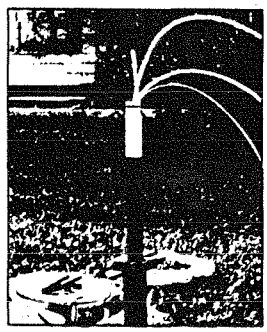
Sampling Ports

Sample ports are now available in either stainless steel or PVC.

Stainless steel ports are chosen when the highest quality VOC and chemical samples are critical and when later removal of the System is not anticipated. PVC can be selected when organic reactions to steel may be a factor. PVC ports also make it possible to drill out the System should it be desired to decommission the borehole.

Formation water enters the port and is sampled from the monitoring tube that connects each port to the surface.

Dual stem ports have the advantage of allowing water samples and pressure measurements to be taken at the same time and from the same elevation.



PVC ports are less expensive, and may be drilled out later.

Joints

A patented new method of joining components of the Waterloo System together uses a nylon shear wire and an o-ring. This gives a reliable, leakproof joint that has been tested to 2,000 pounds (tensile load) and avoids concerns of cross-threading or twisting lines.

A nylon shear wire and o-ring provide a reliable and leakproof seal between components.

Monitoring Options

A technical representative from Solinst will help you design your Waterloo System.

The System is able to provide the user with any combination of groundwater samples, water level measurements, and hydraulic conductivity information from each zone. Each System is customized to provide the information required from each site.

Equipment Alternatives

Dedicated equipment includes Double Valve Pumps to obtain groundwater samples, and pressure transducers to provide readings which determine hydraulic conductivity and water level measurement.

Open tubes allow water levels to be measured with a narrow-diameter Water Level Meter and samples to be taken from the same tube with a portable sampler.

Dedicated equipment with the Waterloo System makes multilevel monitoring quick and easy.

Portable vs Dedicated

Advantages of Dedicated Equipment

- No risk of cross-contamination
- No repeated decontamination needed
- Faster: because it is not necessary to lower equipment to the appropriate depths, take the sample, then raise the equipment to the surface and decontaminate. Dedicated equipment connections are all conveniently together at the Well Head Manifold allowing quick, one-step monitoring for multiple zones.
- No risk of getting instruments stuck as they are lowered downhole
- Best alternative for deep applications
- Allows datalogging and remote monitoring

Portable Equipment

Portable equipment is generally considered for shallow and/or short-term monitoring applications.

While it requires less initial capital investment than dedicated equipment, portable equipment is more costly over time because of repeated decontamination and time spent lowering and retrieving equipment in open tubes.

Removable Waterloo System

-- Case Study --

Telemark College, Norway

A Removable Waterloo System proved ideal for Telemark College's monitoring program at Foxvalley Landfill in Norway.

Restrictions on the landfill did not allow for any equipment to be left behind after the monitoring sessions. Also, the contaminant patterns were difficult to predict in this particular geological setting which led hydrogeologists to favor a variable level, removable multilevel monitoring system.

Hydraulic Packers

Regular Waterloo Systems are characterized by the permanent packer seals. The Removable System replaces the permanent packers with hydraulically inflated packers. All other components of the System remain the same.

The Removable System replaces the permanent packers with hydraulically inflated packers.

The rubber packers are inflated with sufficient water pressure to provide an effective seal between each zone.

Variable Level Multilevel Monitoring

Two fully screened 4 inch wells were installed to facilitate variable level monitoring and to provide a solid surface for the packers to expand against. When monitoring was completed from this particular configuration the packers were deflated and removed. Then the System could be re-arranged to sample from different zones within the well.

The Removable Waterloo System was ideal for the monitoring application that Telemark College faced.

Deep Waterloo System Installations

— Case Study —

Earth Technology, California

The California office of Earth Technology used Waterloo Systems for a challenging project recently near a California military base.

Earth Technology consultants knew that the site was contaminated by chlorinated solvents, but the amount and extent of the contamination needed to be determined. Contaminant migration patterns were uncertain because of the variable conditions of the site. It was essential to sample from many zones and to great depths around the base.

Drilling costs would be exceptionally high and the disturbance to the subsurface would be significant.

Waterloo System Installations

The Waterloo System was ideal to efficiently provide the three dimensional data Earth Technology required. Eight Waterloo Systems were installed to depths from 400 to 700 feet in steel cased wells with screened sections at each sampling zone. The steel cased wells provided a solid foundation for the packers to seal against.

All installations used dedicated Double Valve Pumps for efficient purging and sampling.

The deeper zones used dedicated vibrating wire pressure transducers for measuring hydraulic head. Vibrating wire transducers were chosen as they are inexpensive and stable over the long-term.

It is only necessary to purge the annular space around each port and not the entire water column.

For the shallower zones, open tubes and narrow diameter Water Level Meters (Solinst Model 102) were used to minimize initial capital expenses.

Earth Technology was pleased by the ease of installation.

Technicians found it easy to take samples and pressure readings with the Waterloo System due to the user-friendly well head manifold design.

Reduced Purge Times

The ability to reduce purge volumes was a big advantage for Earth Technology. They could minimize the amount of purged water to be disposed of and save time on each sampling round, particularly from the deeper zones. Packers isolate each sampling port so it is only necessary to purge the annular space around each port and not the entire water column. The time savings are dramatic.

Earth Technology feels the installations and ongoing monitoring program from the Waterloo Systems have been a great success providing them with the long-term reliability they needed.

Waterloo System in Overburden

The recently introduced Sand/Bentonite Injector from Solinst makes multilevel installation in overburden easier and much more efficient.

Overburden conditions do not provide a solid formation for the standard Waterloo packers to expand against. Outer casing or properly placed bentonite seals are needed to provide the effective seals required.

Existing options for bentonite placement are neither reliable nor easy. Gravity feed or tremie pipe methods are often inaccurate because of bentonite bridging, voids and short-circuits. Grout preparation is messy and time consuming.

The Injector is brought on site on a trailer.

An Easier, Reliable Alternative

The **Sand/Bentonite Injector** precisely and easily places sand filters and bentonite seals within a monitoring well. Dry granular material is delivered to the level it is required through a narrow diameter tube by compressed air. Swelling of bentonite takes place only at the level required. Avoids problems of bridging, voids and short-circuits.

Waterloo Systems can now be installed with confidence in overburden.

CETCO backs the Injector

Colloid Environmental Technologies Company (CETCO), a wholly owned subsidiary of American Colloid Company, and Solinst have entered into an agreement to promote the Injector in the United States and Canada. The Injector will be sold or rented through both companies and their network of distributors. Call Solinst or the CETCO corporate office at (708) 392-5800 for information of the Injector.

Waterloo System Users

Waterloo Systems have been installed throughout the US, most of Canada and several countries around the world. Some of our customers include:

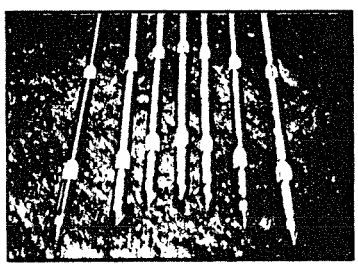
Conestoga Rovers, New Jersey
Earth Technology, California
Engineering Tectonics, North Carolina
ENSR Inc., Massachusetts
Golder Associates, Pennsylvania
Hydrologic Consultants, Iowa
ICF Kaiser, California
Kerr-McGee, Missouri
Laval University, Quebec
Martin Marietta & Advanced Sciences Inc., Massachusetts
Metcalf and Eddy, Massachusetts
Ohio State University, Ohio
Ontario Hydro, Niagara Falls
URS Consultants, California
Telemark College, Norway
US Army Corps of Engineers, Pennsylvania
Waste Management of North America, Massachusetts

Drive-In Multilevel System

A Drive-In Multilevel System was recently developed by Solinst for use in soft or loose overburden soils. It is ideal for multi-point vadose zone soil gas monitoring and for shallow groundwater monitoring.

Stainless steel monitoring tubes run down the inside of the piezometer to the required depths and connect to a screened zone. Samples are removed with a vacuum or peristaltic pump.

The System minimizes disturbance to the subsurface and is extremely flexible, allowing many sampling ports within a short space.



Monitoring tubes run down the inside of the piezometer to the sampling zone.

Waterloo System on Video

Solinst and the **Waterloo Centre for Groundwater Research** were recently featured in a short video segment outlining the advantages of multilevel groundwater monitoring and the Waterloo System. It will air on *Business Today* on WJMK (Florida cable) in May.

Dr. John Cherry of the Waterloo Centre for Groundwater Research lent his expertise in the video. Dr. David Rudolph, also with the Centre, helped demonstrate installation and monitoring with the Waterloo System.

Receive your own copy of this video tape by calling Solinst.

Solinst

35 Todd Road
Georgetown, ON
L7G 4R8
Canada

Solinst invites you to compare and save.

Tell us about your site. We will prepare a cost quotation for a Waterloo System to compare to your multiple piezometer installation.

Depth of installation: _____

Borehole diameter: _____

Number of sampling points you wish to monitor from: _____

Depths to each zone: _____

Monitoring options: Dedicated Double Valve Pumps at _____ zones

Dedicated Pressure Transducers at _____ zones

Open tubes (portable sampling) to _____ zones

Borehole geology:

_____

_____

Major contaminants to be monitored for:

_____

_____

Call Solinst to discuss any questions you may have for your application.

Telephone:
(905) 873-2255
(800) 661-2023
Fax:
(905) 873-1992

Please send me:

☐ Waterloo System Video ☐ Sand/Bentonite Injector Video

☐ More information on Solinst groundwater monitoring instruments

Fold back and over

_____

_____

_____

_____

Place Stamp Here

Solinst Canada Ltd.
35 Todd Road
Georgetown, ON L7G 4R8
CANADA

The Waterloo Multilevel Groundwater Monitoring System

Jim Pianosi, B.Sc.
Doug Belshaw, B.Sc., M.Sc., P. Eng.
Solinst Canada Ltd.
Glen Williams, Ontario

HWHM '90

ABSTRACT

The Waterloo Multilevel Groundwater Monitoring System provides direct and easy monitoring of static water levels and sampling of groundwater for organic and inorganic contaminants at multiple intervals in a single borehole. The simple modular system isolates discrete zones within bedrock through the use of the unique Waterloo packers. The system installs easily and provides for time and cost-effective monitoring. The modular component design and the effectiveness of the engineered seals used in the Waterloo System will be discussed in this paper.

Multilevel monitoring at appropriate locations across a site provides accurate three dimensional data collection. The ability to monitor several intervals within a single borehole affords a more accurate determination of groundwater conditions, even considering the complexity of flow networks within fractured media. Due to the long-term nature of many groundwater monitoring projects, the operational/monitoring time required as well as the cost of the monitoring equipment are of prime importance.

This paper discusses the applicability of the system to long-term monitoring and compares it to other types of groundwater monitoring installations.

Multilevel monitoring systems offer technical and cost advantages over nested and bundle type piezometers. These advantages and cost considerations are addressed in this paper.

The Waterloo Multilevel Monitoring System can be customized through the use of special materials, sizes, etc., to meet the monitoring needs, site conditions and budget constraints of any particular project. The various options of monitoring instruments and customized designs which can be used with the Waterloo System will be described. The combination of cost savings, technical advantages, site-specific design and customization options makes the Waterloo System ideal for long-term groundwater monitoring projects.

INTRODUCTION

Groundwater monitoring programs are designed to obtain information regarding piezometric elevation, flow velocity, flow direction, chemical parameters and hydraulic conductivity. At the same time, consideration must be given to costs, data quality, reliability and long-term monitoring capability.

In attempting to satisfy these requirements, hydrogeologists typically install numerous standpipe piezometers in separate boreholes around a site. These standpipes are often installed in cluster arrangements to obtain better information regarding flow determination and aquifer correlation. Single hole, nested type piezometer installations are used to limit drilling costs and disturbance to the aquifer. Problems involved with these monitoring methods include: (1) high drilling, instrumentation and monitoring costs, (2) uncertain seal placement and effectiveness and (3) sample integrity assurance.

A multilevel device was designed at the University of Waterloo which allows the monitoring of discrete intervals through individual small diameter tubes installed within a PVC casing string. Unique packers and ports form part of the casing string and effectively isolate and provide screened access to each monitoring interval. An early prototype of this system is described by Cherry and Johnson[1].

The Waterloo System has since been modified at Solinst Canada Ltd. to form a very flexible, effective device offering a high degree of reliability in all aspects of groundwater monitoring.

WHAT IS MULTILEVEL MONITORING

Generally, the term multilevel infers that several elevations are monitored to obtain a variety of hydrogeological data. Multilevel installations have been used for many years to obtain detailed data for groundwater assessments.

Various terminology has been used to describe the common forms of multilevel monitoring. In this paper, cluster type monitoring refers to the installation of a number of standpipes in separate boreholes and to various depths. Nested type installations involve using a number of standpipes installed to various depths in a single borehole. For the purposes of this paper, Waterloo type multilevel installations are those which allow the monitoring of many elevations within a single borehole, and a single standpipe. The Waterloo System is shown along with conventional monitoring systems in Figure 1.

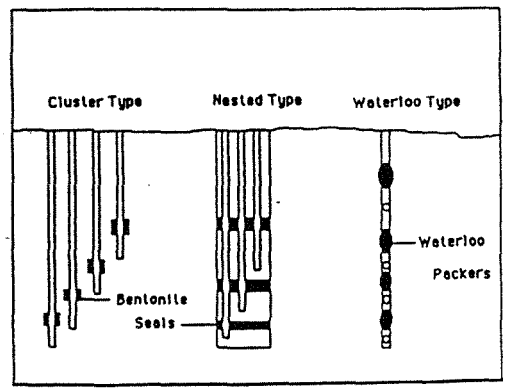


Figure 1
Comparison of Multilevel Installation Types

Each of the above methods allows a hydrogeologist to determine various parameters relating to groundwater conditions. The differences between the methods are cost, reliability, system integrity, accuracy of packer location, ease of use and the ability to obtain data regarding all points of hydrogeologic concern.

THE WATERLOO MULTILEVEL SYSTEM

General Description

The Waterloo Multilevel Monitoring System is a system specifically designed and engineered to obtain quality data from many elevations in a single bedrock borehole. It is of modular design and is installed in much the same way as a typical PVC standpipe piezometer.

The system is comprised of stainless steel sample/pressure ports and permanent, positive-seal packers built into a PVC casing string. Individual tubes and/or cables extend within the casing string from each port to the surface. This system provides monitoring access to each zone which is separated from other zones by the Waterloo packers.

The tubes connecting the monitoring ports to the surface can be polyethylene, Teflon or stainless steel. Water levels, water samples and hydraulic conductivity measurements are obtained by inserting specially designed, portable, small diameter monitoring devices into each tube to static water level or below. Alternatively, these tubes can be replaced with dedicated pumps and/or pressure transducers at the time of installation. Any combination of these methods is possible depending upon project requirements.

The individual sample/pressure ports, reliable packer seals and flexibility of design of the Waterloo system make it applicable to most groundwater assessment projects.

The Waterloo Packer

One of the most important components of the Waterloo Multilevel System is the self-inflating packer which provides a continuous seal within the borehole annulus. The packer is composed of layers of flexible gum rubber, woven Kevlar and Dowell sealant over a PVC screen section (Fig. 2).

The backbone of the packer, a length of slotted PVC screen, is covered with a molded sleeve of Dowell sealant. The Dowell is a unique material which expands by simply absorbing water from inside the casing string. The Dowell is covered with a layer of gum rubber to retain the sealant material. A woven Kevlar wrap is installed over the gum rubber. While designed to allow expansion, the strong Kevlar affords protection against rupture due to possible overexpansion into a large void or fracture or against a sharp protuberance in a borehole. A final layer of gum rubber is used to cover the Kevlar and provide a soft, pliable outer layer capable of conforming to an irregular borehole wall.

As the Waterloo packer is designed of inert materials, and only the outer gum rubber comes in contact with the groundwater being monitored, there is no concern about sample degradation as there is when bentonite seals are used.

After installation of a Waterloo system, water is added to fill the casing string. This water passes through the PVC screen and is absorbed by the Dowell in each packer, causing simultaneous packer expansion. The packers expand exponentially with time as long as there is water adjacent to them in the casing string. Typically, it takes 24 to 48 hr for a standard Waterloo packer to effectively seal a borehole. Laboratory tests have proved the packers effectively separate intervals with pressure differentials of up to 100 psi. The effectiveness of the Waterloo System packer in ensuring a tight seal within a borehole, without the need to constantly monitor or reinflate the packer, is a major benefit both in technical and cost considerations.

Sample/Pressure Ports

The sample/pressure ports of the Waterloo System are made of 316 stainless steel. Access to the monitoring interval is through a 0.25 in. inlet tube which is covered by a double wrap of 200 mesh stainless steel screen (Fig. 3).

Dedicated pressure transducers and sampling pumps are easily connected to each port during installation. A number of ports can be installed between packers to accommodate a variety of monitoring methods. Purging volumes and lag time effects are limited due to the unique design of the Waterloo system. These features lead to greater accuracy and cost savings.

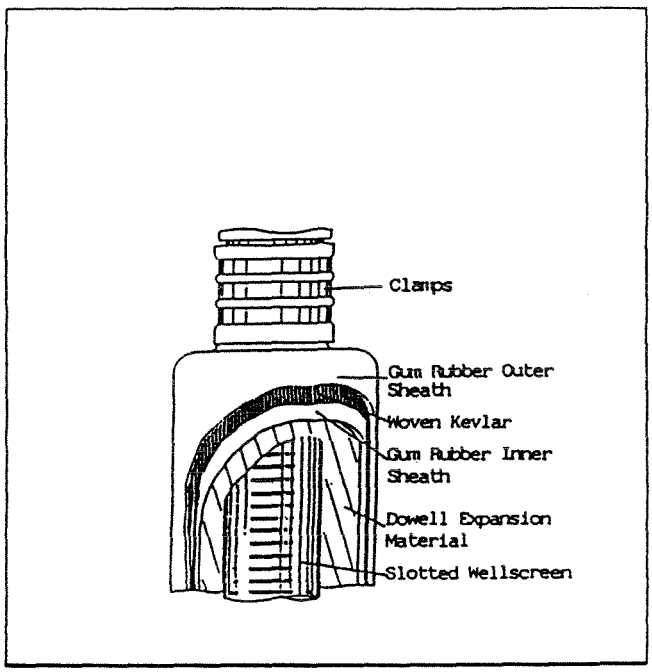


Figure 2
Section Through a Waterloo Packer

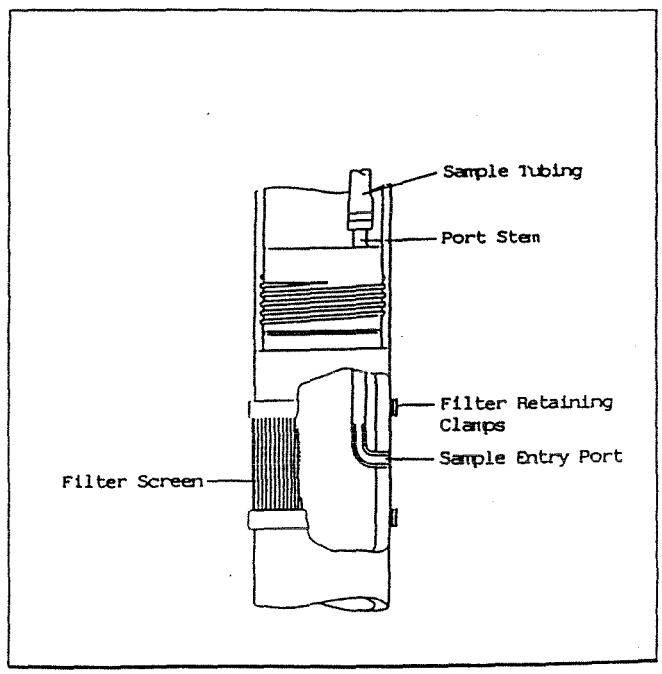


Figure 3
Waterloo Sample/Pressure Port

Monitoring Options

The flexibility of the Waterloo Multilevel Monitoring System is most obvious when noting the variety of monitoring options available. These options are available to make the system more adaptable to a wide variety of applications regardless of budget, time or technical monitoring requirements.

Portable sampling equipment, such as peristaltic pumps, bailers and inertial pumps is inexpensive to purchase, operate and decontaminate. Portable equipment is most applicable when sampling is infrequent, when VOC samples are not required or when the project budget is low. Gas drive samplers and discrete interval samplers are available for higher quality groundwater samples.

Open tubes for use with small diameter water level meters are an inexpensive method of determining hydraulic head when high accuracy or rapid readings are not of prime importance. Optional vibrating wire or pneumatic pressure transducers are available when accuracy is very important or when rapid readings are required during pumping tests.

Readout devices, data loggers and sampling pump control equipment are available which can operate remotely, automatically and simultaneously from different levels.

Any combination of sampling and pressure monitoring equipment can be used to best fit a project's budget and technical requirements.

BENEFITS OF THE WATERLOO SYSTEM

High Quality Seals

The most important aspects of any piezometer device, whether multilevel or not, are the quality and reliability of the seals and packer placement accuracy. In the Waterloo system packer, there is continuous expansion as long as the casing string is filled with water. Packer failure is eliminated through the use of the full Kevlar wrap which provides great strength. The soft gum rubber is pliable enough to mold to the most irregular borehole wall. Seal integrity is maintained without the need to monitor packer pressure. Accurate packer placement is assured, due to the flexibility of the modular component design. Sample alteration is minimized since no reactive materials (such as bentonite) come in contact with the groundwater. The Waterloo packer is designed to withstand very high differential pressures. The modular design provides for easy installation with no downhole inflation tools required.

Cost Reductions

Figure 4 illustrates some of the cost savings realized when comparing a Waterloo multilevel installation, to a cluster type installation, with the same number and depths of monitoring intervals. The major cost reduction is due to reduced drilling requirements. However, dedicated monitoring devices and the reduced field time required for subsequent sampling and monitoring also offer substantial savings. These advantages are especially important in long-term projects.

Dedicated Monitoring Devices

The ability to dedicate sampling and pressure monitoring devices makes the Waterloo system effective for reducing the potential for cross-contamination and maintaining sample integrity. High quality dedicated instruments also allow rapid monitoring by one technician, thus limiting field time. Sampling pumps can be operated automatically, and simultaneously, with automatic control units and multipurge manifolds. Data loggers can be used to operate and record data from pressure transducers simultaneously, continuously and remotely.

Ease of Installation

The Waterloo System is installed by two technicians. The installation method is similar to installing a simple standpipe. The modular components are threaded together in the appropriate order and lowered one section at a time. Casing clamps are used for support, and water is added to the casing string to overcome buoyancy, as required. No special installation equipment or downhole tools are necessary for assembly or packer inflation. Finally, because of the modular design and simple assembly of the Waterloo system, drilling rigs are not required to be on-site during installation.

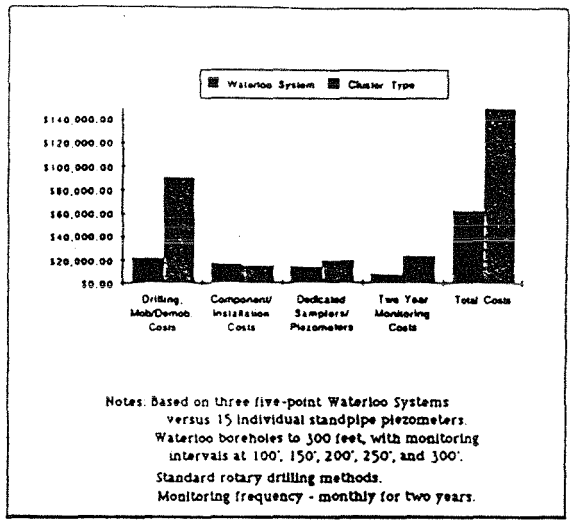


Figure 4
Cost Comparison of Waterloo and Cluster Type Multilevel Installations

Limited Drilling and Aquifer Disturbance

One of the benefits of the Waterloo multilevel system is that it can effectively monitor several levels in each borehole, thus reducing the amount of drilling necessary. The cost savings are substantial when comparing similar drilling methods with the Waterloo System versus nested piezometers. Reduced drilling and smaller diameter boreholes lessen the likelihood of causing interconnection between aquifers. The limitation of disturbance to the aquifers due to drilling reduction with the Waterloo system is also an important benefit.

Three-Dimensional Data

Installation of three or more Waterloo Multilevel systems across a site provides data which gives a three-dimensional view of the groundwater flow regime (Fig. 5). This installation allows for accurate plume delineation and determination of groundwater flow patterns. Errors due to improper correlation of fracture systems are reduced by accurate packer placement and the ability to monitor many levels.

Fracture Flow Monitoring

Fracture flow patterns are typically very complex. Waterloo system packers can be accurately placed immediately above and below monitoring zones to aid in cross-correlation. Angled boreholes are possible with the Waterloo system and, in many cases, increase the likelihood of intersecting fractures.

Long-Term Monitoring

Long-term monitoring is simplified, and field time and costs are reduced with the Waterloo system. The permanent, engineered seals eliminate the need to monitor or reinflate packers. High quality stainless steel pressure transducers and sampling pumps provide reliability and long life. Also, with dedicated pumps and transducers, there is no equipment to be lowered into the piezometers, thus reducing the chance of equipment damage or loss and further reducing the field time required for monitoring.

Customization

The Waterloo system has been designed to be as flexible as possible to provide access to multiple levels within a borehole. To further its applicability to a variety of projects, optional construction materials are available. Teflon or stainless steel tubes and stainless steel casing are available when required. Packer outer sheath material can be varied to suit chemical conditions. Generally, the gum rubber is suitable; however, polyurethane or Viton can be used.

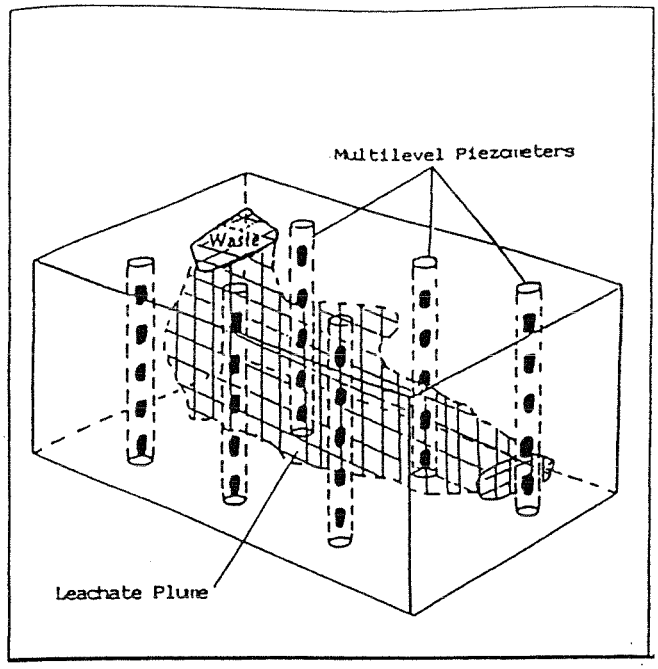


Figure 5
Three-Dimensional Data Collection System
with the Waterloo System

In order to fit the system to existing or irregular boreholes, Waterloo packers can be designed in a variety of diameters and lengths. Special reducer couplings can adapt a small diameter casing to a much larger borehole.

Each Waterloo Multilevel Monitoring System is individually designed to suit the cost, monitoring frequency, sample integrity and other technical requirements of each application.

TYPICAL APPLICATIONS

The Waterloo system is suitable for use in a variety of applications, such as: contaminant plume delineation, defining groundwater flow patterns, determination of aquitard leakiness, pump test monitoring, water quality studies, disposal site effectiveness monitoring, slope stability studies, dam assessments and evaluating pollution abatement measures.

Recent projects which used the Waterloo system include the following:

- A solid waste landfill site incorporated five Waterloo systems with a total of 25 monitoring points to delineate a contaminant plume. A single Waterloo packer effectively separated a contaminated and a non-contaminated aquifer between which there was a pressure differential of 14 psi.
- In an oil pipeline leak assessment, the use of the Waterloo System helped determine that the contamination was restricted to the upper aquifer only. It was also used to provide ongoing information regarding cleanup assessment.
- A large remediation project which involved pump-and-treat systems used numerous Waterloo Multilevel Systems to monitor and assess the performance of cleanup work.

The Waterloo Multilevel Monitoring System has been used in numerous projects across the United States, Canada and overseas, including some with RCRA or CERCLA designations. It has proven to be an effective technology for the monitoring of hydrogeological parameters in groundwater assessment projects.

CONCLUSIONS

The Waterloo Multilevel Monitoring System was designed at the University of Waterloo and modified at Solinst Canada Ltd. in response to the need for a reliable method of obtaining high quality water samples and level determinations from several intervals within a single borehole.

The problems of ineffective seals, uncertain packer placement and water quality degradation associated with other forms of multilevel monitoring were overcome through the use of engineered permanent packers to isolate discrete monitoring intervals. Field time monitoring requirements are reduced by the low purge volumes required, as well as by the ability to dedicate sample pumps and pressure transducers. Further time reductions are possible through the use of multipurge manifolds and dataloggers. Customization of the Waterloo multilevel system allows adaptation to fit almost any project requirement. Existing boreholes can be retrofitted to provide more meaningful data. Special materials can be used to provide a best fit with sampling protocols for each job.

The Waterloo Multilevel Groundwater Monitoring System is very effective in providing high quality data which is cost-effective and reliable even during very long-term projects.

REFERENCES

1. Cherry, J. A. and Johnson, P. E. "A Multilevel Device for Monitoring in Fractured Rock," *Ground Water Monitoring Review*, 2 (3) pp. 41 - 44, 1982.

A MULTILEVEL DEVICE FOR MONITORING IN FRACTURED ROCK

A new device for monitoring ground-water quality and water levels in fractured rock is described and analyzed.

by John A. Cherry and Paul E. Johnson

The identification and delineation of contaminated ground-water zones in fractured bedrock at waste disposal sites is difficult due to the complex nature of flow in the fracture networks. The rates of ground-water flow and contaminant concentrations can be greatly different from one fracture to another. At sites where contaminated ground water is expected to occur, contaminants may be present in fractures that intersect only a small segment of the total borehole. Because of these complexities and uncertainties, it is often appropriate to acquire samples from numerous depth intervals at each monitoring site when monitoring ground-water quality in fractured rock. This can be accomplished by drilling several separate boreholes to different depths at each site for installation of a nest of piezometers or observation wells or by the installation of multilevel monitoring devices in a single hole at each site. The use of piezometers in several boreholes at each monitoring site is often prohibitively expensive for detailed monitoring of contaminant plumes.

This article describes a simple, inexpensive multilevel monitoring device that was developed for installation in open boreholes. The device provides for the measurement of hydraulic head and the collection of water samples from any selected depth in the hole. If the water levels in the borehole are less than about 8m (26 feet), samples can be obtained simply by vacuum pumping. Where water levels are deeper, samples can be obtained using the gas-drive sampler for narrow-diameter piezometers described by Robin (et al 1982). Where water levels are deep, this sampler is an integral part of the multilevel monitoring system.

Two prototypes of the multilevel device were constructed and subjected to preliminary tests in the laboratory. A full-scale assembly was then installed in a borehole in fractured limestone near a hazardous waste landfill in the city of Hamilton, Ontario. This installation served to demonstrate that the device can be conveniently assembled in the field and also provided a preliminary evaluation of performance. The device is now being used on a routine basis in investigations of ground water quality at waste-disposal sites on bedrock and on deposits of cohesive clay or clayey till.

Description of the Device

The device consists of a bundle of tubes contained within a PVC pipe (casing) that is capped on the bottom (Figure 1). Each of the tubes is connected to a 90° elbow, which protrudes through the casing. If free sediment from the formation is expected to be a problem, the open end of the tube can be covered with a screen. Each tube extends to a different depth in the casing so that water can be drawn from different depths in the borehole. The interval of borehole associated with each tube is isolated from above and below by packers that expand so that the annulus between the casing and the wall on the borehole is sealed over specified intervals.

The number of tubes that can be installed in a single borehole depends on the diameter of the borehole and on the diameter of the tubes. The borehole used in the experimental field installation had a diameter of 7.5cm (3 in.). The PVC casing used in the installation had an outside diameter of 6.0cm (2.4 in.) and a 0.3cm (1/8 in.) wall thickness. A total of six 1.2cm (1/2 in.) O.D. polyethylene tubes were used in this assembly. One or two additional tubes could have been used, but because of space restrictions, would have caused greater difficulty in assembling the device in the field. Standard sizes of PVC pipe and couplings can also be used for construction of assemblies for 10cm (4 in.) diameter boreholes, in which case a much larger number of sampling tubes can be used.

In order for the device to be suitable for investigations of hazardous organic chemicals in ground water, the use of glues or solvents can be avoided in assembling nearly all parts of the device. The 90° elbow (polyethylene) has a 3mm (1/8 in.) pipe thread on one end that protrudes through a 10mm (13/32 in.) hole drilled in the PVC pipe. A small O-ring 1.5mm x 6.5mm x 9.5mm (1/16 x 1/4 x 3/8 in.) is placed on the thread to prevent leakage of water between the elbow and the PVC pipe. To hold each elbow tightly in place, a threaded piece of nylon is screwed onto the threaded part of the elbows protruding to the outside of the PVC casing.

Other materials could be used for the various components of the device if one desires to avoid some of the plastics because of concerns regarding their influence on the trace-organics composition of the water samples. Teflon-lined polyethylene or polypropylene tubing could be used rather than the normal tubing.

The packers were made from a solid but flexible sealant that expands when contacted by water. The sealant, which resembles a soft light rubber, is formed into a cylindrical sleeve in a mold. The cylindrical sleeve is placed around pre-cut lengths of PVC pipe, the same type of pipe that is used for the casing. The cylindrical sealant sleeves used in the device installed at the demonstration site were 9cm (3.6 in.) long. If desired, much longer cylindrical sleeves of sealant can also be made. The packers can be conveniently jointed into the casing using standard threadless couplings with a small amount of solvent joiner. The casing and packer couplings were the only locations where solvent

was used in the experimental field device. Solvent can be avoided entirely if threaded pipe and couplings are used for the packers and for the joining of the PVC casing at other points in the assembly.

The cylindrical packers must be isolated from the ground water in the boreholes along the outside of the casing because the sealant contains inorganic and organic compounds that have significant solubility. The sealant must be contacted by water from inside the casing so that volume expansion will occur. To provide for this water contact, holes were drilled radially around the PVC pipe. Monofilament screen cloth (Nitex, 210 mesh) was taped around the pipe and over the holes. The sealant cylinder was installed around the PVC pipe, with the screen in place between the pipe and the cylinder. The purpose of the screen is to facilitate the entry of water from inside the PVC casing into the very thin annulus between the exterior of the pipe and the interior surface of the sealant mass. Because the bottom of the casing is capped and because the elbows connected to the tubes are tightly sealed where they protrude from the casing into the borehole, the water for expansion of the sealant must be provided by filling the inside of the casing with foreign water. If the elbows have a water-tight fit where they pass through the PVC pipe and if all of the casing couplings are sealed, this water cannot mix with formation water at any time. Whether or not leakage of fluid occurs from the casing can be determined by filling the water column to surface and monitoring the water level with time.

The outside of the cylindrical sleeve of sealant was covered with a flexible rubber membrane (5cm [2 in.] diameter) held in place above and below the sealant sleeve by O-rings. The O-rings sit in grooves that were cut into the PVC pipe. A standard threadless PVC coupling was joined onto each end of the length of pipe containing the packer assembly. For the six-tube demonstration device installed at the field site, 12 packers were constructed and taken to the field in a fully-assembled state.

The sealant used in the construction of the packers was obtained from the Dow Chemical Co. It is known as Dowell sealant. The cylindrical mass of sealant was formed by mixing three chemical components together and pouring this mixture into brass molds constructed in a machine shop. The

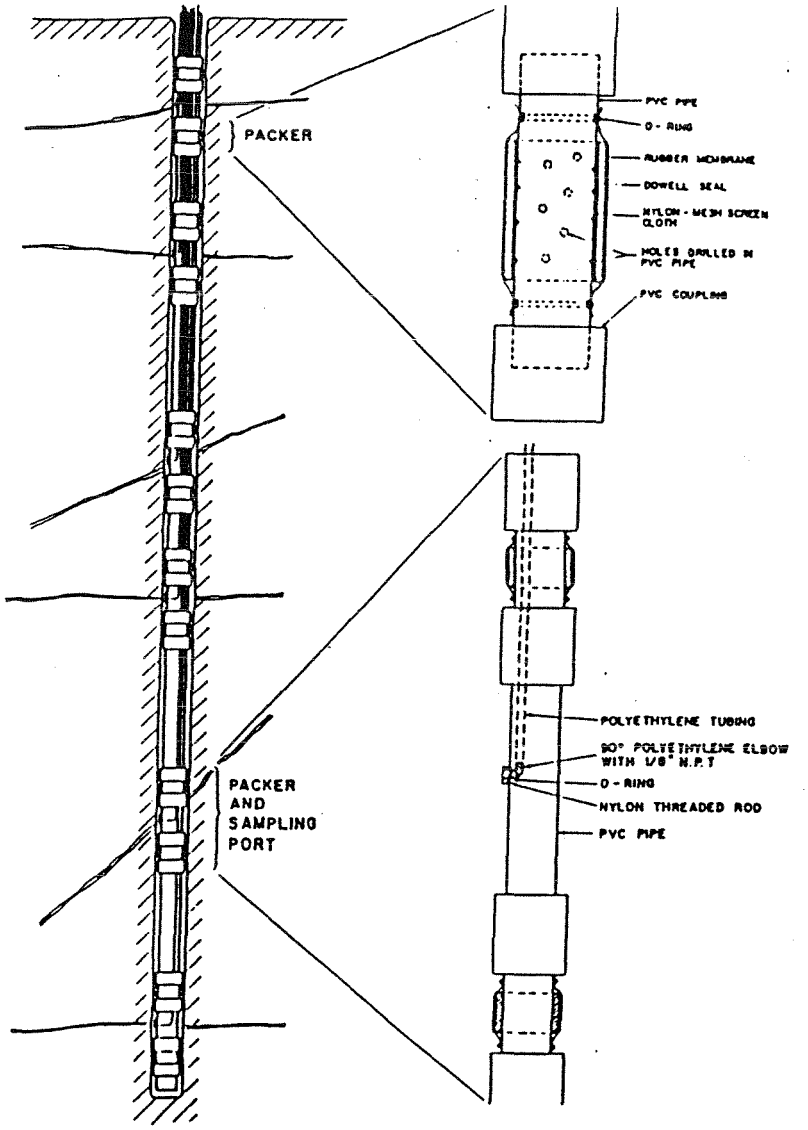


Figure 1. Schematic diagram of a six-port multilevel assembly and detailed views of a packer and sampling port systems.

rubber-like cylindrical sleeves are removed from the molds after an overnight setting period. When the cylindrical sleeve of sealant is contacted by water from inside the casing in the borehole, it expands until it presses tightly against the wall of the borehole. In the assembly installed at the field site, the outside diameter of the cylindrical sleeve was initially 6.7cm (2.7 in.) and it expanded to fill the borehole, which had a diameter of 7.5cm (3 in.). The thickness of the sleeve expanded from 0.35cm (0.14 in.) to 0.75cm (0.3 in.). Various diameters were used in the laboratory prototypes. The seal is capable of expanding to a much larger diameter if necessary. The sleeves expanded sufficiently to cause the packers to squeeze very tightly against the wall of the pipe used to represent the borehole in the laboratory.

The size of the cylindrical sleeve was such that its outside diameter prior to expansion was slightly smaller than the outside diamet of the coupling on each end of th length of PVC pipe used for th packer assembly. This arrangemer provided protection for the sealar when the complete monitorin device was lowered down the bor hole. Scraping of the couplings o the wall of the borehole would occu rather than scraping of the thir less durable, membrane that cover the cylindrical sleeve of sealant.

Except for the sealant sleeves, al of the materials used in the multi level monitoring device are availabl as standard-sized items from com mercial suppliers. Once the bras molds are made, the only machine shop services needed are for th cutting of the grooves for the O rings around the rubber membran on the packers.

Assembly and Installation

The packers and fittings for the 90° elbows were constructed in the laboratory but were assembled in

the field. It is desirable to assemble the monitoring device in the field so that information obtained while drilling and coring the borehole can be utilized when choosing the spacing of the sampling intervals and packers. The depths at which the most important open fractures occur can be determined by a variety of methods including inspection of cores, injection tests, flow metering, caliper logging and visual viewing using downhole cameras. The depths at which open fractures are detected can serve as the sampling zones and the packers can be placed in positions to seal each zone from the zones above and below. At the field installation site, the spacing of sampling tubes and packers was based solely on the results of visual inspection of cores.

Once the depth intervals for the sampling ports are specified, each sampling port is constructed by drilling a hole in a length of PVC pipe so that the 90° elbows and tubing can be attached to form the sampling ports. A packer is attached by means of coupling joints above and below the length of pipe containing the sampling ports. Lengths of PVC pipe are coupled into the assembly to provide spacing between the sampling intervals. Packers can be coupled into these segments of casing to provide additional assurance that the borehole intervals between sampling zones are effectively sealed.

The borehole at the field site was 19.5m (64 ft.) deep. The entire monitoring device was assembled in 6.5m (21.5 ft.) sections. After each 6.5m (21.5 ft.) section was put together, a rope was passed through each section in order to assist with the stringing of the sampling tubes when the assemblies were installed in the borehole. The first 6.5m (21.5 ft.) section was inserted in the borehole to a depth at which only the upper meter protruded from the hole. The bundle of sampling tubes from this section was then drawn by the rope through the next section of PVC pipe. The two sections were coupled together and then lowered into the hole. The procedure was repeated for the third section and the entire assembly was lowered to the bottom of the hole. The PVC casing was then filled with water so that the packers would expand to provide seals between the sampling intervals.

More recently, this procedure has been used to install assemblies in boreholes (7.5cm (3 in.) diameter) as deep as 60m (200 ft.). It is expected that it will be possible to use this monitoring system to depths of 100m (330 ft.) or more. For the installation to occur successfully, however, it is necessary that the borehole remain open with no protrusions of rock rubble or overburden into the hole.

Monitoring and Sampling

The measurement of water levels in each of the sampling tubes is accomplished using a narrow-diameter electric probe. Suitable probes are available from commercial suppliers or they can be constructed using coaxial cable, a battery and a small voltmeter. If the sampling port is properly isolated from zones above and below, the measured water level represents the hydraulic head of the water in the zone of fractures adjacent to the sampling port. A measurement of the apparent hydraulic conductivity of the packer-isolated interval can be performed by falling-head, rising-head or constant-head tests in the conventional manner. If the depth to water is shallow, these tests can be performed by extending the sampling tubes above ground surface so that water level changes can be observed visually.

The gas-drive sampler (Robin et al. 1982) that is used to obtain water samples displaces the water using positive pressure of nitrogen. The sampler forces out the entire column of water in the tube as a continuous stream. The water level in the tube is allowed to recover and the water column is once again expulsed. Although the tubes have a small diameter, the volume of water that can be obtained readily in this manner is normally sufficient to permit analysis for the chemical constituents of interest. If the sampling port draws water from a very low-permeability zone, the time required for the equilibrium water level to be achieved in the tube may be many tens of minutes or longer. Large volume samples can be obtained by repeated water column expulsions if sufficient time is allocated to the task.

The sampler can be used in tubes as small as 0.9cm (3/8 in.) ID. Because the sampler displaces the water from the tubes by means of positive pressure, there is minimal opportunity for the inorganic chemical composition of the water to change because of loss of dissolved gas such as CO_2 or because of uptake in oxygen. The loss of volatile organic compounds during sampling by this method has not yet been evaluated.

Performance of the Device

After the device was installed at the field site, several weeks were allowed to pass before the device was used for water-level monitoring and sampling. It was expected that this period would allow for the disturbance of the hydrochemical system in the fracture zones caused by drilling to be diminished or obliterated by the natural flow of ground water. Before and after ground-water sampling, the depths to water were measured. The water level in the deepest tube was above ground surface. The levels in the other tubes were all different and in the range of 1.435m (4.74 ft.) to 2.375m (7.84 ft.) below the top of the casing, which was 1m (3.3 ft.) above ground level. The fact that the water levels were reproducible before and after pumping and that each tube had a different level supports the conclusion that the Dowell seals in the packers expanded sufficiently to isolate each sampling port from the ones above and below.

This conclusion was evaluated further by response tests. As water was pumped from a single tube, the water level in the tube above the pumped tube was monitored. In each case, there was no observed effect of pumping on these water levels, which is what is expected in a situation where the packer seals are effective and the fractures are primarily horizontal. One of the sampling ports (the third one up from the bottom) was shown to have a crack somewhere in the connectors or coupling caused during installation. When the tube for this port was pumped, an immediate decline in water level in the interior of the PVC casing was observed.

The demonstration multilevel device and the devices that have been installed more recently are situated at locations near the landfill where contaminated ground water was expected to occur in the fractured limestone. The second stage in the evaluation of the performance of the demonstration device involved the acquisition of water samples from the tubes and analysis of the samples for electrical conductance and concentrations of total dissolved organic carbon (DOC) and chloride (total) concentrations in samples passed through 0.45 micron filter paper. For these two parameters, water from each of the six sampling tubes provided considerably different values. For example, the Cl^- con-

centrations ranged from a maximum of 67,000 mg/l in the deepest tube to a minimum of 1,600 mg/l in the tube second from the top. The DOC values ranged from a maximum of 4,200 mg/l (expressed as C) in the third tube down from the top to a minimum of 13 mg/l in the next tube downward. The values of Cl^- and DOC from nearly all of the tubes are indicative of severe contamination.

From the water level and chemical results there is no significant doubt that each sampling port draws water form a discrete zone of fractures within the borehole and that each of these zones is sampled in isolation from any influence from zones above and below. Similar results have been obtained from other sites at which multilevel devices have been installed. We conclude, therefore, that the multilevel monitoring device is performing at the field site in the desired manner.

Discussion and Conclusions

The multilevel sampling device described in this paper has an advantage over conventional standpipe piezometer nests in that it provides data from numerous depth levels at a site where only one borehole is drilled. Considerable economy with respect to the costs of drilling and of field personnel can therefore be realized. An alternative to the multilevel monitoring device is the installation of numerous narrow-diameter piezometers in a single borehole with separate sand or gravel packs and bentonite or grout seals installed from the surface as the individual piezometers are lowered into the hole. However, when this approach is used, difficulty is often encountered during the emplacement of the sand, bentonite or grout and therefore uncertainty often arises with respect to the integrity of the data obtained from some of the piezometers. In formations with low permeability and consequently low flushing rates, reactions between the slowly moving water in the sand pack and the grout or bentonite seal may be significant even if the sand pack and seal are placed properly in the hole. The multilevel monitoring device described here avoids most of this uncertainty because the seal is isolated from the formation water by the protective rubber membrane. If reactions with the rubber are of concern, the rubber membrane can be covered with a Teflon membrane. It is necessary, however, to be vigilant with respect to identification of the effects of tears in the membrane that could impact the chemistry of the ground-water samples. There is also the possibility that one or more of the sealant sleeves will not provide an adequate seal in the borehole. The uncertainty in this regard can be decreased by the use of longer sleeves and more packers in situations where borehole roughness and degree of fracturing are particularly adverse.

The PVC casing in the multilevel sampling device occupies most of the borehole, so the open annulus between the casing and the borehole in each sampling interval has a small volume. It is expected therefore, that as natural flow occurs in the fractured rock, this annulus will be more readily flushed with the flowing ground water than would the sand pack of a normal piezometer or observation well. Because the annulus is small, the volume of water that must be pumped prior to sample collection in order to ensure that water is drawn into the tube from the formation is also small.

Although the multilevel device described in this paper should be viewed as a permanent monitoring installation in much the same manner as normal wells or piezometers, there is a possibility that the device can be removed from the borehole after a period of use. When the Dowell sealant is not in contact with water, considerable shrinkage occurs. If the water in the casing is removed, the seals will shrink and thereby provide an opportunity for removal of the assembly. This has been demonstrated in the laboratory, but removal has not yet been attempted at a field site.

Although the multilevel monitoring device described here was developed for use in fractured rock, we expect that it will also be useful in deposits of consolidated clay. However, for the packers to effectively seal the various sampling levels, the hole needs to be free from infilling that would occur if interbeds of cohesionless gravel, sand or silt are present within the clayey deposit. When used in clay, the sampling ports should be covered with sleeves of screening or permeable plastic that would reduce the potential for clogging.

Acknowledgments

Several individuals provided information and ideas that contributed to the development of the multilevel sampling device described in this paper. Douglas Hermann of Soil Testing Services Inc. drew our attention to the existence of the Dowell sealant as a material for use in packer assemblies. Discussions with Rob Blair, Thomas Dance and Stan Feenstra of Golder Associates Ltd. aided considerably when various design options were being formulated. Ray Blackport supervised the drilling and core logging at the experimental site and assisted with the installation and testing of the device in the field. Michel Robin provided helpful comments on the manuscript. Funds for the development of the prototypes and the field installation were provided by the Upper Ottawa Street Landfill Study of the Province of Ontario.

References

Hvorslev, M.J. 1951. Time lag and soil permeability in ground-water observations. U.S. Army Corps of Engineers, Waterways Experiment Station Bulletin, No. 36, Vicksburg, Mississippi.

Robin, M.J.L., D.J. Dytynyshyn and S.J. Sweeney. 1982. Two gas-drive sampling devices for deep narrow piezometers. Ground Water Monitoring Review, vol. 2, no. 1, pp. 63-66.

Biographical Sketch

John A. Cherry is a professor in the Department of Earth Sciences at the University of Waterloo, Waterloo, Ontario. His research interests are in the areas of contaminant occurrence and migration in ground water and waste disposal.

Paul E. Johnson is an earth science graduate from the University of Guelph. For the past six years he has been a research technician in the Department of Earth Sciences at the University of Waterloo, where his main area of responsibility has been the development of devices for ground-water monitoring and the installation of monitoring networks at waste disposal sites.

To the old lady for the [illegible]

[illegible] your garden grown all [illegible]

I'd hate to say

You're old today

So I'll tell you

You'll find it's too small for your shoes

Whenever I see you

I would want to [illegible] you

Call me a Sap

But You really like to Sap

~~And~~ until Tim's [illegible] all [illegible]

Bristo

You really like to Sap

But They Say you're no Sap

~~And Tim's [illegible] a big fool~~

~~[illegible] Tim! [illegible] time [illegible] to [illegible] all through [illegible]~~