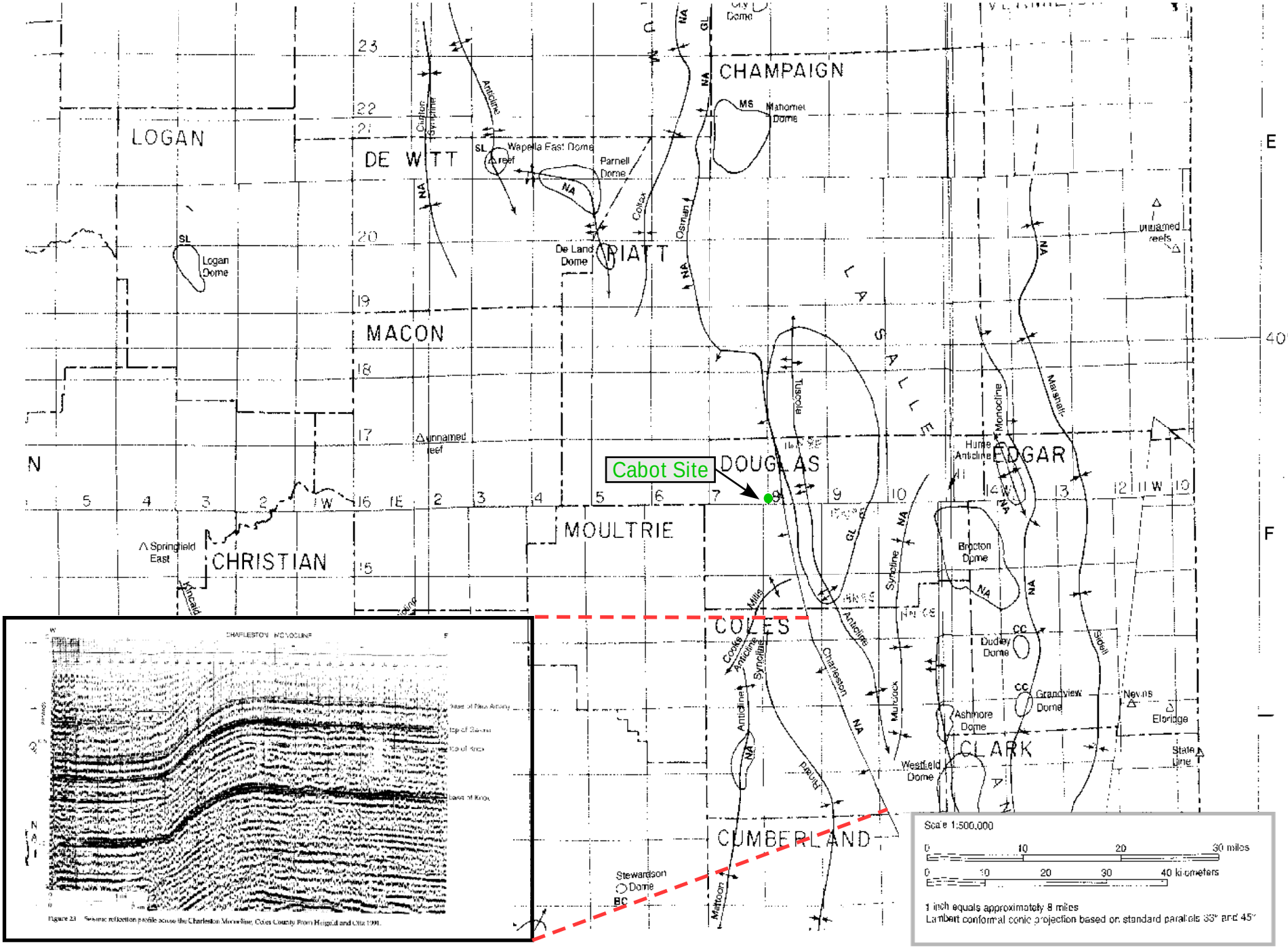
GLOSSARY AND DEFINITION OF ACRONYMS
For Figures 1-5, 1-6, 1-7

RKB	-	rotary kelly bushing
ppf	-	pounds per foot
DV tool	-	cementing stage tool
EUE	-	external upset ends – forging in ends on API pipe to provide additional thickness for strengthening connections
TAM	-	TAM International (oilfield services company)
RTS	-	radioactive tracer survey
H-40	-	API pipe grade
J-55	-	API pipe grade
K-55	-	API pipe grade
ST&C	-	short thread & coupled
LT&C	-	Long thread & coupled
sx	-	sacks
ID	-	inside diameter
PBR	-	polished bore receptacle
EPSEAL	-	epoxy resin cement



Attachment 1 Structural Features in Illinois and Seismic Reflection Profile through Charleston Monocline with location of Cabot Facility

(adapted from W. John Nelson, ISGS Bulletin 100, 1993)

Drawn by PWP 9-19-08
Sandia Technologies, LLC

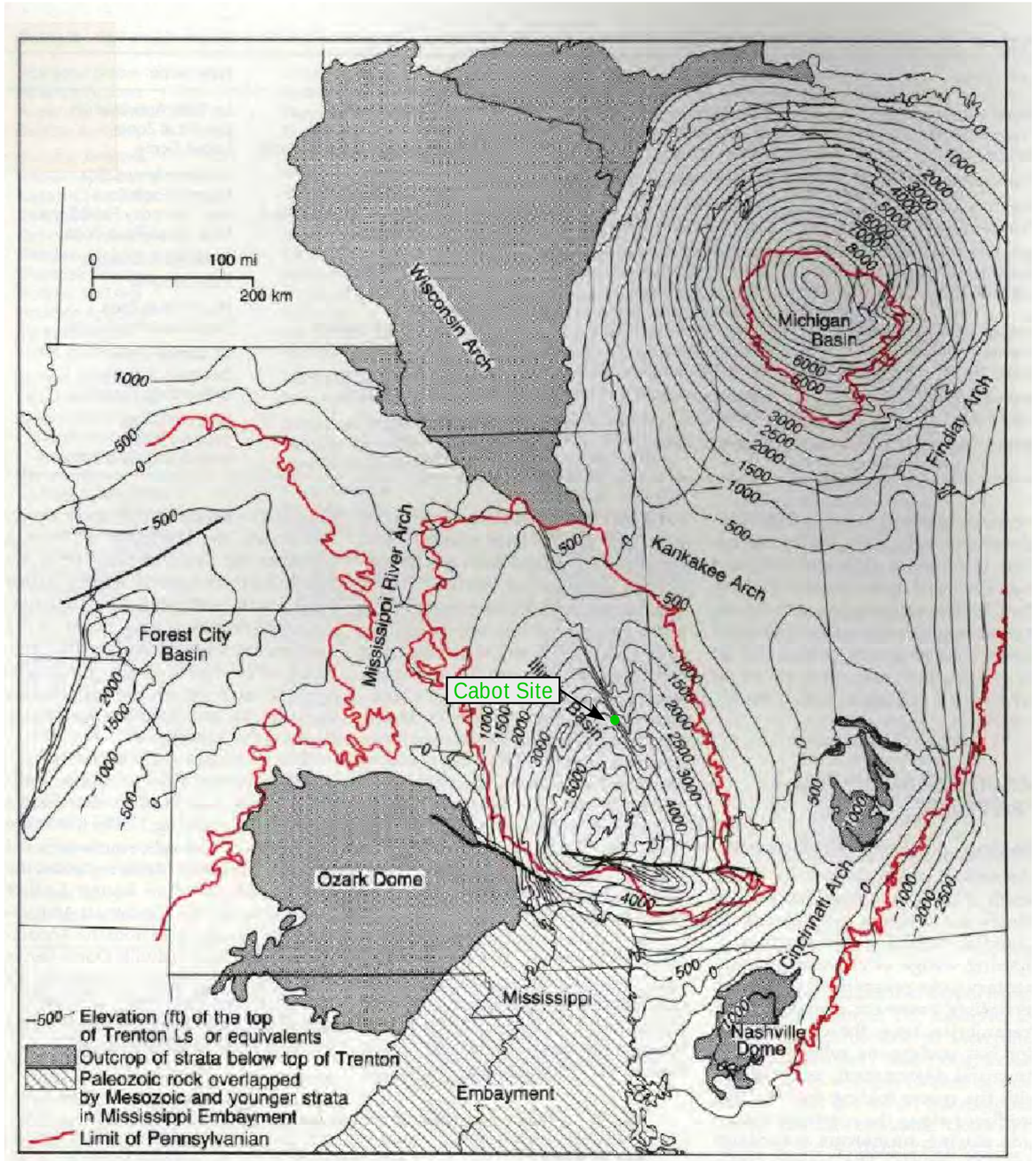


Figure 1 Regional structural setting of Illinois. From Collinson et al. 1988.

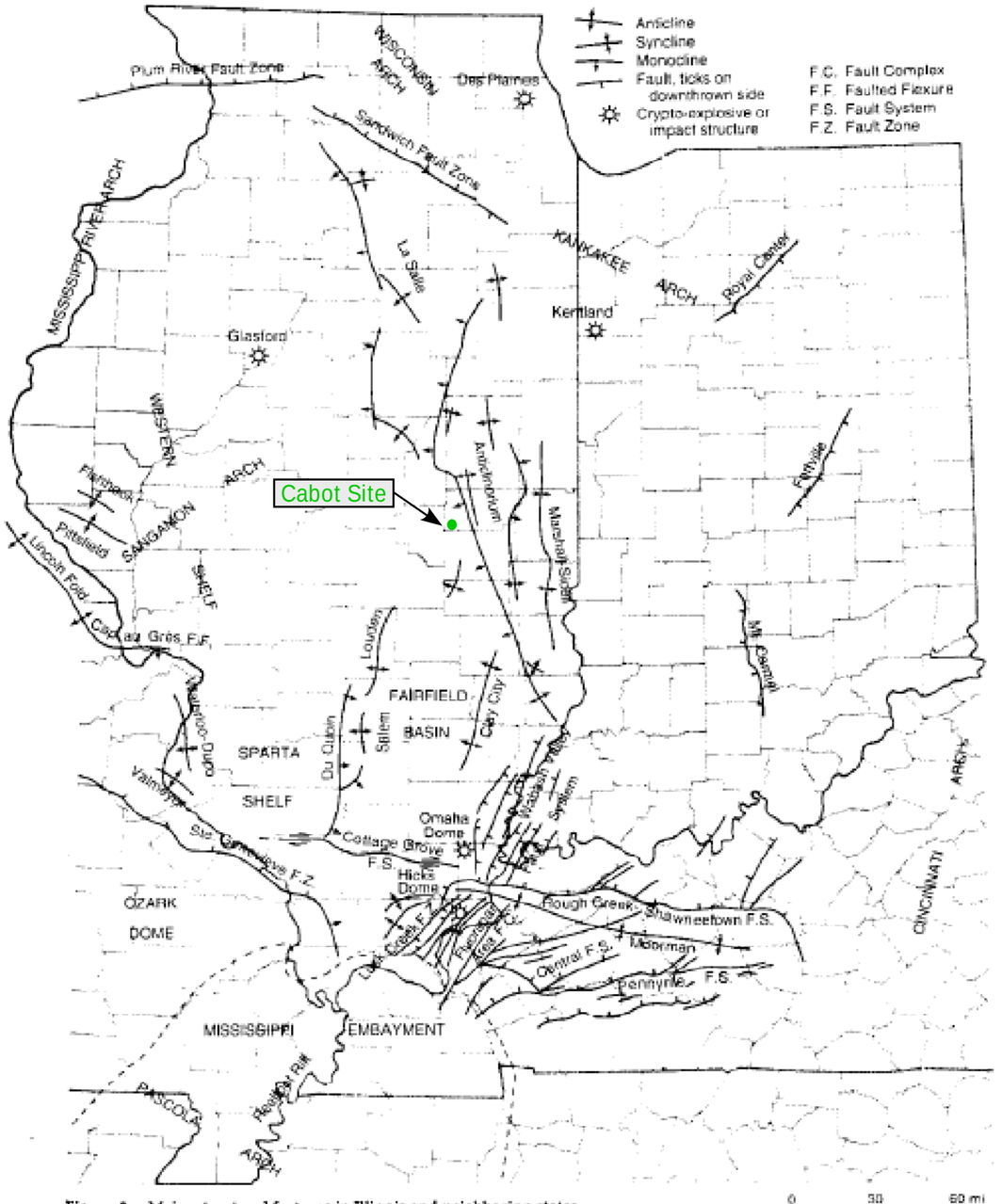


Figure 2 Major structural features in Illinois and neighboring states.

Attachment 2 Major Structural Features in Illinois and Regional Setting (adapted from W. John Nelson, ISGS Bulletin 100, 1993)

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ASSESSMENT OF FOURTH QUARTERLY (ANNUAL1991) COLLECTED GROUNDWATER SAMPLES, CLOSED RCRA IMPOUNDMENT, CABOT CORPORATION PLANT TUSCOLA, ILLINOIS (U.S. EPA I.D. No. ILD042075333)

December 1991

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ASSESSMENT OF FOURTH QUARTERLY COLLECTED GROUNDWATER SAMPLES

INTRODUCTION

This report is the assessment of the fourth quarterly (annual) collected groundwater samples from the monitoring wells for the closed hazardous waste impoundment at the Cabot Corporation plant near Tuscola, Illinois, in 1991. The report has been prepared to satisfy the requirements of Section 725.193 (d)(5), Subpart F : Groundwater Monitoring (IPCB, 1986) and of the "Consent Agreement and Final Order, Cabot Corporation, Tuscola, IL" of the U.S. EPA, dated 12/9/88.

Groundwater quality assessment reports are to be prepared as indicated in the "Groundwater Quality Assessment Program Proposal for Cabot Corporation Plant, Tuscola, Illinois", (Hydropoll, 1988). The assessment program had been prepared to satisfy the requirements of Section 725. 193 (d) (4) and approved by the U.S. EPA in December 1988. Previous to this fourth quarterly report, the 1991 third quarterly assessment report was prepared and submitted to Cabot Corporation (Hydropoll, 1991).

The purpose of this report is both to determine types and concentrations of contaminants and to estimate the rate and extent of migration of contaminants in groundwater, beneath the plant property, in vertical and horizontal directions based on the fourth quarterly sampling.

Monitoring System

A total of 25 monitoring wells are at the plant grounds. Of the 25 wells, 19 make up the monitoring system for the closed impoundment as approved by the IEPA (Figure 1). The remaining six wells are not in the system; however, they are kept operational to determine water levels in them. Of the 19 wells, R101 is the upgradient well and G106, G107, R108, G110, G111, G112, G116, and G124 are the downgradient wells from the closed

impoundment. These nine wells are 20-30 ft deep and are completed in the weathered till. Five wells (G01D, R119, G121, G122 and R123) are screened in a deeper sand unit in the till. These wells are approximately 100 ft deep. In addition, four wells (G109, G114, R117 and G118) are 50 to 75 ft deep. One deep well (G120) was drilled to a depth of 212 ft (very close to bedrock) and screened in a silt approximately between 199 and 203 ft.

Four wells of the above 19 are located singly and 15 in six well clusters. The R101/G01D cluster is upgradient and the five clusters: R108/ G122, G111/G118, G116/R117, R123/G124, and G106/G109/G114/R119/G120 are downgradient from the closed impoundment. The latter is next to the impoundment (Figure 1). The clusters were installed to assess migration of contaminants in a downward vertical direction. Three wells, G117, G119, and G123 were plugged, abandoned and replaced by R117, R119, and R123 in April and May of 1991.

Sampling Program

Depth to water and water elevation in all monitoring wells and the depth of the sampled wells (below land surface) are determined every quarter prior to sample collection. Of the 19 wells in the monitoring system, 14 (R101, G01D, G110, G111, G114, G116, R117, G118, R119, G120, G121, G122, R123 and G124) are sampled quarterly , four (G106, G107, R108 and G109) semi-annually (second and fourth quarters), and one (G112) is sampled annually (fourth quarter). The wells are evacuated at least three volumes of water before sampling. The evacuated water is collected in a drum and disposed of into the injection wells at the plant. The collected samples are analyzed for pH, specific conductance and hazardous constituents (volatile organic compounds) every quarter. Annual samples (fourth quarter) are also analyzed for groundwater quality parameters. The water samples from R101, G01D, G120, G121, G122, R123, and G124 were analyzed once for priority pollutants in the second quarter after their installation. Priority pollutants found to be exceeding their detection limits were added to the quarterly analyses.

Analyzed Parameters and Assessment Methods

Prior to collection of the water samples, depth to water and well depth were measured on October 4, 1991 and water level elevations were determined in 25 monitoring wells at the plant (Table 1). The screened intervals of the sampled wells are also in Table 1.

The samples were collected from all of the 19 wells in the monitoring system on October 7, 1991. The samples were analyzed for pH and specific conductance (SC) in the field (Table 2), and for volatile organic compounds (VOC), base neutrals and acid extractables. The results of the analyses are in the Appendix. Hazardous constituents which are above their respective detection limits are summarized in Table 3. Analyses results of total cyanide and total recoverable phenolics are in Table 5. Concentration of groundwater quality parameters is shown in Table 6. Analyses of a trip blank (G125) is also in the Appendix. All samples were analyzed using the U.S. EPA methods.

ASSESSMENT

Potentiometric Levels and Flow Direction

Before taking the fourth quarterly groundwater samples, depth to water was measured in the monitoring wells on October 4, 1991, and the elevation of groundwater was calculated (Table 1). Based on the water elevations at the wells, potentiometric maps have been prepared for the shallow water in weathered till and the water in the sand.

Previous assessment reports, prepared before the closure of the impoundment in November 1987, indicated that the groundwater flow was affected and a groundwater mound had formed in the shallow water beneath the impoundment. Since the closure, it appears that the mounding has been disappearing. The potentiometric surface map of the shallow groundwater in Figure 1 indicates the groundwater contours near the closed impoundment on October 7, 1991. The direction of regional groundwater flow has been estimated from water elevations in R101, G110, and G116. The regional flow direction is towards the southeast. A groundwater divide, across which no flow occurs, is located just north of the closed impoundment. The divide prevents flow of groundwater from the impoundment in the northerly direction. Hydraulic conductivity is calculated as 0.0064 in the regional flow direction on Figure 1. Field hydraulic conductivity was 62.1 ft/yr. Effective porosity of the weathered till is estimated to be 0.1. Using these values, Darcy's equation results a 4.0 ft/yr groundwater velocity.

Elevations of the water level in the deep sand are in Table 1. The water elevations do not vary significantly in these wells. The water levels range from 658.50 to 659.07 ft and present a relief of 0.57 ft. Although the elevations are not much different, the water flow direction is tentatively determined towards the west (Figure 2). Hydraulic gradient is approximately 0.0025. Field hydraulic conductivity was determined as 3400 ft/yr previously. Effective porosity is estimated as 0.20. Thus, Darcy's equation yields a groundwater velocity of 42.5 ft/yr

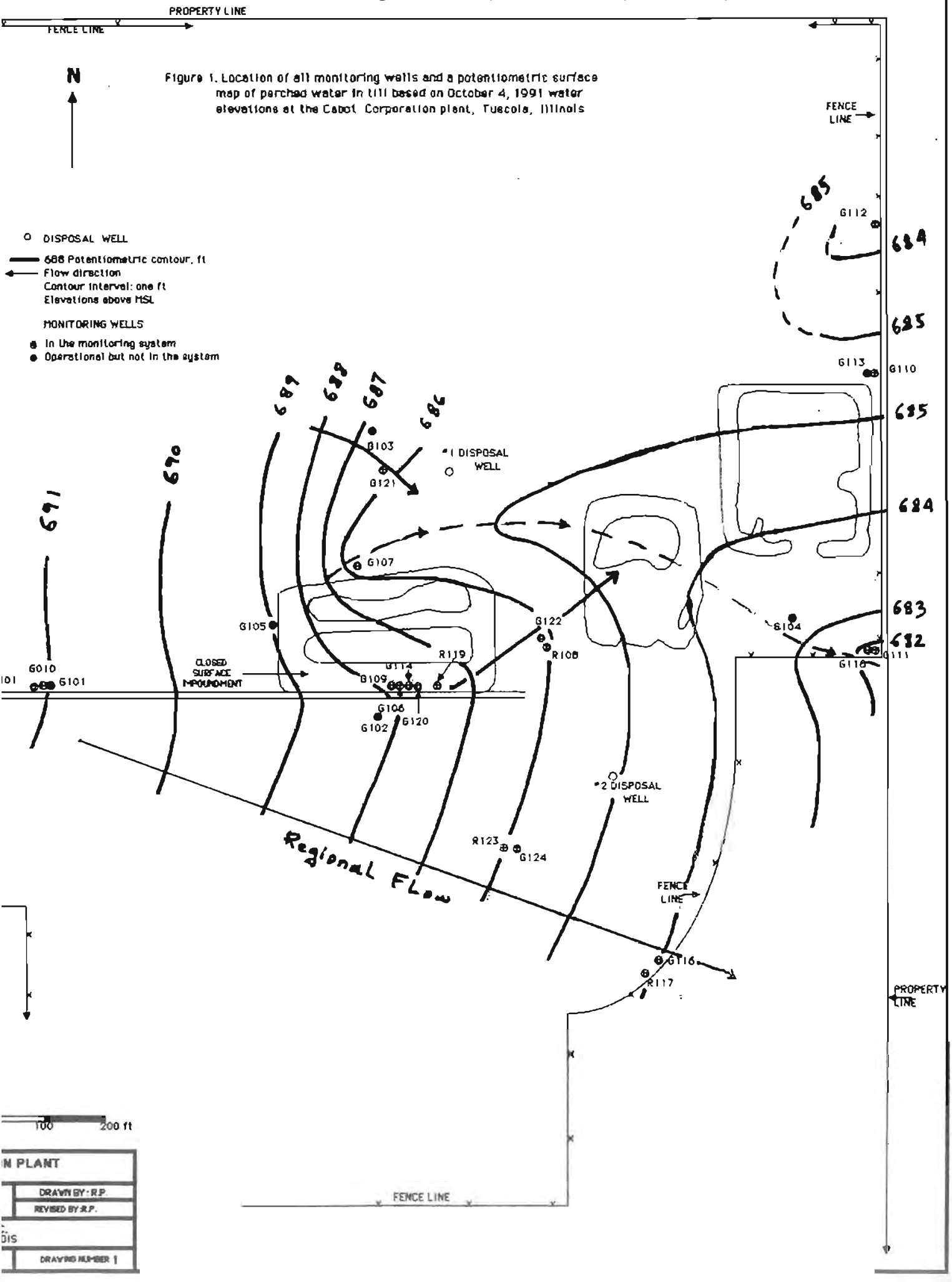
Water level differences in the well clusters indicate that the groundwater moves downward (Table 1). The pressure head ranges from 26.97 to 30.56 ft between the shallow till wells and deep sand wells in the same cluster. The pressure head is 42.02 ft between G106 and G120 which are in the cluster next to the closed impoundment.

Table 1. Depth to and elevation of water levels, well depth and screen interval in all monitoring wells at the Cabot Plant on 10/04/91

Well No.	Ground Elev., ft	Well Depth, ft	Depth to Water, ft	Water Level Elev., ft	Screen Int., ft	Level difference in well clusters, ft
			A. Shallow Wells in Till			
G101	693.44	31.35	2.40	691.04	11.4-31.3	
R101	693.42	29.81	4.36	689.06	20.2-29.8	
G102	690.68	29.10	2.25	688.43	11.4-31.4	
G103	690.87	29.35	4.00	686.87	10.0-29.8	
G104	686.90	26.60	3.35	683.55	10.6-30.5	
G105	694.04	29.15	5.00	689.04	10.5-29.8	
G106	691.84	30.45	4.10	687.74	10.9-30.2	
G107	690.60	30.35	4.90	685.70	10.9-30.2	
R108	689.29	20.75	3.25	686.04	10.7-20.7	
G110	689.66	16.30	4.30	685.36	6.8-16.3	
G111	686.64	15.63	4.78	681.86	6.0-15.7	
G112	690.97	16.58	7.68	683.29	6.9-16.5	
G116	688.92	20.11	4.91	684.01	10.4-20.3	
G124	689.58	20.83	3.68	685.90	11.1-20.6	
			B.Deep Wells in Sand			
G01D	693.48	97.03	34.98	658.50	95.6-100.4	
R119	690.07	95.59	31.44	658.63	93.8-98.9	
G121	690.99	96.41	32.21	658.78	93.2-97.9	
G122	689.78	97.11	30.71	659.07	92.9-97.6	
R123	689.51	94.58	30.58	658.93	90.5-95.5	
			C. Well Clusters			
R101	693.42	29.81	4.36	689.06	20.2-29.8	
						30.56
G01D	693.48	97.03	34.98	658.50	95.6-100.4	
G106	691.84	30.45	4.10	687.74	10.9-30.2	
						17.42
G109	691.59	50.57	21.27	670.32	45.7-50.9	
						11.28
G114	691.75	73.66	32.71	659.04	70.1-75.1	
						0.41
R119	690.07	95.59	31.44	658.63	93.8-98.9	
						12.91
G120	691.68	201.41	45.96	645.72	198.7-203.4	

Table 1. Cont'd

Well No.	Ground Elev., ft	Well Depth, ft*	Depth to Water, ft	Water Level Elev., ft	Screen Int., ft	Level diff in well clusters, ft
R108	689.29	20.75	3.25	686.04	10.7-20.7	26.97
G122	689.78	97.11	30.71	659.07	92.9-97.6	
G110	689.66	16.30	4.30	685.36	6.8-16.3	6.21
G113	689.05	47.70	9.90	679.15	45.5-50.5	
G111	686.64	15.63	4.78	681.86	6.0-15.7	22.94
G118	686.27	50.03	27.35	658.92	45.8-50.7	
G116	688.92	20.11	4.91	684.01	10.4-20.3	26.57
R117	689.25	50.26	31.81	657.44	46.8-51.8	
G124	689.58	20.83	3.68	685.90	11.1-20.6	26.97
R123	689.51	94.58	30.58	658.93	90.5-95.5	


PROPERTY LINE
FENCE LINE
N
Figure 1. Location of all monitoring wells and a potentiometric surface map of perched water in till based on October 4, 1991 water elevations at the Cabot Corporation plant, Tuscola, Illinois
FENCE LINE
DISPOSAL WELL
686 Potentiometric contour, ft
Flow direction
Contour interval: one ft
Elevations above MSL
MONITORING WELLS
In the monitoring system
Operational but not in the system
685
684
G112
G113
G110
G111
G116
G104
G103
G121
#1 DISPOSAL WELL
G107
G105
G122
R108
R119
G114
G109
G106
G102
G120
G101
G010
CLOSED SURFACE IMPOUNDMENT
#2 DISPOSAL WELL
R123
G124
FENCE LINE
G118
R117
PROPERTY LINE
Regional Flow
100
200 ft
IN PLANT
DRAWN BY: R.P.
REVISED BY R.P.
DRAWING NUMBER 1

pH and Specific Conductance

pH and specific conductance (SC) were measured in the field when the samples were collected on October 7, 1991.

pH

The results of the pH measurements are in Table 2. They are between 5.74 (R108) and 10.60 (G109) among the 19 sampled wells.

pH ranges from 5.74 to 7.40 in the shallow wells. The background well, R101, has a pH of 7.09. The downgradient wells near the closed impoundment (G106, G107 and R108) exhibit a pH of less than 7.0; the other downgradient wells, G110, G111, G112, G116 and G124 show a pH slightly above 7.0. The deep sand wells present pH values varying from 6.90 (G121) to 7.64 (G123). High pH values found in G117, G119 and G123 in the previous quarters were not present in this quarter's samples from their replacement wells (R117, R119, R123). This suggests that high pH in the two sand wells was possibly due to leaching of calcium from the cement in the annular areas of these wells. Similarly, the high pH in G109 may suggest leaching of cement in this well, too. pH generally increases downward in the well clusters (Table 2).

It appears that migration of the acidic fluids from the closed impoundment in the past lowered pH of the shallow groundwater from about neutral to acidic near the impoundment. However, pH of the shallow groundwater is slightly greater than neutral in other areas. pH slightly increases with depth in groundwater.

Specific Conductance

The SC values range from 482 µmhos in G118 to 13960 µmhos in G107 (Table 2). The SC of water in the shallow wells varies from 734 µmhos (G116) to 13960 µmhos (G107). The upgradient well, R101, shows a SC of 746 µmhos. SC is high in the wells near the impoundment. SC does not vary significantly in the deep sand wells. The lowest SC, 635 µmhos, is associated with G123; the highest, 761 µmhos is associated with G122. SC of G01D is 708 µmhos.

Table 2. pH and specific conductivity of the groundwater samples collected from the monitoring wells at the Cabot Corporation plant on 10/07/91

A. Shallow Wells

Well No.	pH (unit)	Sc (µmhos)
R101	7.09	746
G106	6.14	4640
G107	6.02	13960
R108	5.74	13510
G110	7.32	823
G111	7.40	790
G112	7.29	1470
G116	7.37	734
G124	7.32	1870

B. Deep Wells in Sand

G01D	7.49	732
R119	7.47	721
G121	6.90	713
G122	7.13	761
R123	7.64	635

C. Well Clusters

R101	7.09	746
G01D	7.49	732
G106	6.14	4640
G109	10.60	6380
G114	6.53	4580
R119	7.47	721
G120	7.52	4100
R108	5.74	13510
G122	7.13	761
G111	7.40	790
G118	7.81	482
G116	7.37	734
R117	8.03	698
G124	7.32	1870
R123	7.64	635
Trip Blank	G125	7.70	10 (DI Water)

Note: pH and Sc were determined in the samples at the field

SC generally decreases with depth in the well clusters. SC is relatively high in all of the wells in the G106/G109/G114/R119/G120 cluster, except R119.

It appears that migration of the fluid in the past from the closed impoundment had caused elevated SC values in the shallow groundwater near the impoundment. In general, SC decreases with depth and distance from the impoundment. High SC in G120 is probably affected by the water in the Pennsylvanian bedrock.

Hazardous Constituents

Type

Analyses of the fourth quarterly collected water samples from 19 wells indicated that none of the base neutrals and acid extractables were above their detection limits (Appendix). Of the volatile organic compounds (VOCs), eight had concentrations exceeding their detection limits. The eight VOCs are : trichloroethene, 1,2,t dichloroethene, tetrachloroethene, vinyl chloride, ethyl benzene, 1,1,1 trichloroethane, toluene and xylenes (Table 3). Of these, the last four have not been detected during recent years.

All of the individual phenol compounds were below their detection limits (Appendix).

Occurrence

Thirteen of the 19 wells sampled do not have any detectable VOCs. These wells are: five shallow wells (R101, G110, G111, G112, G124), two intermediate depth wells (R117, G118), five sand wells R119, G121, G122, R123, G01D) and the deepest well (G120) near the bedrock (Table 3). One or more of the eight VOCs occur in six wells. They include four (G106, G107, R108, G116) of the nine shallow wells in the weathered till and two wells (G109, G114) monitoring intermediate depths in the till. The five monitoring wells with detectable VOCs are located near the closed impoundment. The other well, G116, is located approximately 600 ft downgradient (southeast) from the impoundment.

Neither the deepest well nor the five sand wells had detectable VOCs.

No VOCs were found above their detection limits in three well clusters which are located at some distance from the closed impoundment. Three wells (G106, G109, G114) in the G106/G120 cluster, one well (R108) in the R108/G122 cluster and G116 in the G116/R117 cluster showed detectable VOCs concentrations. Vertical distribution of VOCs in the G106/G120 well cluster is shown in Figure 3.

It appears that eight detectable VOCs primarily occurred in shallow and intermediate depth wells near the impoundment. A few VOCs had occurred sporadically in G116. Because G124, Which is between G106 and G116, did not have any HCs, it is unlikely that the closed impoundment is the source of these occurrences. The low concentrations in G116 may also originate from laboratory/sampling errors.

Table 3. Hazardous constituents (VOC) with above detection limit concentrations (µg/l) in the groundwater samples collected from the monitoring wells at the Cabot Corporation plant on 10/07/91

Well No.	Trichloroethene	1,2 t Dichloroethene	Tetrachloroethene	Vinyl chloride	Ethyl benzene	1,1,1 Trichloroethane	Toluene	Xylenes
A. Shallow Wells								
R101	<2	<5	<5	<5	<2	<5	<2	<5
G106	587	1440	2710	149	30	<5	78	79
G107	32	3590	23	992	<2	<5	<2	<5
R108	48	893	40	3950	<2	<5	<2	<5
G110	<2	<5	<5	<5	<2	<5	<2	<5
G111	<2	<5	<5	<5	<2	<5	<2	<5
G112	<2	<5	<5	<5	<2	<5	<2	<5
G116	<2	85	<5	<5	<2	<5	<2	<5
G124	<2	<5	<5	<5	<2	<5	<2	<5
B. Deep Wells in Sand								
G010	<2	<5	<5	<5	<2	<5	<2	<5
R119	<2	<5	<5	<5	<2	<5	<2	<5
G121	<2	<5	<5	<5	<2	<5	<2	<5
G122	<2	<5	<5	<5	<2	<5	<2	<5
R123	<2	<5	<5	<5	<2	<5	<2	<5
C. Well Clusters								
R101	<2	<5	<5	<5	<2	<5	<2	<5
G010	<2	<5	<5	<5	<2	<5	<2	<5
G106	587	1440	2710	149	30	<5	78	79
G109	25	90	7	<5	9	<5	<2	<5
G114	110	3110	40	275	48	23	188	131
R119	<2	<5	<5	<5	<2	<5	<2	<5
G120	<2	<5	<5	<5	<2	<5	<2	<5
R108	48	893	40	3950	<2	<5	<2	<5
G122	<2	<5	<5	<5	<2	<5	<2	<5
G111	<2	<5	<5	<5	<2	<5	<2	<5
G118	<2	<5	<5	<5	<2	<5	<2	<5
G116	<2	85	<5		<2	<5	<2	<5
R117	<2	<5	<5	<5	<2	<5	<2	<5
G124	<2	<5	<5	<5	<2	<5	<2	<5
R123	<2	<5	<5	<5	<2	<5	<2	<5
G125 (trip bl)	<2	<5	<5	<5	<2	<5	<2	<5

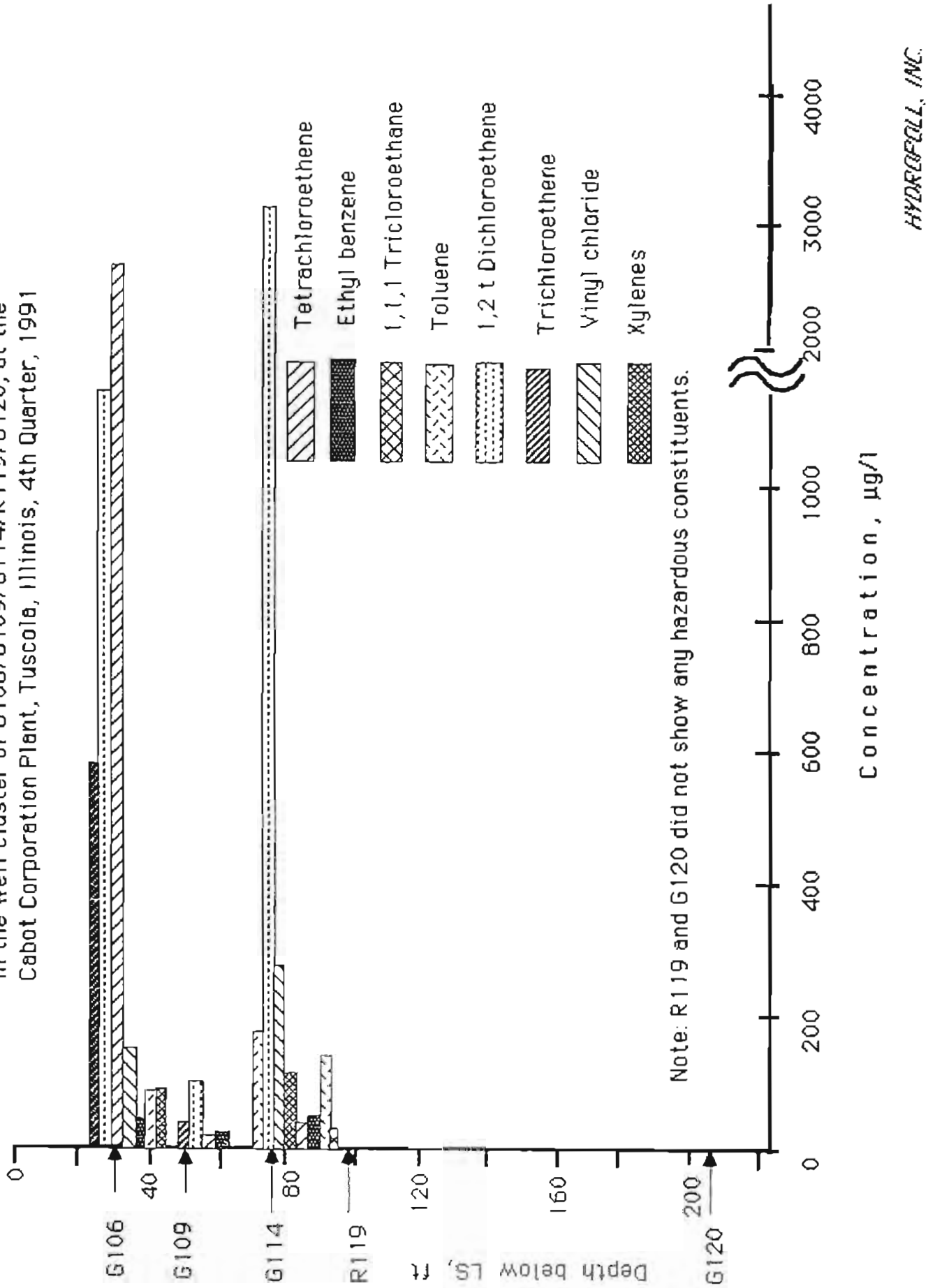


Figure 3. Vertical distribution of hazardous constituents (volatiles) in the well cluster of G106/G109/G114/R119/G120, at the Cabot Corporation Plant, Tuscola, Illinois, 4th Quarter, 1991

Concentrations

Concentrations of VOCs (HCs) are below their detection limits in 13 of the 19 sampled monitoring wells at the site (Table 3). In the remaining six wells, detectable concentrations of eight VOCs are between seven µg/l tetrachloroethene and 3950 µg/l vinyl chloride in R108 (Table 3). Relatively high concentrations are primarily associated with vinyl chloride, 1,2 t dichloroethene and tetrachloroethene. The other five HCs (trichloroethene, ethyl benzene, 1,1,1 trichloroethane, toluene and xylenes) occur with relatively low concentrations. Relatively high concentrations are associated with G107, R108 and G114. Figures 4, 5, 6 and 7 present concentrations of four VOCs which are detected in more than one shallow wells.

Of the nine shallow monitoring wells in the weathered till, five (R101, G110, G111, G112, and G124) do not have any VOCs. The five sand wells, the deepest well (G120) and two intermediate depth wells (R117 and G118) do not have any detectable VOCs either (Table 3).

Statistical Analyses

Concentrations of eight detectable HCs were analyzed statistically (Table 4). Results indicated that 1,2 t dichloroethene was detectable in six wells, tetrachloroethene and trichloroethene in five, vinyl chloride in four, ethyl benzene in three, toluene and xylenes in two, and 1,1,1 trichloroethane in one. Range, mean, median, standard deviation, and coefficient of variation of the eight HCs are in Table 4.

The mean represents a measure of central tendency of the concentration and is an arithmetically calculated average. The median is the concentration of the middle item of the population when the concentrations are arranged according to magnitude.

Dispersion of concentrations about the mean is generally measured using standard deviation which shows variability of concentrations. The highest standard deviation, 1050, is related to 1,2 t dichloroethene which is, therefore, the most variable among the detectable HCs.

Coefficient of variation is a relative measure of dispersion and is expressed as percent. Higher coefficient of variation means relatively high dispersion about the mean. The higher coefficient of variation is associated with tetrachloroethene.

Table 4. Statistical data on hazardous constituents (VOC) in the groundwater samples from the monitoring wells at the Cabot Corporation Plant, Tuscola, Illinois, fourth quarter 1991

Contaminants	Sample * Population	No of Samples * LessThanDetection Limit/AboveLimit	Range of * Concentr. ug/l	Mean Concentr. ug/l	Median Concentr. ug/l	Standard Deviation	Coefficient of Variation, %
1,2 t Dichloro-ethene	19	13/6	<5-3590	486	<5	1050	2.16
Tetrachloro-ethene	19	14/5	<5-2710	150	<5	603	4.02
Trichloro-ethene	19	14/5	<2-587	42.9	<2	131	3.05
Vinylchloride	19	15/4	<5-3950	284	<5	893	3.14
Ethylbenzene	19	16/3	<2-48	5.4	<2	12.0	2.22
1,1,1 Tri-chloroethane	19	18/1	<5-23	3.6	<5	4.6	1.28
Toluene	19	17/2	<2-188	14.9	<2	44.3	2.97
Xylenes	19	17/2	<5-131	13.3	<5	32.6	2.45

* See Table 3

Note: Below detection limit concentrations were treated as BDL/2 µg/l in the statistical analyses.

Migration

Concentrations and estimated extent of contamination boundaries of the four HCs which occur more than one well in shallow groundwater are presented in Figures 4 through 7.

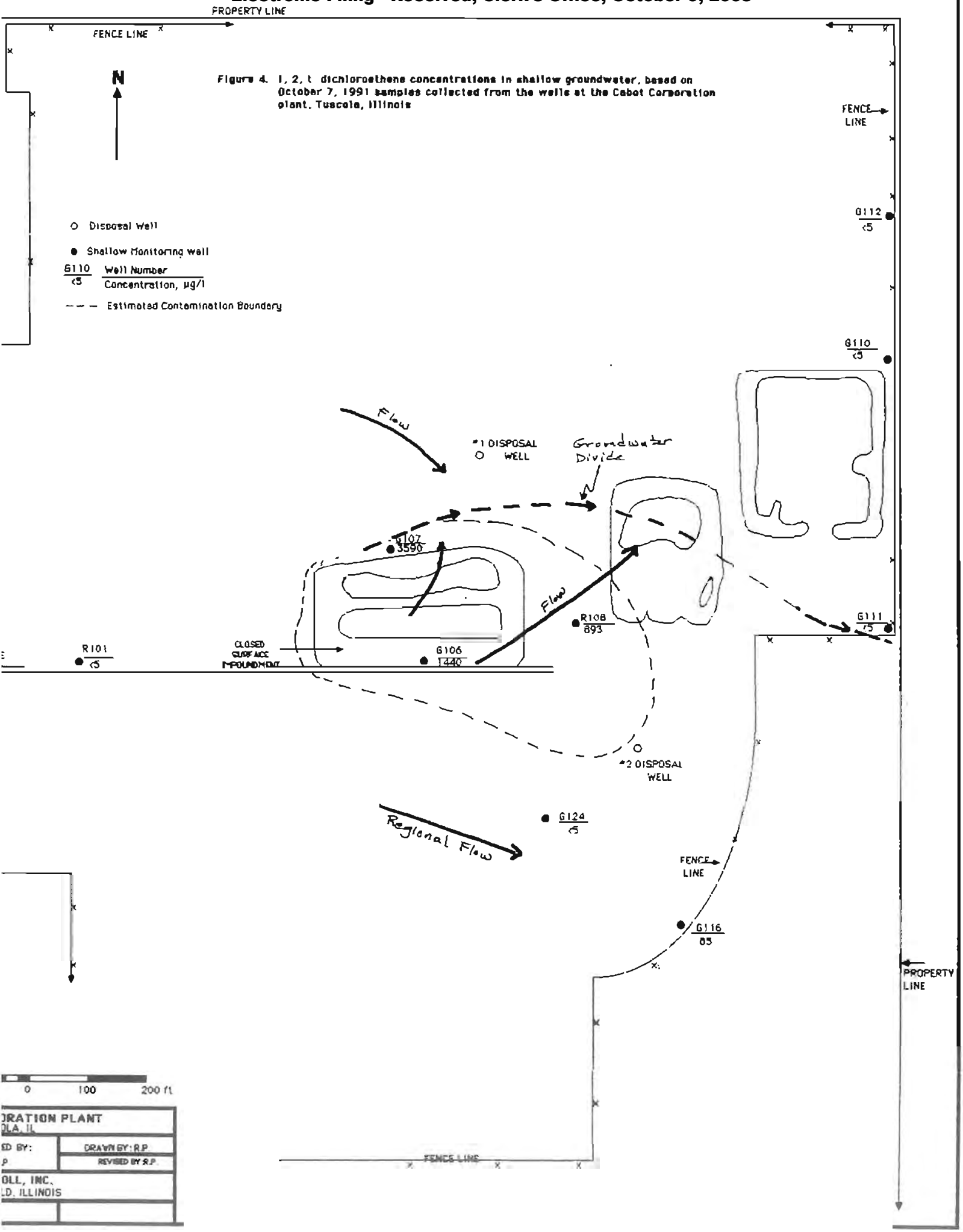
Lateral Extent of Migration in Shallow Water (Weathered Till).

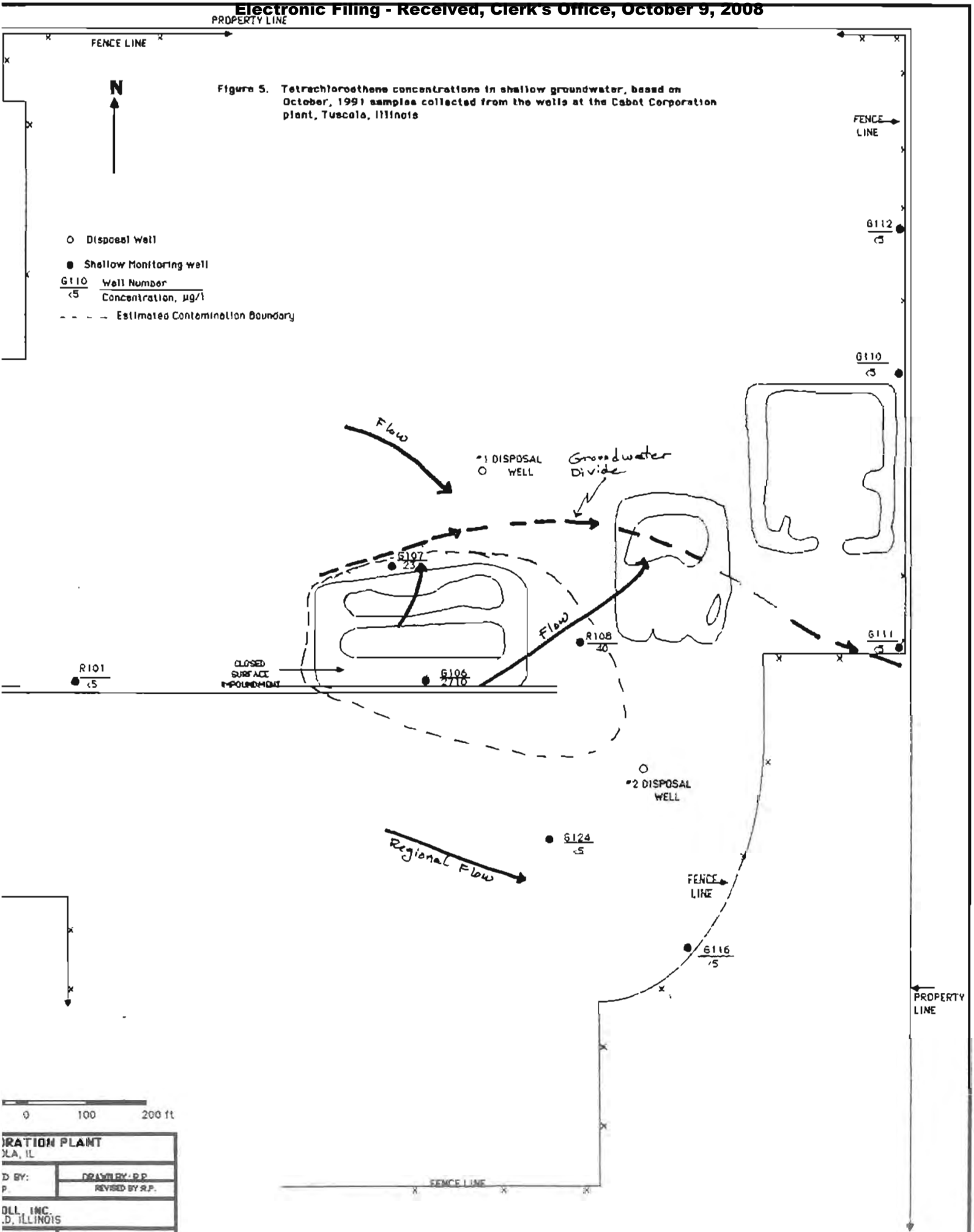
The regional flow direction is towards the southeast. Therefore, the maximum extent of migration is expected to occur in this direction. The northerly extent of the migration from the impoundment is limited due to presence of a groundwater divide just to the north of the impoundment. Because no flow occurs across the divide, thus it constitutes the northernmost boundary of the contamination from the impoundment. The extent of the contamination in the westerly direction is also limited because the west is upgradient from the impoundment. Radial flow, which had a westerly component for short distance in the past, has disappeared since the closure of the impoundment in November 1987.

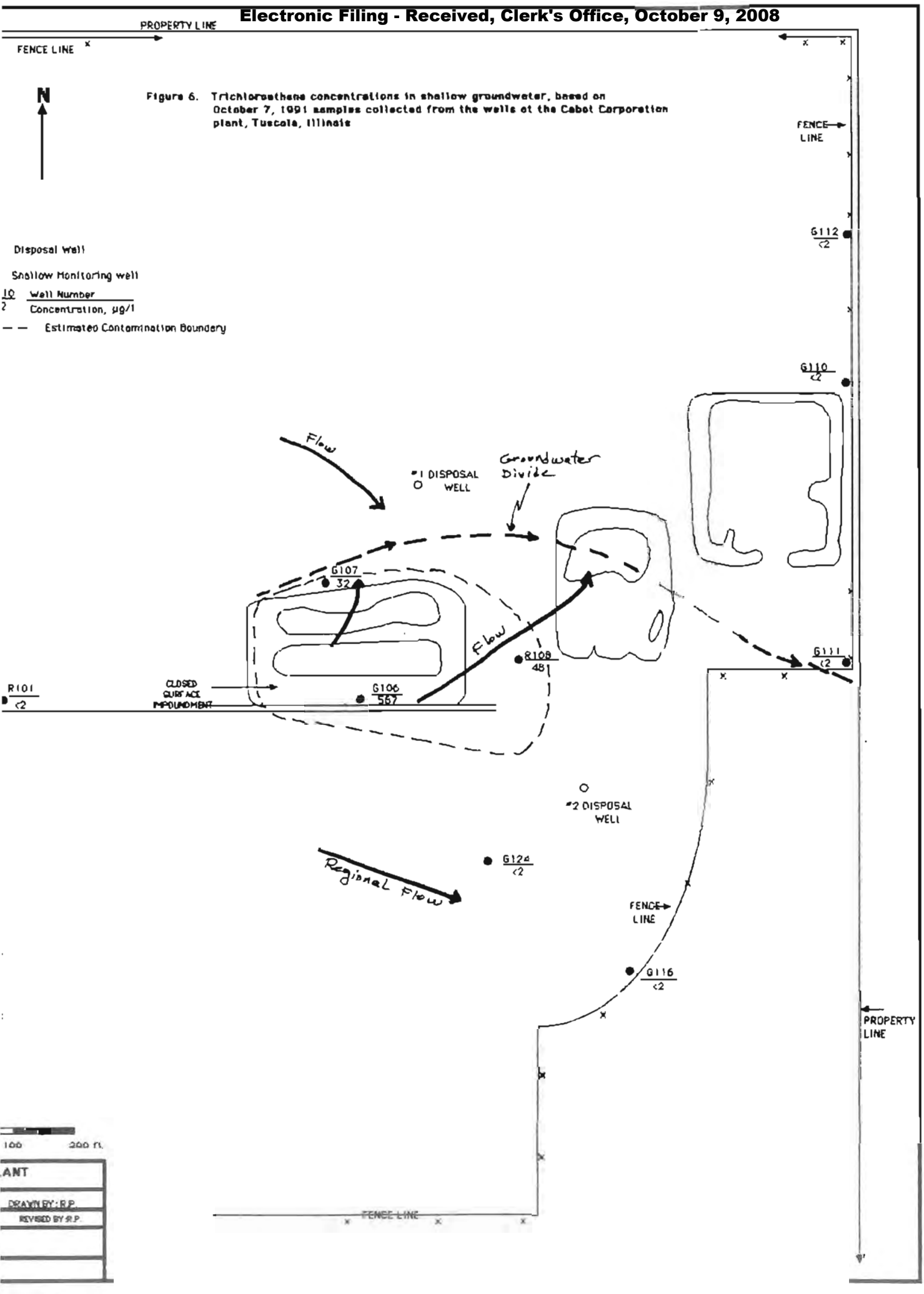
The shallow wells G106, G124 and G116 are approximately lined at the regional groundwater flow direction (Figure 1). They are located about 10, 300, and 600 ft, respectively, from the closed impoundment. Concentrations in the shallow wells and estimated extent of contamination boundaries of the four HCs are shown in Figures 5, 6, 7 and 8. They and Table 3 indicate that only G106, G107 and R108 have detectable concentrations of HCs. G106 and G107 are next to the closed impoundment and R108 is 100 ft from it.

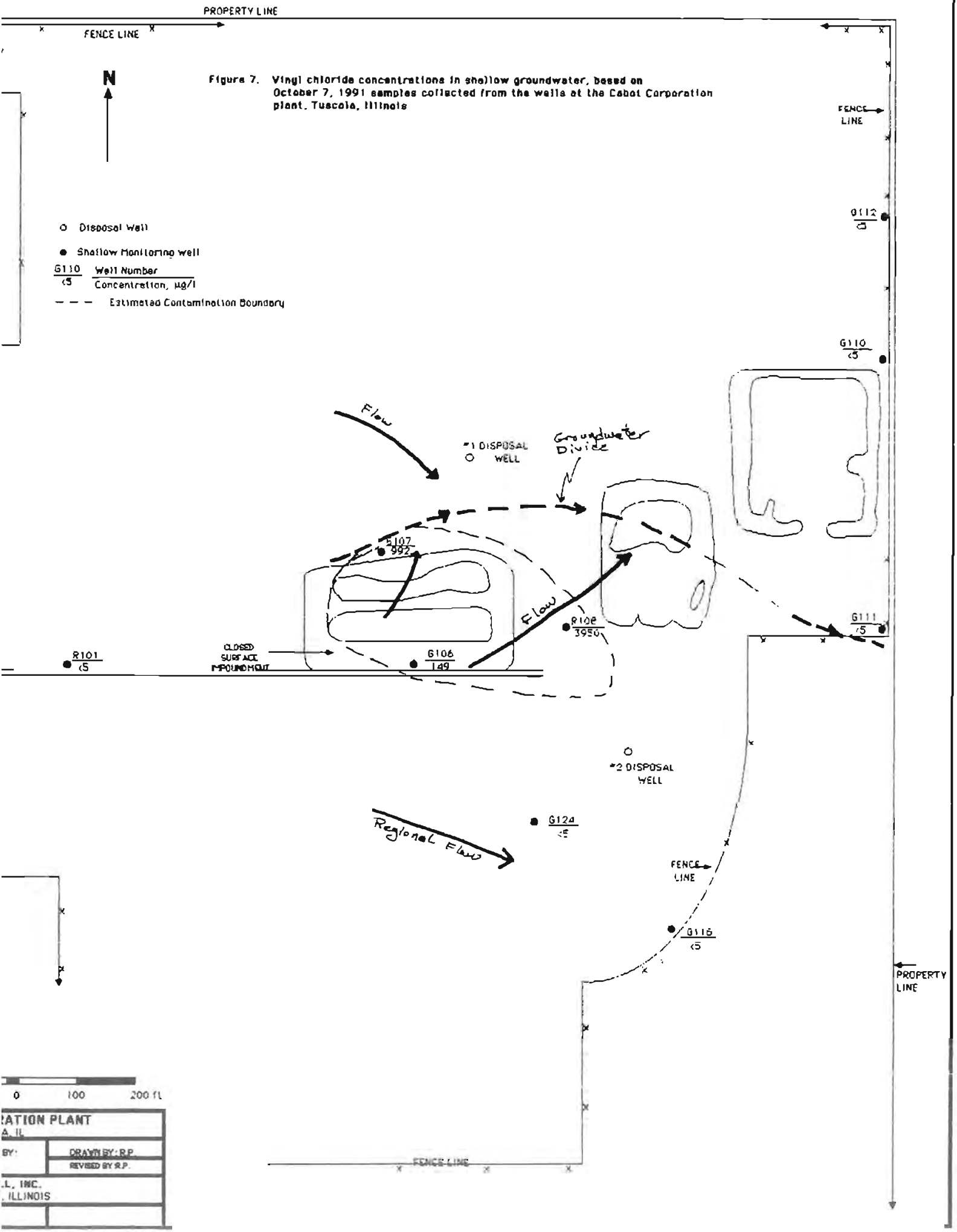
Occurrence of 1,2 t dichloroethene is shown in Figure 4. The extent of the lateral migration of 1,2 t dichloroethene at the regional flow direction is estimated to be 150 ft from G106 (about one half the distance between G106 and G124) or 160 ft from the toe of the berm, although the exact location of the migration boundary is not known. This distance may be shorter in other directions.

Because the impoundment began to operate in 1966 and the migration distance was estimated as 160 ft first in 1989, the estimated migration distance was traveled in 23 years. Thus, the average rate of migration is approximately seven ft/yr within the 160 ft distance. The rate of migration should be slower in other directions. Also, it should be slower in future years because of the closure of the impoundment in 1987.


PROPERTY LINE
FENCE LINE
N
Figure 4. 1, 2, t dichloroethene concentrations in shallow groundwater, based on October 7, 1991 samples collected from the wells at the Cabot Corporation plant, Tuscola, Illinois
FENCE LINE
G112 <5
O Disposal Well
● Shallow Monitoring Well
G110 <5 Well Number / Concentration, µg/l
– – – Estimated Contamination Boundary
G110 <5
Flow
#1 DISPOSAL WELL
Groundwater Divide
R107 3590
Flow
R108 893
G111 <5
R101 <5
CLOSED SURFACE IMPOUNDMENT
G106 1440
#2 DISPOSAL WELL
G124 <5
Regional Flow
FENCE LINE
G116 85
PROPERTY LINE
FENCE LINE
0
100
200 ft
RATION PLANT
LA, IL
D BY:
DRAWN BY: R.P.
REVISED BY R.P.
OLL, INC.
D, ILLINOIS


PROPERTY LINE
FENCE LINE
N
Figure 5. Tetrachloroethene concentrations in shallow groundwater, based on October, 1991 samples collected from the wells at the Cabot Corporation plant, Tuscola, Illinois
FENCE LINE
G112 <5
O Disposal Well
● Shallow Monitoring well
G110 / <5 Well Number / Concentration, µg/l
- - - - Estimated Contamination Boundary
G110 <5
Flow
#1 DISPOSAL WELL
Groundwater Divide
G107 25
Flow
R108 40
G111 <5
R101 <5
CLOSED SURFACE IMPOUNDMENT
G106 710
#2 DISPOSAL WELL
G124 <5
Regional Flow
FENCE LINE
G116 <5
PROPERTY LINE
FENCE LINE
0 100 200 ft
RATION PLANT
LA, IL
D BY:
DRAWN BY: R.P.
REVISED BY R.P.
OLL, INC.
D, ILLINOIS

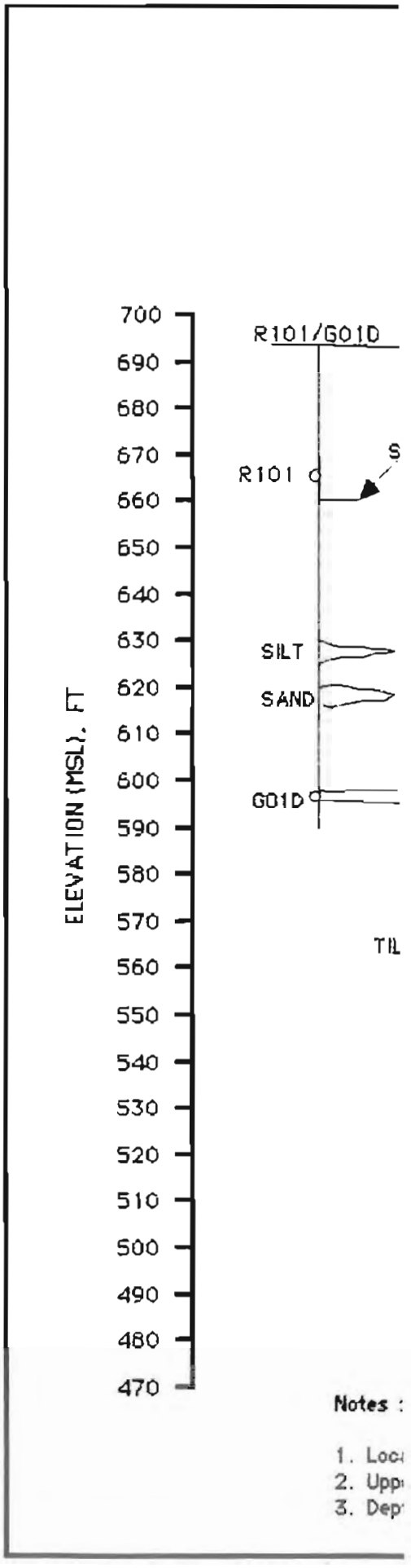

PROPERTY LINE
FENCE LINE
N
Figure 6. Trichloroethene concentrations in shallow groundwater, based on October 7, 1991 samples collected from the wells at the Cabot Corporation plant, Tuscola, Illinois
FENCE LINE
G112 <2
Disposal Well
Shallow Monitoring well
10 Well Number
2 Concentration, µg/l
Estimated Contamination Boundary
G110 <2
Flow
#1 DISPOSAL WELL
Groundwater Divide
G107 32
Flow
R108 481
G111 <2
R101 <2
CLOSED SURFACE IMPOUNDMENT
G106 567
#2 DISPOSAL WELL
G124 <2
Regional Flow
FENCE LINE
G116 <2
PROPERTY LINE
100
200 ft
ANT
DRAWN BY: R.P.
REVISED BY R.P.
FENCE LINE


PROPERTY LINE
FENCE LINE
N
Figure 7. Vinyl chloride concentrations in shallow groundwater, based on October 7, 1991 samples collected from the wells at the Cabot Corporation plant, Tuscola, Illinois
FENCE LINE
G112
<5
Disposal Well
Shallow Monitoring Well
G110 <5 Well Number / Concentration, µg/l
Estimated Contamination Boundary
G110
<5
Flow
#1 DISPOSAL WELL
Groundwater Divide
G107
992
Flow
R108
3950
G111
<5
R101
<5
CLOSED SURFACE IMPOUNDMENT
G106
149
#2 DISPOSAL WELL
G124
<5
Regional Flow
FENCE LINE
G116
<5
PROPERTY LINE
FENCE LINE
0
100
200 ft
ATION PLANT
A, IL
BY:
DRAWN BY: R.P.
REVISED BY R.P.
L, INC.
ILLINOIS

Tetrachloroethene, trichloroethene and vinyl chloride occurred above their detection limits in G106, G107 and R108 (Figures 5, 6 and 7) which are next to the impoundment. Therefore, the maximum extent of contamination involving these parameters should be less than 160-ft estimated for 1,2 t dichloroethene.

Because G124 did not have any detectable VOCs and G116 had a few VOCs sporadically in low concentrations whose source may not be the impoundment, G116 is not included in the contaminated area from the impoundment.

Vertical Extent of Migration . Concentrations of HCs in the well clusters are in Table 3 and Figure 3. The well cluster G106/G109/G114/ R119/G120 is the one located closest to the impoundment (about 10 ft). Three wells G106, G109 and G114, in this cluster have some HCs. G106 is 20 ft, G109 50 ft and G114 approximately 75 ft deep in the till. R119, 100 ft deep in the sand, and G120 which is the deepest well (212 ft) in the cluster, do not have any HCs (Table 3). Considering both the estimated lateral extent of the migration front in the shallow groundwater and no contamination in the sand, it is estimated that the HCs have migrated no more than 5 ft below the bottom of G114, that is 80 ft vertically below the land surface near the impoundment. The exact vertical migration distance is not known. Estimated contamination boundary of HCs in vertical direction is shown in Figure 8. As indicated previously, contamination in G114 was probably resulted from the migration of contaminated shallow groundwater through the annular area of G114 rather than mass movement of shallow water through the till.


ELEVATION (MSL), FT
700
690
680
670
660
650
640
630
620
610
600
590
580
570
560
550
540
530
520
510
500
490
480
470
R101/G01D
R101
S
SILT
SAND
G01D
TIL
Notes :
1. Loc
2. Upp
3. Dep

TOTAL CYANIDE AND TOTAL RECOVERABLE PHENOLICS

Analysis of total recoverable phenolics, and total cyanide made on water samples from 19 wells are Table 5 and in the Appendix. In general, the concentrations are low and range from <0.003 to 0.062 mg/l. The Public Food Processing Water Supply Standard (PFPWSS) of the IPCB for cyanide and phenols are 0.025 and 0.001 mg/l, respectively.

Total cyanide was undetected in 18 wells. It was measurable only in one well (R114) with a concentration of 0.004 mg/l (Table 5) which is below the IPCB's standard. Total recoverable phenolics were detected in most of the monitoring wells (17). Detectable concentrations ranged from 0.003 mg/l (G114 and G111) to 0.062 mg/l (R101). Of the shallow wells, R101 (the upgradient well) showed the highest concentration of total phenolics (Figure 9). Among the deep sand wells concentrations ranged from 0.005 to 0.010 mg/l (Figure 10). The deepest well, G120, had a concentration of 0.004 mg/l. The detectable concentrations exceed the IPCB's standard of 0.001 mg/l for total phenols (IPCB, 1988).

Occurrence and distribution of these two parameters suggest that the closed impoundment may not be the source of them in groundwater. Total recoverable phenolics are analyzed with a colorimetric method. This method is not precise as the gc/ms method and the results are usually affected by other solutes in the water samples (personal communication with Dr. Gayle Marks of TEI Analytical, Inc. on 6/21/91). Interference by a glycol/diol type compound on total phenol results was indicated in the first quarter report (Hydropoll, 1991). As indicated before, the water samples were also analyzed for acid extractables which included individual phenolic compounds (Appendix). These analyses indicated that phenol and all of the phenolic compounds were below their detection limits. Daily Analytical Laboratories analyzed water samples from some of the Cabot's monitoring wells for phenols in 1990 (Hydropoll, 1990). Two blank samples (reagent grade pure laboratory water) were used to investigate potential contamination from laboratory procedures. The analyses showed 0.006 mg/l phenols in the two blank samples. Thus, a laboratory error of 0.006 mg/l was added to the analysis results in the laboratory

Based on the above discussions, it is concluded that the groundwater below the Cabot facility is not contaminated with phenol.

Table 5. Concentration (mg/l) of total cyanide and recoverable phenolics in the groundwater samples collected from the monitoring wells at the Cabot Corporation plant on 10/7/1991

Well No.	Total cyanide	Total recoverable phenolics
	A. Shallow Wells	
R101	<0.003	0.062
G106	<0.003	0.018
G107	<0.003	<0.003
R108	<0.003	0.008
G110	<0.003	0.004
G111	<0.003	0.003
G112	<0.003	0.008
G116	<0.003	0.004
G124	<0.003	<0.003
	B. Deep Wells in Sand	
G01D	<0.003	0.010
G119	<0.003	0.006
G121	<0.003	0.005
G122	<0.003	0.010
G123	<0.003	0.007
	C. Well Clusters	
R101	<0.003	0.062
G01D	<0.003	0.010
G106	<0.003	0.018
G109	<0.003	0.017
G114	0.004	0.003
G119	<0.003	0.006
G120	<0.003	0.004
R108	<0.003	0.008
G122	<0.003	0.010
G111	<0.003	0.003
G118	<0.003	0.014
G116	<0.003	0.004
G117	<0.003	0.031
G124	<0.003	<0.003
G123	<0.003	0.007
G125 (Trip Blank)	<0.003	<0.003

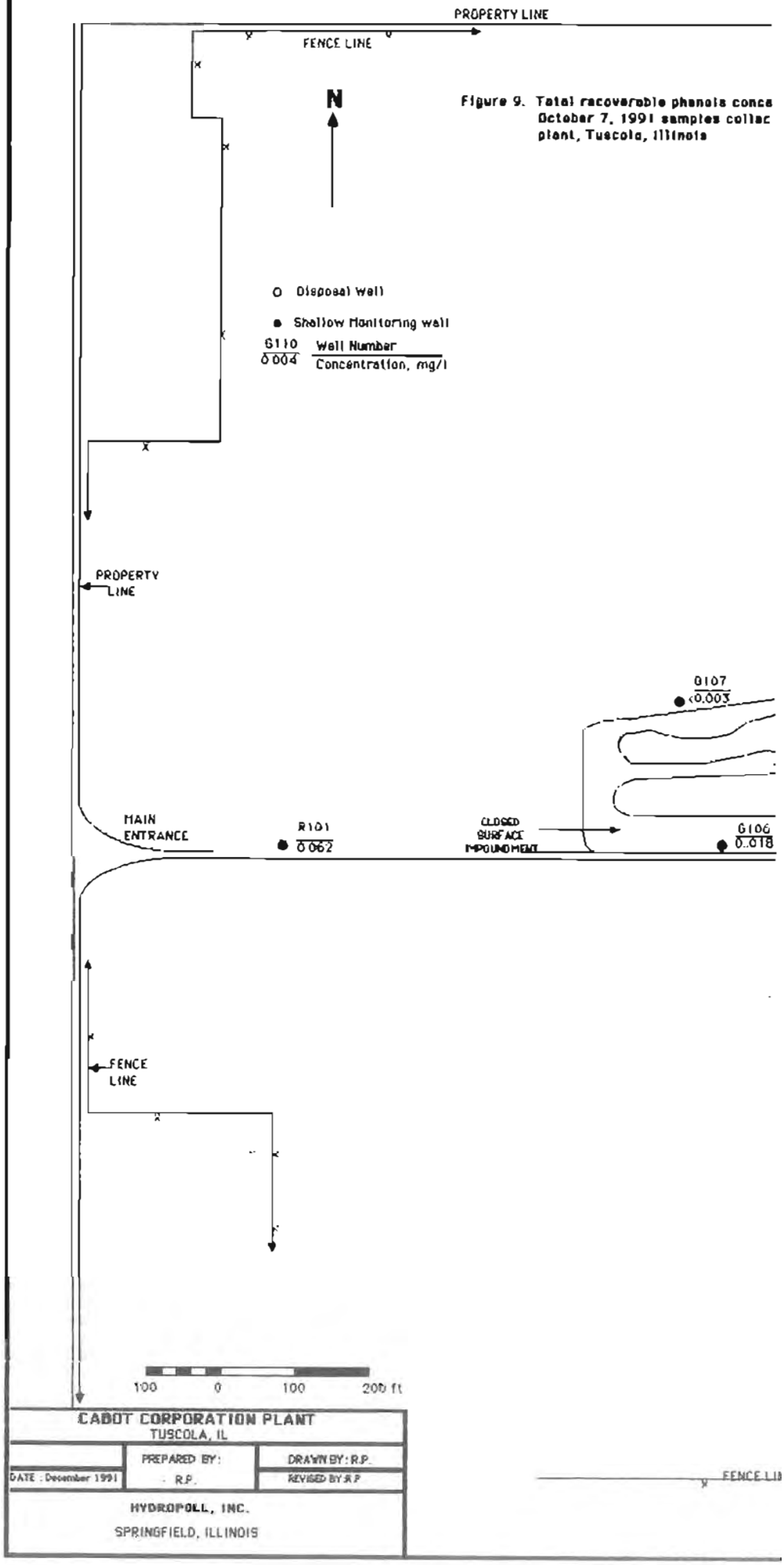
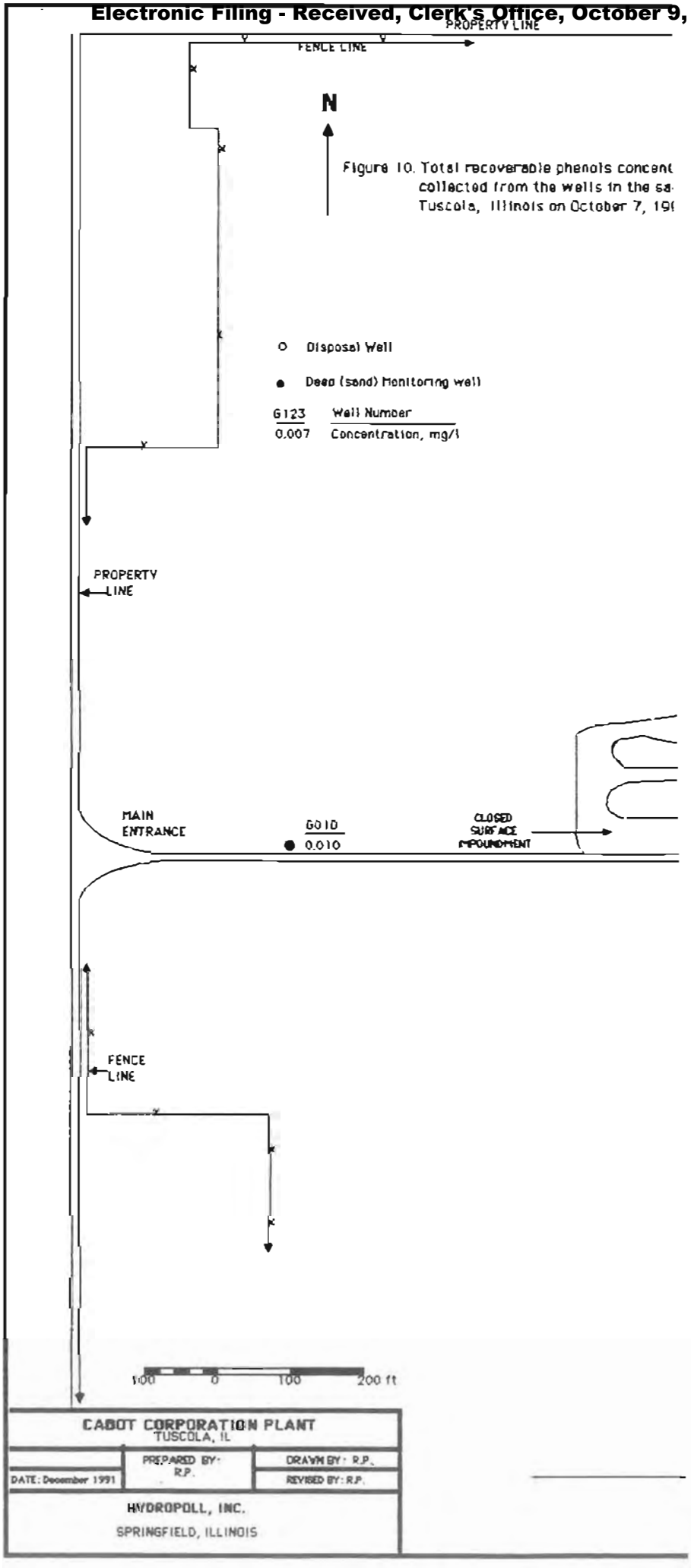


Figure 9. Total recoverable phenols conce
October 7, 1991 samples collec
plant, Tuscola, Illinois


PROPERTY LINE
FENCE LINE
N
Figure 10. Total recoverable phenols concent
collected from the wells in the sa
Tuscola, Illinois on October 7, 19
Disposal Well
Deep (sand) Monitoring well
G123
0.007
Well Number
Concentration, mg/l
PROPERTY LINE
MAIN ENTRANCE
G010
0.010
CLOSED SURFACE IMPOUNDMENT
FENCE LINE
100
0
100
200 ft
CABOT CORPORATION PLANT
TUSCOLA, IL
PREPARED BY: R.P.
DRAWN BY: R.P.
DATE: December 1991
REVISED BY: R.P.
HYDROPOLL, INC.
SPRINGFIELD, ILLINOIS

PARAMETERS ESTABLISHING GROUNWATER QUALITY

Initial Background vs Shallow Wells

The concentrations of the groundwater quality parameters in the samples from the monitoring wells and the means of the initial background concentrations in the previous upgradient well, G101 (which was replaced by R101 in 1989), are presented in Table 6. The means of the initial background concentrations are based on the four quarterly samples taken during the first year of monitoring (Hydropoll, 1984). The concentration of chloride, iron, and sulfate in R101 are lower and that of manganese, phenols and sodium are higher than the means of the initial background.

The concentrations in the shallow downgradient wells (G106, G107 and R108) next to the impoundment are higher than the initial means, except sulfate in three wells and iron in G107. Contrarily, the analysis of the samples from the four shallow monitoring wells (G110, G111, G112, G116 and G124) along the eastern plant boundary show lower concentration of the parameters than the initial background means, except chloride in G112 and G124, and phenols in all five.

Shallow Wells

The analyses in Table 6 indicate that the concentrations in the upgradient well (R101) are relatively low, except total phenols of 0.051 mg/l which is the highest among the shallow wells. The monitoring wells near the impoundment (G106, G107, and R108) have generally higher concentrations than the upgradient well (R101) except phenols. Similarly, G106, G107, and R108 show higher concentrations than those in the other downgradient shallow wells (G110, G111, G112, G116 and G124) although G112 and G124 show relatively high concentration of chloride. Thus, the concentrations of the groundwater quality parameters in the shallow groundwater generally decreases east and southeastward away from the impoundment.

Deep (Sand) Wells

Concentrations of groundwater quality parameters are relatively low in the deep sand wells. Among the five wells, the highest concentration of chloride, iron, manganese and phenols occurs in G123. The highest sodium and sulfate concentrations are in G122 and G123, respectively (Table 6).

Table 6. Initial background and concentrations of parameters establishing groundwater quality in the samples taken from the monitoring wells at the Cabot Corporation plant, Tuscola, Illinois on 10/7/1991

A. Shallow Wells

Parameters	G101		R101	G106	G107	R108	G110	G111	G112	G116	G124
	*InitiaBackground										
	Range	Mean									
Chloride, mg/l	142-162	155.5	16.0	619	10600	4710	68.5	75.2	293	29.1	550
Iron diss., mg/l	2.9-23	9.025	0.07	45.1	0.05	226	0.10	0.45	0.31	0.12	0.11
Manganese diss.,mg/l	0.43-1.4	0.925	2.13	5.33	39.2	20.5	0.13	0.17	<0.05	<0.05	0.83
Phenols, Total, µg/l	1.0-5.0	2.15	62	18	<3	8	4	3	8	4	<3
Sodium diss.,mg/l	22-30	25.75	22.3	8.19	51.2	24.1	4.43	5.19	6.01	5.46	25.6
Sulfate diss.,mg/l	208-252	234	41.0	2360	133	3.8	170	108	128	75.0	93.4

B. Deep Wells in Sand

	G010	G119	G121	G122	G123
Chloride, mg/l	62.7	62.2	46.2	64.3	30.9
Iron diss., mg/l	0.28	0.06	0.08	0.15	0.08
Manganese diss.,mg/l	0.43	0.09	<0.05	<0.05	0.06
Recoverable Phenols Total, µg/l	10	6	5	10	7
Sodium diss.,mg/l	56.5	58.5	52.2	57.9	52.7
Sulfate diss.,mg/l	6.0	2.9	3.5	4.2	18.6

Table 6. Cont'd.

C. Well Clusters

	Well	Chloride, mg/l	Iron diss.,mg/l	Manganese diss.,mg/l	Recoverable Phenols,Total, µg/l	Sodium diss.,mg/l	Sulfate diss.,mg/l
I.	R101	16.0	0.07	2.13	62	22.3	41.0
	G01D	62.7	0.28	0.43	10	56.5	6.0
II.	G106	619	45.1	5.33	18	8.19	2360
	G109	2280	0.05	<0.05	17	23.2	25.5
	G114	1700	<0.05	0.54	3	27.1	92.9
	G119	62.2	0.06	0.09	6	58.5	2.9
	G120	1040	0.42	4.78	4	365	<1
III.	R108	4710	226	20.5	8	24.1	3.8
	G122	64.3	0.15	<0.05	10	57.9	4.2
IV.	G111	75.2	0.45	0.17	3	5.19	108
	G118	3.8	<0.05	0.23	14	40.0	13.7
V.	G116	29.1	0.12	<0.05	4	5.46	75.0
	G117	16.1	10.2	0.11	31	70.9	103
VI.	G124	550	0.11	0.83	<3	25.6	93.4
	G123	30.9	0.08	0.06	7	52.7	18.6
G125 (Trip blnk)		2.6	<0.05	0.05	<3	<0.1	1.5

* determined in G101 which is not sampled anymore

Well Clusters

In the well clusters, the concentration of sodium increases with depth while that of the other parameters decreases in general. Relatively high concentrations of chloride, iron and manganese occur in the shallow wells of two clusters near the impoundment: G106/G109/G114/G119/G120 and R108/G122. High concentrations of chloride, iron, sodium and manganese in G120, the deepest well, are due to influence of water in the bedrock. The relatively high concentrations of Cl, in G114 and G109 in comparison to G106 and G119 probably suggest movement of contaminants in a slug.

A comparison of the analysis results in Table 6 with those in the last annual report (Hydropoll, 1990) generally indicates lower concentrations for most parameters. The generally declining concentrations may be due to the closure of the impoundment in November 1987.

The analysis data of the groundwater quality parameters show what had been indicated by the analysis of the hazardous waste constituents. That is, the closed impoundment had been leaking. The leakage has caused high concentrations of the groundwater quality parameters in the shallow groundwater near the impoundment. Because G112 is located in areas outside the groundwater flow originating from the impoundment, relatively high concentration of chloride in this well may not originate from the impoundment. The analyses also indicate that the groundwater quality parameters have not traveled from the impoundment to the eastern and southeastern boundaries of the plant. The deeper groundwater in the sand beneath the plant is not contaminated.

FINDINGS AND CONCLUSIONS

Based on the analyses made for the fourth (annual) quarterly sampling in 1991, the following include findings and conclusions:

1. Regional flow direction of the shallow groundwater is towards the southeast.

2. A mound in the shallow groundwater, that had formed just beneath the closed impoundment due to migration of the waste fluids in the past, has disappeared.

3. The potentiometric surface of the water in the deep sand is almost flat. Groundwater flows to the west.

4. The closed impoundment was leaking. The leakage lowered pH, increased SC, and caused contamination of the shallow groundwater near the closed impoundment.

5. SC generally decreases with depth and distance from the impoundment while pH increases with depth.

6. Shallow groundwater in the weathered till away from the plant and in the upgradient well appears to be unaffected by the impoundment.

7. None of the base neutrals and acid extractables were detectable in groundwater at the Cabot facility. Only eight VOCs were detectable.

8. VOCs were undetectable in monitoring 13 wells, including all of the five sand wells and the deepest well.

9. Eight detectable VOCs were: 1,2 t dichloroethene, tetrachloroethene, vinyl chloride, trichloroethene, ethyl benzene, 1,1,1trichloroethane, toluene and xylenes) have been measured above their detection limits in the groundwater samples. The last four parameters are new this quarter and have not been detected in recent years.

10. VOCs were found primarily in three shallow wells (G106, G107, R108) and two intermediate depth wells (G109, G114) all of which are next to the impoundment. A low concentration of1,2 t dichloroethene was also detected in G116, which is unlikely to originate from the impoundment.

11. The deep sand unit is not contaminated.

12. Detectable VOCs concentrations were relatively low. The highest concentration was 3.95 mg/l of vinyl chloride in R108 and the lowest was 7 µg/l tetrachloroethene in G109.

13. 1,2 t dichloroethene occurred in six wells, trichloroethene and tetrachloroethene in five and vinyl chloride in four. The other four parameters occurred in one to three wells in relatively low concentrations.

14. Water analyses from the G106/G109/G114/R119/G120 well cluster indicate that some HCs have traveled vertically downward into the G114 near the closed impoundment. The sand well (R119) and the deepest well (G120) did not show any HCs. Migration into G114 may have been through the annular area of the well.

15. pH,SC and water quality in G120 are probably affected by water in the bedrock.

16. It is estimated that the maximum extent of lateral migration of HCs in the shallow water is approximately 160 ft from the impoundment in the regional flow direction although the exact location of the migration boundary was not known. The extent is shorter in the other directions.

17. The vertically downward migration of HCs is estimated to be 80 ft below the land surface at G114.

18. The average flow velocity is estimated as 4.0 and 42.5 ft/yr in the shallow water and the deep sand water, respectively.

19. Total cyanide and total recoverable phenolics were in low concentrations.

20. The groundwater below the Cabot facility is not contaminated with phenols.