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Minnesota Pollution Control Agency

july 8, 1994

Mr. David Cabiness, Code 1862
Commanding Officer
Southern Division
Naval Facilities Engineering Command
P.O. Box 190010
North Charleston, South Carolina 29419-9010

Dear Mr. Cabiness:

You requested at the last technical review committee meeting that we send to you a copy of another site specific application of our soil leaching model.

I include for your review our modeling results for one of the sites at the Twin Cities Army and Ammunition Plant that contains many of the same contaminants that are found at the Naval Industrial Reserve Ordnance Plant. Enclosed you will find spreadsheets containing the modeling calculations, together with the explanatory memorandum. A compilation of soil clean-up goals for each compound of interest can be found in Table 2 on page six of the memorandum.

If I can be of further assistance, or if you have any questions concerning the enclosed information, please do not hesitate to call me at (612) 296-7775.

Sincerely,

Mark L. Ferrey
Research Scientist
Response Unit I
Site Response Section
Ground Water and Solid Waste Division

MLF:ch

Enclosure

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MEMORANDUM

To: Dagmar Romano/Project Manager
From: John K. Seaberg, CGWP/Hydrogeologist
Subject: Application of Soils Cleanup Model to Determine Preliminary Cleanup Goals for Site G
Date: February 22, 1993

Introduction

This memorandum discusses the application and preliminary results of applying Jim Pennino's Soils Cleanup Procedures leaching model to organic contamination of Site G at TCAAP. This site was selected as the first site to be analyzed by this method since the hydrogeology and nature of contamination are relatively simple. The model was applied in an attempt to determine acceptable levels of organic contamination in the soil such that they would not impact groundwater above established groundwater protection criteria. This memo describes the application of the model to Site G and discusses the results.

Approach

The analysis was conducted using Excel spreadsheets that were prepared by Jim Pennino as templates upon which to base analysis of the TCAAP sites. The spreadsheets incorporate the equations presented in Version 1 of the MPCA Procedures for Establishing Soil Cleanup Levels (Procedures). The spreadsheets were modified to account for the contaminant- and site-specific characteristics of Site G. Inputs were bracketed with the range of values shown in the literature to develop a range of possible cleanup levels to evaluate. Conservative inputs or outputs refer to those values that result in lower final cleanup levels.

Contaminant-Specific Inputs

Five volatile organic compounds (VOCs) were targeted for analysis with the model based on their presence in groundwater samples collected from monitoring wells placed to monitor Site G contamination, and also based on their occurrence in Site G soil samples. These VOC compounds are chloroform, 1,1-dichloroethane, *trans*-1,2-dichloroethene (or *trans*-1,2-dichloroethylene), 1,1,1-trichloroethane, and trichloroethene (or trichloroethylene). Of these, 1,1-dichloroethane, 1,1,1-trichloroethane, and trichloroethene have impacted groundwater at Site G.

Because no spreadsheets had previously been prepared for the types of chlorinated solvent compounds present at TCAAP, the spreadsheets from Jim Pennino were modified to incorporate the necessary chemical-specific information. Specifically, the solid phase organic carbon partitioning coefficients (K_{oc}) and the half-lives for the individual contaminants were required in the analysis. A K_{oc} value represents the ratio of contamination sorbed to organic carbon to aqueous concentration. The K_{oc} values were obtained from the logarithmic form given in Montgomery and Welkom (1990) and the half-lives were those presented by Howard and others (1991) as being appropriate for groundwater. The half-life values for groundwater were given instead of the values for soils because they provided the most conservative set of numbers. The minimum half-life values for groundwater were roughly twice those for soil conditions. Of the contaminants listed above, the only exception to this was 1,1,1-

trichloroethane, which had the same minimum half-life (20 weeks) listed for both soil and groundwater conditions. The higher half-lives for compounds are the most conservative inputs.

Groundwater quality criteria were used to establish the preliminary cleanup numbers calculated for the soils. The criteria were chosen for individual contaminants from the Minnesota Department of Health Recommended Allowable Limits for Drinking Water Contaminants (RALs) for private water supplies and the federal Maximum Contaminant Levels (MCLs) for public water supplies. The values for each, where established, are given below. For contaminants having two values, the lower one is used in this analysis. Values are input in units of mg/L in the worksheets used to calculate the clenaup numbers.

The input values and water quality criteria are presented in Table 1. Note that the groundwater quality criterion used in the analysis for each parameter is presented in bold:

Table 1

Contaminant-Specific Input Parameters

Compound	*Half Life (years)*	*Log K_{oc}*	*K_{oc} (ml/g)*	*Groundwater Quality Crit. (µg/L)*
Chloroform	0.15 - 4.9	1.64	43.7	**60** (RAL)
1,1-Dichloroethane	0.15 - 0.99	1.48	30.2	**70** (RAL)
trans-1,2-Dichloroethene	0.15 - 7.9	1.77	58.9	**100** (MCL/RAL)
1,1,1-Trichloroethane	0.38 - 1.5	2.017 - 2.18	104 - 151	**200** (MCL)/600 (RAL)
Trichloroethene	0.88 - 4.5	1.81 - 2.10	64.6 - 126	**5** (MCL)/30 (RAL)

Site-Specific Inputs

Site G is located in the south-central portion of TCAAP and is underlain by glacial surficial sediments. Silty sand fill and mixed wastes, which are the first materials encountered at the surface, are underlain by Unit 2, a complex mixture comprised largely of glacial till that can serve as an effective aquitard. Unit 2 is underlain by Unit 3, which is comprised of the permeable Arsenal and Hillside Sands. The water table is within the sand units and lies approximately 130 feet below the ground surface.

Although Unit 2 underlies much of Site G, it is not incorporated into this analysis as being an effective barrier to downward migration of contamination. This conclusion is based on two reasons. First, it is absent in places and mixed wastes and fill have been emplaced so that they are in direct contact with the underlying permeable sands. Second, the groundwater quality appears to be adversely affected by contamination from Site G, indicating that Unit 2 indeed has not been effective in stopping downward contaminant migration.

Volatilization was not included in the analysis, since field data indicate that contamination at the surface is insignificant compared to the contamination occurring with depth, all the way down to the water table. This indicates that volatilization is not likely to noticeably reduce the amount of VOC contamination impacting the groundwater at Site G.

The input parameters related to Site G are listed and discussed as follows:

- OC/OM = conversion factor from organic matter (OM) to organic carbon content (OC). This value is set at 1.00, since the total OM is assumed to be in the form of organic carbon.

- OM = organic matter content of soil. In the absence of site-specific data, the value is assumed to be 0.0003 fractional content organic carbon, based on measured numbers determined by CRA for the Hillside Sand unit in the 96-10-8 triangle. As noted under OM/OC, all organic matter is assumed to be in the form of organic carbon.

- K_d = distribution or adsorption coefficient of soils (ml/g). It is calculated by the spreadsheet as the product of K_{oc}, OC/OM, and OM. It represents the ratio of the concentration of contaminant sorbed to soil to the aqueous concentration.

- Z = thickness of soil containing natural organic matter (cm). Assumed to be 0 for Site G, since mixed wastes and fill materials were emplaced well below the soil zone. The presence of Z in the tables is an artifact of the old method of calculating time of travel. Because using the revised method of calculating the travel time does not use Z, it is actually not necessary to include it here.

- ρ = bulk density of soil (g/cm^3). Assumed to be 1.5 g/cm^3 for Site G in the absence of site-specific data. monitor for PCAT ??

- G = depth to groundwater (cm) from the center of the contaminated zone. Two values are evaluated in the spreadsheet. The first value is 1980 cm (65 feet), which provides the most conservative approach based on the assumption that the entire unsaturated zone is contaminated. The second value used is 3660 cm (120 feet), which is based on the assumption that the contamination is confined to the top 20 feet of the soils, which are comprised of mixed wastes and fill.

- θ = volumetric water content (average soil moisture content) of the soil at the midpoint between the wilting point and field capacity. Assumed to be 0.2 for Site G soils.

- IR = infiltration rate or amount of recharge per year (cm/year). A value of 15.24 cm/year (6.0 inches/year) was used for the analysis.

- t = time of travel from the center of the contaminated zone to the groundwater (years). Is calculated on the basis of the parameters input above. See discussion that follows below.

- k = degradation rate. Calculated from the half-life.

- MCL/RAL = Maximum Contaminant Level/Recommended Allowable Limit (see previous section). The MCL or RAL, whichever is lower, is presented for use in the analysis.

A change to the procedures that was made by Jim Pennino was incorporated into the analyses presented here. The equation for calculating the travel time t was modified, and no longer includes Z, the thickness of the soil containing organic matter, as a factor. The old equation was

$$t = \frac{(Z \rho K_d + G \theta)}{IR}$$

This has been replaced by

$$t = \frac{G(\rho K_d + \theta)}{IR}$$

Note that Z no longer is a factor in the travel time equation.

Results

Attachments 1 through 5 are worksheets extracted from the computer spreadsheets used to conduct the analysis for up to eight different cases for each contaminant (chloroform, 1,1-dichloroethane, *trans*-1,2-dichloroethene, 1,1,1-trichloroethane, and trichloroethene, respectively). Each worksheet used a range of input values in the analysis for each compound. The first section of each attachment converts depth to groundwater from feet to centimeters. The remaining sections of each attachment document input variables and calculated outputs that are used to arrive at the preliminary cleanup numbers. Adsorption coefficients (K_d) are calculated in the first portion. These are used to calculate time of travel and cleanup levels in the two following sections. For those compounds that have a range of K_d values, cases numbered 1 through 4 are based on a minimum K_d value and those numbered 5 through 8 are based on a maximum K_d value. Cases 1 through 4 are identical to Cases 5 through 8, respectively, where only one K_d value is given for a compound. This is seen for the results under the section of each attachment labeled Cleanup Levels, in which maximum and minimum K_d values are used in calculating the preliminary cleanup levels in mg/kg for the unsaturated zone. The last section, Summary of Input Variables and Results, summarizes the inputs and results of the analysis for each attachment. Results for each of the contaminants are are discussed below.

The depth to groundwater (G) exerts a very noticeable influence on the results for all five contaminants. The low value (1980 cm) is based on the assumption that the contamination is distributed throughout the soil column all the way down to the groundwater. The high value (3660 cm) was derived from the assumption that the contamination is confined to the top 20 feet of the soils. Because the groundwater has been impacted by VOCs at Site G, it is appropriate to assume that the entire soil column is contaminated and the lower value should be used.

Chloroform

The results of the analysis for chloroform are summarized in the last section of Attachment 1. The parameter that produces the greatest impact in the results is the half life value. The low value (0.15 years) produces unrealistically high cleanup numbers. These results indicate that the low half life for chloroform should not be used in the analysis.

Using the low value for the depth to groundwater and the high value for half life for chloroform at Site G leaves only K_d as the remaining variable (see Case Numbers 1 & 5). However, only one value of K_d was found in the literature (see above). This value yields a preliminary cleanup goal concentration of 0.045 mg/kg for chloroform in Site G soils.

1,1-Dichloroethane

The results of the analysis for 1,1-dichloroethane are summarized in the last section of Attachment 2. The parameter that produces the greatest impact in the results is the half life value. The low value (0.15 years) produces unrealistically high cleanup numbers. These results, as well as the occurrence of the contaminant in the groundwater at the site, indicate that the low half life for 1,1-dichloroethane should not be used in the analysis.

Using the low value for the depth to groundwater and the high value for half life for 1,1-dichloroethane at Site G leaves only K_d as the remaining variable (see Case Numbers 1 & 5). However, only one value of K_d was found in the literature (see above). This value yields a cleanup goal concentration of 170,000,000 mg/kg for 1,1-dichloroethane in Site G soils. This high number reflects the relatively short half life of the contaminant, and may indicate that there is no need to establish a cleanup goal for this compound in Site G soils on the basis of leachability to groundwater.

trans-*1,2-Dichloroethene*

The results of the analysis for *trans*-1,2-dichloroethene are summarized in the last section in Attachment 3. The parameter that produces the greatest impact in the results is the half life value. The low value (0.15 years) produces unrealistically high cleanup numbers. These results indicate that the low half life should not be used in the analysis.

Using the low value for the depth to groundwater and the high value for half life for *trans*-1,2-dichloroethene at Site G leaves only K_d as the remaining variable (see Case Numbers 1 & 5). However, only one value of K_d was found in the literature (see above). This value yields a preliminary cleanup goal concentration of 0.023 mg/kg for *trans*-1,2-dichloroethene in Site G soils.

1,1,1-Trichloroethane

The results of the analysis for 1,1,1-trichloroethane are summarized in the last section in Attachment 4. The parameter that produces the greatest impact in the results is the half life value. The low value (0.38 years) produces unrealistically high cleanup numbers. These results, as well as the persistence of the compound at the site, indicate that the low half life for 1,1,1-trichloroethane should not be used in the analysis.

Using the low values for the depth to groundwater and the high value for half life for 1,1,1-trichloroethane at Site G leaves only K_d as the remaining variable (see Case Numbers 1 & 5). The low (conservative) value of K_d yields a cleanup goal concentration of 17,000 mg/kg for the Site G soils. The high value provides a cleanup value of 88,000 mg/kg for the same soils. On the basis of these numbers, the preliminary cleanup goals for 1,1,1-trichloroethane at Site G are between 17,000 mg/kg and 88,000 mg/kg.

Trichloroethene

The results of the analysis for trichloroethene are summarized in the last section in Attachment 5. The parameter that produces the greatest impact in the results is the half life value. The low value (0.88 years) produces unrealistically high cleanup numbers. These results, as well as the persistence of the

compound at the site, indicate that the low half life for trichloroethene should not be used in the analysis.

Using the low value for the depth to groundwater and the high value for half life for trichloroethene at Site G leaves only K_d as the remaining variable (see Case Numbers 1 & 5). The low (conservative) value of K_d yields a cleanup goal concentration of 0.0096 mg/kg for the Site G soils. The high value provides a cleanup value of 0.032 mg/kg for the same soils. On the basis of these numbers, the preliminary cleanup goals for trichloroethene at Site G are between 0.0096 mg/kg and 0.032 mg/kg.

Conclusions and Summary

Application of the soils cleanup procedures to Site G organic compounds was conducted using ranges of input values to bracket extremes in the calculated preliminary cleanup numbers based on leachability to groundwater. The variables having the most impact on the cleanup number results were depth to groundwater, chemical half life, and distribution coefficient of soils (K_d), which is derived from the organic carbon content of soils and the organic carbon partitioning coefficient (K_{oc}). The presence of contamination in soils with depth and in the groundwater at Site G indicates that the depth should reflect the fact that the entire vadose zone at Site G is contaminated. Therefore, a depth to groundwater of 1,980 cm is considered most appropriate for Site G. The lower half life values provide the least conservative inputs, and result in unrealistically high cleanup values, which exceed 1,000,000 ppm for all the contaminants. Therefore, the higher half life values were used for each contaminant analyzed. The preliminary cleanup goals were determined from the K_d values presented and the parameters discussed above.

The results from the analyses are presented in Table 2. The calculated value for soils cleanup for 1,1-dichloroethane is high, with a value of 170,000 mg/kg (ppm), indicating that there may be no need to establish a cleanup goal for that compound at Site G on the basis of the approach presented here. The preliminary soils cleanup goals at Site G for chloroform and *trans*-1,2-dichloroethene are 0.045 mg/kg and 0.023 mg/kg, respectively. The range of preliminary cleanup goal values for 1,1,1-trichloroethane and trichloroethene is 17,000 to 88,000 mg/kg and 0.0096 to 0.032 mg/kg, respectively.

Table 2

Summary of Calculated Preliminary Cleanup Goals for Soil

Compound	*Soil Cleanup Goal (mg/kg)*
Chloroform	0.045
1,1-Dichloroethane	170,000
trans-1,2-Dichloroethene	0.023
1,1,1-Trichloroethane	17,000 - 88,000
Trichloroethene	0.0096 - 0.032

The calculated preliminary cleanup goals for the contaminants at Site G are based on information that is presently available. These values can be updated as additional information is made available through the feasibility study process.

References Cited

Howard, P.H., R.S. Boethling, W.F. Jarvis, W.M. Meylan, and E.M. Michalenko, 1991, *Handbook of Environmental Degradation Rates*, Lewis Publishers, Inc., Chelsea, Michigan, 725 p.

Montgomery, J.H., and L.M. Welkom, 1990, *Groundwater Chemicals Desk Reference*, Lewis Publishers, Inc., Chelsea, Michigan, 640 p.

Attachment 1: Chloroform

Site: TCAAP--Site G Compound: Chloroform

Depth to Groundwater	*feet*	*cm*
Entire Thickness (conserv.)	65	1981.2
Top 20 feet	120	3657.6

Case No.	*Adsorption Coefficient (Kd):*			
	Koc	OC/OM conv.	Total OM	Kd
1	43.7	1.00	0.0003	0.01311
2	43.7	1.00	0.0003	0.01311
3	43.7	1.00	0.0003	0.01311
4	43.7	1.00	0.0003	0.01311
5	43.7	1.00	0.0003	0.01311
6	43.7	1.00	0.0003	0.01311
7	43.7	1.00	0.0003	0.01311
8	43.7	1.00	0.0003	0.01311

Case No.	*Time of travel (t):*						
	Z	Soil Density	Kd	G	Water Cont.	IR	t
1	0	1.5	0.01311	1980	0.2	15.24	28.539
2	0	1.5	0.01311	1980	0.2	15.24	28.539
3	0	1.5	0.01311	3660	0.2	15.24	52.754
4	0	1.5	0.01311	3660	0.2	15.24	52.754
5	0	1.5	0.01311	1980	0.2	15.24	28.539
6	0	1.5	0.01311	1980	0.2	15.24	28.539
7	0	1.5	0.01311	3660	0.2	15.24	52.754
8	0	1.5	0.01311	3660	0.2	15.24	52.754

Attachment 1: Chloroform (Cont'd)

Case No.	Half Life (yr)	k (Degr. Rate)	exp(-kt)	Kd	MCL/RAL *(mg/L)*	*Cleanup Levels (mg/kg)*
1	4.9	0.141428571	0.0176636	0.01311	0.060	0.044532368
2	0.15	4.62	5.469E-58	0.01311	0.060	1.43836E+54
3	4.9	0.141428571	0.0005751	0.01311	0.060	1.36773959
4	0.15	4.62	1.42E-106	0.01311	0.060	5.545E+102
5	4.9	0.141428571	0.0176636	0.01311	0.060	0.044532368
6	0.15	4.62	5.469E-58	0.01311	0.060	1.43836E+54
7	4.9	0.141428571	0.0005751	0.01311	0.060	1.36773959
8	0.15	4.62	1.42E-106	0.01311	0.060	5.545E+102

Summary of Input Variables and Results

Case No.	G	Half Life (yr)	Kd	*Cleanup Levels*
1	1980	4.9	0.01311	0.045
2	1980	0.15	0.01311	1.44E+54
3	3660	4.9	0.01311	1.4
4	3660	0.15	0.01311	5.55E+102
5	1980	4.9	0.01311	0.045
6	1980	0.15	0.01311	1.44E+54
7	3660	4.9	0.01311	1.4
8	3660	0.15	0.01311	5.55E+102

Attachment 2: 1,1-Dichloroethane

Site: TCAAP--Site G Compound: 1,1-Dichloroethane

Depth to Groundwater	*feet*	*cm*
Entire Thickness (conserv.)	65	1981.2
Top 20 feet	120	3657.6

Case No.	*Adsorption Coefficient (Kd):*			
	Koc	OC/OM conv.	Total OM	Kd
1	30.2	1.00	0.0003	0.00906
2	30.2	1.00	0.0003	0.00906
3	30.2	1.00	0.0003	0.00906
4	30.2	1.00	0.0003	0.00906
5	30.2	1.00	0.0003	0.00906
6	30.2	1.00	0.0003	0.00906
7	30.2	1.00	0.0003	0.00906
8	30.2	1.00	0.0003	0.00906

Case No.	*Time of travel (t):*						
	Z	Soil Density	Kd	G	Water Cont.	IR	t
1	0	1.5	0.00906	1980	0.2	15.24	27.750
2	0	1.5	0.00906	1980	0.2	15.24	27.750
3	0	1.5	0.00906	3660	0.2	15.24	51.295
4	0	1.5	0.00906	3660	0.2	15.24	51.295
5	0	1.5	0.00906	1980	0.2	15.24	27.750
6	0	1.5	0.00906	1980	0.2	15.24	27.750
7	0	1.5	0.00906	3660	0.2	15.24	51.295
8	0	1.5	0.00906	3660	0.2	15.24	51.295

Attachment 2: 1,1-Dichloroethane (Cont'd)

Case No.	Half Life (yr)	k (Degr. Rate)	exp(-kt)	Kd	MCL/RAL *(mg/L)*	*Cleanup Levels (mg/kg)*
1	0.99	0.7	3.663E-09	0.00906	0.070	173125.3412
2	0.15	4.62	2.097E-56	0.00906	0.070	3.02492E+52
3	0.99	0.7	2.546E-16	0.00906	0.070	2.49054E+12
4	0.15	4.62	1.2E-103	0.00906	0.070	5.2853E+99
5	0.99	0.7	3.663E-09	0.00906	0.070	173125.3412
6	0.15	4.62	2.097E-56	0.00906	0.070	3.02492E+52
7	0.99	0.7	2.546E-16	0.00906	0.070	2.49054E+12
8	0.15	4.62	1.2E-103	0.00906	0.070	5.2853E+99

Summary of Input Variables and Results

Case No.	G	Half Life (yr)	Kd	*Cleanup Levels*
1	1980	0.99	0.00906	1.73E+05
2	1980	0.15	0.00906	3.02E+52
3	3660	0.99	0.00906	2.49E+12
4	3660	0.15	0.00906	5.29E+99
5	1980	0.99	0.00906	1.73E+05
6	1980	0.15	0.00906	3.02E+52
7	3660	0.99	0.00906	2.49E+12
8	3660	0.15	0.00906	5.29E+99

Attachment 3: Trans-1,2-Dichloroethene

Site: TCAAP--Site G Compound: Trans-1,2-Dichloroethene

Depth to Groundwater	*feet*	*cm*
Entire Thickness (conserv.)	65	1981.2
Top 20 feet	120	3657.6

Case No.	*Adsorption Coefficient (Kd):*			
	Koc	OC/OM conv.	Total OM	Kd
1	58.9	1.00	0.0003	0.01767
2	58.9	1.00	0.0003	0.01767
3	58.9	1.00	0.0003	0.01767
4	58.9	1.00	0.0003	0.01767
5	58.9	1.00	0.0003	0.01767
6	58.9	1.00	0.0003	0.01767
7	58.9	1.00	0.0003	0.01767
8	58.9	1.00	0.0003	0.01767

Case No.	*Time of travel (t):*						
	Z	Soil Density	Kd	G	Water Cont.	IR	t
1	0	1.5	0.01767	1980	0.2	15.24	29.428
2	0	1.5	0.01767	1980	0.2	15.24	29.428
3	0	1.5	0.01767	3660	0.2	15.24	54.397
4	0	1.5	0.01767	3660	0.2	15.24	54.397
5	0	1.5	0.01767	1980	0.2	15.24	29.428
6	0	1.5	0.01767	1980	0.2	15.24	29.428
7	0	1.5	0.01767	3660	0.2	15.24	54.397
8	0	1.5	0.01767	3660	0.2	15.24	54.397

Attachment 3: Trans-1,2-Dichloroethene (Cont'd)

Case No.	Half Life (yr)	k (Degr. Rate)	exp(-kt)	Kd	MCL/RAL *(mg/L)*	*Cleanup Levels (mg/kg)*
1	7.9	0.087721519	0.075664	0.01767	0.10	0.023353242
2	0.15	4.62	9.012E-60	0.01767	0.10	1.96063E+56
3	7.9	0.087721519	0.0084653	0.01767	0.10	0.208733697
4	0.15	4.62	7.18E-110	0.01767	0.10	2.4622E+106
5	7.9	0.087721519	0.075664	0.01767	0.10	0.023353242
6	0.15	4.62	9.012E-60	0.01767	0.10	1.96063E+56
7	7.9	0.087721519	0.0084653	0.01767	0.10	0.208733697
8	0.15	4.62	7.18E-110	0.01767	0.10	2.4622E+106

Summary of Input Variables and Results

Case No.	G	Half Life (yr)	Kd	*Cleanup Levels*
1	1980	7.9	0.01767	0.023
2	1980	0.15	0.01767	1.96E+56
3	3660	7.9	0.01767	0.21
4	3660	0.15	0.01767	2.46E+106
5	1980	7.9	0.01767	0.023
6	1980	0.15	0.01767	1.96E+56
7	3660	7.9	0.01767	0.21
8	3660	0.15	0.01767	2.46E+106

Attachment 4: 1,1,1-Trichloroethane

Site: TCAAP--Site G **Compound: 1,1,1-Trichloroethane**

Depth to Groundwater	*feet*	*cm*
Entire Thickness (conserv.)	65	1981.2
Top 20 feet	120	3657.6

Case No.	*Adsorption Coefficient (Kd):*			
	Koc	OC/OM conv.	Total OM	Kd
1	104	1.00	0.0003	0.0312
2	104	1.00	0.0003	0.0312
3	104	1.00	0.0003	0.0312
4	104	1.00	0.0003	0.0312
5	151	1.00	0.0003	0.0453
6	151	1.00	0.0003	0.0453
7	151	1.00	0.0003	0.0453
8	151	1.00	0.0003	0.0453

Case No.	*Time of travel (t):*						
	Z	Soil Density	Kd	G	Water Cont.	IR	t
1	0	1.5	0.0312	1980	0.2	15.24	32.065
2	0	1.5	0.0312	1980	0.2	15.24	32.065
3	0	1.5	0.0312	3660	0.2	15.24	59.271
4	0	1.5	0.0312	3660	0.2	15.24	59.271
5	0	1.5	0.0453	1980	0.2	15.24	34.812
6	0	1.5	0.0453	1980	0.2	15.24	34.812
7	0	1.5	0.0453	3660	0.2	15.24	64.350
8	0	1.5	0.0453	3660	0.2	15.24	64.350

Attachment 4: 1,1,1-Trichloroethane (Cont'd)

Case No.	Half Life (yr)	k (Degr. Rate)	exp(-kt)	Kd	MCL/RAL (mg/L)	*Cleanup Levels (mg/kg)*
1	1.5	0.462	3.685E-07	0.0312	0.20	1.69E+04
2	0.38	1.823684211	4.021E-26	0.0312	0.20	1.55E+23
3	1.5	0.462	1.281E-12	0.0312	0.20	4.87E+09
4	0.38	1.823684211	1.139E-47	0.0312	0.20	5.48E+44
5	1.5	0.462	1.035E-07	0.0453	0.20	8.75E+04
6	0.38	1.823684211	2.679E-28	0.0453	0.20	3.38E+25
7	1.5	0.462	1.226E-13	0.0453	0.20	7.39E+10
8	0.38	1.823684211	1.08E-51	0.0453	0.20	8.39E+48

Summary of Input Variables and Results

Case No.	G	Half Life (yr)	Kd	*Cleanup Levels*
1	1980	1.5	0.0312	1.69E+04
2	1980	0.38	0.0312	1.55E+23
3	3660	1.5	0.0312	4.87E+09
4	3660	0.38	0.0312	5.48E+44
5	1980	1.5	0.0453	8.75E+04
6	1980	0.38	0.0453	3.38E+25
7	3660	1.5	0.0453	7.39E+10
8	3660	0.38	0.0453	8.39E+48

Attachment 5: Trichloroethene

Site: TCAAP--Site G **Compound: Trichloroethene (TCE)**

Depth to Groundwater	*feet*	*cm*
Entire Thickness (conserv.)	65	1981.2
Top 20 feet	120	3657.6

Case No.	*Adsorption Coefficient (Kd):*			
	Koc	OC/OM conv.	Total OM	Kd
1	65	1.00	0.0003	0.0195
2	65	1.00	0.0003	0.0195
3	65	1.00	0.0003	0.0195
4	65	1.00	0.0003	0.0195
5	126	1.00	0.0003	0.0378
6	126	1.00	0.0003	0.0378
7	126	1.00	0.0003	0.0378
8	126	1.00	0.0003	0.0378

Case No.	*Time of travel (t):*						
	Z	Soil Density	Kd	G	Water Cont.	IR	t
1	0	1.5	0.0195	1980	0.2	15.24	29.784
2	0	1.5	0.0195	1980	0.2	15.24	29.784
3	0	1.5	0.0195	3660	0.2	15.24	55.056
4	0	1.5	0.0195	3660	0.2	15.24	55.056
5	0	1.5	0.0378	1980	0.2	15.24	33.351
6	0	1.5	0.0378	1980	0.2	15.24	33.351
7	0	1.5	0.0378	3660	0.2	15.24	61.648
8	0	1.5	0.0378	3660	0.2	15.24	61.648

Attachment 5: Trichloroethene (Cont'd)

Case No.	Half Life (yr)	k (Degr. Rate)	exp(-kt)	Kd	MCL/RAL *(mg/L)*	*Cleanup Levels (mg/kg)*
1	4.5	0.154	0.0101853	0.0195	0.0050	0.009572575
2	0.88	0.7875	6.509E-11	0.0195	0.0050	1497930.827
3	4.5	0.154	0.0002079	0.0195	0.0050	0.469062894
4	0.88	0.7875	1.481E-19	0.0195	0.0050	6.58524E+14
5	4.5	0.154	0.005881	0.0378	0.0050	0.03213716
6	0.88	0.7875	3.925E-12	0.0378	0.0050	48157215.32
7	4.5	0.154	7.531E-05	0.0378	0.0050	2.509526117
8	0.88	0.7875	8.238E-22	0.0378	0.0050	2.29429E+17

Summary of Input Variables and Results

Case No.	G	Half Life (yr)	Kd	*Cleanup Levels*
1	1980	4.5	0.0195	0.0096
2	1980	0.88	0.0195	1.50E+06
3	3660	4.5	0.0195	0.47
4	3660	0.88	0.0195	6.59E+14
5	1980	4.5	0.0378	0.032
6	1980	0.88	0.0378	4.82E+07
7	3660	4.5	0.0378	2.5
8	3660	0.88	0.0378	2.29E+17