



**Revitalizing Auto Communities
Environmental Response Trust**

March 23, 2012

Ms. Michelle Kaysen
USEPA Region 5
77 West Jackson Blvd
Mail Code DE-9J
Chicago, IL 60604-3507

RE: Supplemental Memo
Corrective Measures Proposal
RCRA Corrective Action
Former GM Delco Plant 5 Kokomo, Indiana USEPA ID No. IND000806844

Dear Ms. Kaysen:

In an email from you dated February 23, 2012, EPA stated that, "The December 6, 2011 Corrective Measures Proposal submitted by RACER for the Former GM Delco Plant 5 in Kokomo, IN, is acceptable for the purpose of proceeding to the Statement of Basis," and noted two outstanding issues:

1. The cancer unit risk factor for PCE has been revised in IRIS and will change the groundwater and soil gas performance standards.
2. The reference to "cumulative risk estimates" in Appendix C was previously discussed between Bhooma Sundar and Francis Ramacciotti in May 2011. It was agreed during that discussion, and others, that a cumulative risk assessment will not be an acceptable decision point for exceedances of groundwater or soil gas performance standards. EPA's preferred decision criteria is appropriate tiered sampling; soil gas, sub slab, indoor air, etc.

EPA also stated that RACER may address these issues in a supplemental memo to EPA, rather than revising the Corrective Measures Proposal (CMP), and this memo will be incorporated into the administrative record and the Statement of Basis. This supplemental memo documents RACER's response to the two EPA comments (PCE Revised Criteria and Cumulative Risk Estimates), as discussed with you and Bhooma Sundar on 3/1/2012.

PCE Revised Criteria

The groundwater and soil gas vapor intrusion screening criteria for tetrachloroethylene (aka perchloroethylene or PCE) presented in Appendix B of the CMP were revised to reflect the changes in the cancer unit risk factor and the reference concentration for PCE (Integrated Risk Information System, February 10, 2012). These revised criteria are presented in the attached Tables B-1, B-2 and B-3. The supporting documentation for the derivation of the revised PCE

groundwater vapor intrusion criteria are the USEPA Johnson & Ettinger modeling spreadsheets (USEPA, 2004); these spreadsheets are also attached as an update to the 2011 CMP. The soil gas vapor intrusion criteria were derived as before using Equations 95, 96, 103 and 104 of the Indiana Department of Environmental Management (IDEM) Remediation Closure Guide (May 2011) and IDEM's default attenuation factor of 0.1.

The revised criteria for PCE are higher than previously calculated, based solely on changes in toxicity factor values, and are summarized below:

Groundwater and Soil Gas Vapor Intrusion Screening Criteria for Tetrachloroethylene (PCE)		
	December 2011 CMP	Revised Value March 2012
Off-Site Groundwater, within plume, Commercial/Industrial	3.95 mg/L	33 mg/L
Off-Site Groundwater, within plume, Residential	2.35 mg/L	23.8 mg/L
Off-Site Groundwater, outside of plume, Commercial/Industrial	2.05 mg/L	21 mg/L
Off-Site Groundwater, outside of plume, Residential	1.49 mg/L	15 mg/L
Off-Site Soil Gas, Commercial/Industrial	210 ug/m ³	1754 ug/m ³
Off-Site Soil Gas, Residential	41 ug/m ³	417 ug/m ³

Cumulative Risk Estimates

Appendix C of the CMP describes the proposed vapor and groundwater monitoring program. Groundwater and soil vapor data will be compared to the groundwater and soil gas vapor intrusion screening criteria (from Appendix B) to identify the need for additional data collection. These additional data may be necessary to ensure that groundwater and soil gas monitoring meets the corrective measures endpoints in Table 5 of the CMP, which states, "Where an off-site vapor intrusion pathway is complete, demonstrate that exposure medium (soil vapor or indoor air, as appropriate) concentrations are below the cumulative target risk level of 1×10^{-5} and the target hazard index of 1."

Appendix C describes the use of the Appendix B screening criteria and separately the use of cumulative risk estimates to demonstrate that a corrective measures endpoint has been met. For the purpose of **establishing screening criteria**, the target cancer risk for each individual chemical is 1×10^{-5} and the target non-cancer hazard index is 1 so that additional data will be collected if the chemical concentration exceeds the screening criterion. For the purpose of **confirming a corrective measures endpoint**, the concentrations of site-related chemicals detected in groundwater at a particular location combined, have to meet the cumulative target cancer risk of 1×10^{-5} and the target non-cancer hazard index of 1.

If you have any questions on this letter, please call me at the number below.

RACER Trust



Robert W. Hare, P.E. CHMM
Cleanup Manager (IL, IN, KS, MO, NJ, WI)

C: Glynda Oakes, IDEM Office of Land Quality
Howard County Health Department
Carey Stranahan, City of Kokomo
Glen Boise, Kokomo Howard County Plan Commission
Kokomo Public Library (Public Information Repository)
Micheal Hill, Chief Operating Officer, RACER Trust (w/o attachment)
Sarah Fisher, ARCADIS

Attachments

Table B-1: Groundwater Vapor Intrusion Screening Criteria
Table B-2: Groundwater Vapor Intrusion Screening Criteria
Table B-3: Soil Gas Vapor Intrusion Screening Criteria Summary
USEPA Vapor Intrusion Modeling Spreadsheets

**Table B-1: Groundwater Vapor Intrusion Screening Criteria
Former Delco Plant 5, Kokomo, Indiana
Application: Off Site Within Plume**

Chemical	CASRN	Off-Site Commercial/ Industrial Groundwater VI Screening Criteria (mg/L)	Off-Site Residential Groundwater VI Screening Criteria (mg/L)
1,1-Dichloroethene	75-35-4	78.3	55.9
cis-1,2-Dichloroethene	156-59-2	59.5	42.5
trans-1,2-Dichloroethene	156-60-5	73.8	52.7
Tetrachloroethene (revised)	127-18-4	33	23.8
Trichloroethene	79-01-6	2.19	1.57
Vinyl Chloride	75-01-4	0.919	0.547

Note:

Vapor intrusion (VI) screening criteria for groundwater were calculated using USEPA Johnson & Ettinger Model Version 3.1 (February 2004) and a target cancer risk of 1E-5 or target HI of 1; the selected criterion value is the lower of the allowable concentrations for each chemical. Modeling spreadsheets for each chemical are provided in this Appendix. Model default values for the soil types at monitoring well MW-612 were used to derive screening criteria that will be applied to off-Site areas within the groundwater contaminant plume.

CASRN = Chemical Abstract Service Registry Number

**Table B-2: Groundwater Vapor Intrusion Screening Criteria
Former Delco Plant 5, Kokomo, Indiana
Application: Off Site Outside of Plume**

Chemical	CASRN	Off-Site Commercial/ Industrial Groundwater VI Screening Criteria (mg/L)	Off-Site Residential Groundwater VI Screening Criteria (mg/L)
1,1-Dichloroethene	75-35-4	52.4	37.5
cis-1,2-Dichloroethene	156-59-2	30.1	21.5
trans-1,2-Dichloroethene	156-60-5	41.9	29.9
Tetrachloroethene (revised)	127-18-4	21	15
Trichloroethene	79-01-6	1.3	0.93
Vinyl Chloride	75-01-4	0.623	0.371

Note:

Vapor intrusion (VI) screening criteria for groundwater were calculated using USEPA Johnson & Ettinger Model Version 3.1 (February 2004) and a target cancer risk of 1E-5 or target HI of 1; the selected criterion value is the lower of the allowable concentrations for each chemical. Modeling spreadsheets for each chemical are provided in this Appendix. Model default values for the soil types at monitoring well MW-603 were used to derive screening criteria that will be applied to off-Site areas outside of the groundwater contaminant plume.

CASRN = Chemical Abstract Service Registry Number

**Table B-3: Soil Gas Vapor Intrusion Screening Criteria Summary
Former Delco Plant 5, Kokomo, Indiana**

Chemical	CASRN	Off-Site Commercial/Industrial Soil Gas VI Screening Criteria (ug/m³)	Off-Site Residential Soil Gas VI Screening Criteria (ug/m³)
1,1-Dichloroethene	75-35-4	3500	830
cis-1,2-Dichloroethene	156-59-2	NA	NA
trans-1,2-Dichloroethene	156-60-5	2600	630
Tetrachloroethylene	127-18-4	1754	417
Trichloroethene	79-01-6	87	21
Vinyl Chloride	75-01-4	280	16

Note:

Vapor intrusion (VI) screening criteria for soil gas are generic values from IDEM, 2011, *Draft Remediation Closure Guide* (RCG, Pending). These values were calculated by applying an IDEM default soil gas attenuation factor of 0.1 to lower of the IDEM Health Protective Levels (HPLs) for indoor air based on a target cancer risk of 1E-5 and a target hazard index of 1. To reflect final USEPA toxicity factors for TCE and PCE, the HPLs were recalculated for Commercial/Industrial using Equations 103 and 104 of the IDEM RCG and for Residential using Equations 95 and 96 of the IDEM RCG. The lower of the cancer and non-cancer HPLs was then divided by 0.1 to derive soil gas VI screening criteria.

USEPA Vapor Intrusion Modeling Spreadsheets

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES ☒

Reset to
Defaults

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION (enter "X" in "YES" box and initial groundwater conc. below)

YES ☐

ENTER Chemical CAS No. (numbers only, no dashes)		ENTER Initial groundwater conc., C_w ($\mu\text{g/L}$)		Chemical								
127184		4.37E+03		Tetrachloroethylene								
ENTER Average soil/ groundwater temperature, T_s ($^{\circ}\text{C}$)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28) Thickness of soil stratum A, h_A (cm)			ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum directly above water table, (Enter A, B, or C)	ENTER SCS soil type directly above water table	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
10	200	669	365	304				B	SIC	SC		

MORE
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ENTER Stratum A SCS soil type Lookup Soil Parameters	ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum B SCS soil type Lookup Soil Parameters	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum C SCS soil type Lookup Soil Parameters	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)
SC	1.63	0.385	0.197	SIC	1.38	0.481	0.216				

MORE
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ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP (g/cm-s^2)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)	ENTER Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)
10	40	1000	1000	366	0.1	0.5	5

MORE
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ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	25	25	250	1.0E-05	1

END

Used to calculate risk-based
groundwater concentration.

DATA ENTRY SHEET

Diffusivity in air, D_a (cm ² /s)	Diffusivity in water, D_w (cm ² /s)	Henry's law constant at reference temperature, H (atm·m ³ /mol)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm ³ /g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	1.55E+02	2.00E+02	2.6E-07	4.0E-02

END

DATA ENTRY SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm ³ /cm ³)	Stratum B soil air-filled porosity, θ_a^B (cm ³ /cm ³)	Stratum C soil air-filled porosity, θ_a^C (cm ³ /cm ³)	Stratum A effective total fluid saturation, S_{fe} (cm ³ /cm ³)	Stratum A soil intrinsic permeability, k_i (cm ²)	Stratum A soil relative air permeability, k_{rg} (cm ²)	Stratum A soil effective vapor permeability, k_v (cm ²)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm ³ /cm ³)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm ³ /cm ³)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm ³ /cm ³)	Floor-wall seam perimeter, X_{crack} (cm)
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7.88E+08	469	0.188	0.265	ERROR	0.299	1.74E-09	0.837	1.46E-09	192.31	0.481	0.057	0.424	4,000
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Bldg. ventilation rate, $Q_{building}$ (cm ³ /s)	Area of enclosed space below grade, A_B (cm ²)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} (atm-m ³ /mol)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, D_{A}^{eff} (cm ² /s)	Stratum B effective diffusion coefficient, D_{B}^{eff} (cm ² /s)	Stratum C effective diffusion coefficient, D_{C}^{eff} (cm ² /s)	Capillary zone effective diffusion coefficient, D_{cz}^{eff} (cm ² /s)	Total overall effective diffusion coefficient, D_T^{eff} (cm ² /s)	Diffusion path length, L_d (cm)
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5.08E+04	1.80E+06	2.22E-04	200	9,553	7.81E-03	3.36E-01	1.75E-04	1.86E-03	3.74E-03	0.00E+00	2.89E-05	6.92E-05	469
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Convection path length, L_p (cm)	Source vapor conc., C_{source} (μg/m ³)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm ³ /s)	Crack effective diffusion coefficient, D_{crack}^{eff} (cm ² /s)	Area of crack, A_{crack} (cm ²)	Exponent of equivalent foundation Peclet number, $\exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (μg/m ³)	Unit risk factor, URF (μg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
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200	3.36E+02	0.10	8.33E+01	1.86E-03	4.00E+02	#NUM!	5.21E-06	1.75E-03	2.6E-07	4.0E-02
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END

DATA ENTRY SHEET

RISK-BASED GROUNDWATER CONCENTRATION CALCULATIONS:

INCREMENTAL RISK CALCULATIONS:

33.33

Indoor exposure groundwater conc., carcinogen (µg/L)	Indoor exposure groundwater conc., noncarcinogen (µg/L)	Risk-based indoor exposure groundwater conc., (µg/L)	Pure component water solubility, S (µg/L)	Final indoor exposure groundwater conc., (µg/L)	Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
8.97E+04	3.33E+04	3.33E+04	2.00E+05	3.33E+04	NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)

MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL
DOWN
TO "END"

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES ☒

Reset to
Defaults

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION (enter "X" in "YES" box and initial groundwater conc. below)

YES ☐

ENTER Chemical CAS No. (numbers only, no dashes)		ENTER Initial groundwater conc., C_w ($\mu\text{g/L}$)		Chemical	
127184		4.37E+03		Tetrachloroethylene	

ENTER Average soil/ groundwater temperature, T_s ($^{\circ}\text{C}$)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28)			ENTER Soil stratum directly above water table, (Enter A, B, or C)	ENTER SCS soil type directly above water table	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
Thickness of soil stratum A, h_A (cm)	Thickness of soil stratum B, (Enter value or 0) h_B (cm)	Thickness of soil stratum C, (Enter value or 0) h_C (cm)				B	SIC	SC		

MORE
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ENTER Stratum A SCS soil type Lookup Soil Parameters	ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum B SCS soil type Lookup Soil Parameters	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum C SCS soil type Lookup Soil Parameters	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)
SC	1.63	0.385	0.197	SIC	1.38	0.481	0.216				

MORE
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ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP (g/cm-s^2)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)	ENTER Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)
10	40	1000	1000	366	0.1	0.5	5

MORE
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ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	30	30	350	1.0E-05	1

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Used to calculate risk-based
groundwater concentration.

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7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	1.55E+02	2.00E+02	2.6E-07	4.0E-02

END

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9.46E+08	469	0.188	0.265	ERROR	0.299	1.74E-09	0.837	1.46E-09	192.31	0.481	0.057	0.424	4,000
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Bldg. ventilation rate, $Q_{building}$ (cm ³ /s)	Area of enclosed space below grade, A_B (cm ²)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} (atm-m ³ /mol)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, D_{eff}^A (cm ² /s)	Stratum B effective diffusion coefficient, D_{eff}^B (cm ² /s)	Stratum C effective diffusion coefficient, D_{eff}^C (cm ² /s)	Capillary zone effective diffusion coefficient, D_{eff}^{cz} (cm ² /s)	Total overall effective diffusion coefficient, D_{eff}^T (cm ² /s)	Diffusion path length, L_d (cm)
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5.08E+04	1.80E+06	2.22E-04	200	9,553	7.81E-03	3.36E-01	1.75E-04	1.86E-03	3.74E-03	0.00E+00	2.89E-05	6.92E-05	469
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Convection path length, L_p (cm)	Source vapor conc., C_{source} (μg/m ³)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm ³ /s)	Crack effective diffusion coefficient, D_{crack}^{crack} (cm ² /s)	Area of crack, A_{crack} (cm ²)	Exponent of equivalent foundation Peclet number, $\exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (μg/m ³)	Unit risk factor, URF (μg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
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200	3.36E+02	0.10	8.33E+01	1.86E-03	4.00E+02	#NUM!	5.21E-06	1.75E-03	2.6E-07	4.0E-02
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END

DATA ENTRY SHEET

23.81

RISK-BASED GROUNDWATER CONCENTRATION CALCULATIONS:

INCREMENTAL RISK CALCULATIONS:

Indoor exposure groundwater conc., carcinogen (µg/L)	Indoor exposure groundwater conc., noncarcinogen (µg/L)	Risk-based indoor exposure groundwater conc., (µg/L)	Pure component water solubility, S (µg/L)	Final indoor exposure groundwater conc., (µg/L)	Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
5.34E+04	2.38E+04	2.38E+04	2.00E+05	2.38E+04	NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)

MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL
DOWN
TO "END"

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES

Reset to
Defaults

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION (enter "X" in "YES" box and initial groundwater conc. below)

YES

ENTER Chemical CAS No. (numbers only, no dashes)		ENTER Initial groundwater conc., C_w ($\mu\text{g/L}$)		Chemical	
127184		4.37E+03		Tetrachloroethylene	

ENTER Average soil/ groundwater temperature, T_s ($^{\circ}\text{C}$)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28)			ENTER Soil stratum directly above water table, (Enter A, B, or C)	ENTER SCS soil type directly above water table	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
Thickness of soil stratum A, h_A (cm)	Thickness of soil stratum B, (Enter value or 0) h_B (cm)	Thickness of soil stratum C, (Enter value or 0) h_C (cm)				A	C	C		

MORE
↓

ENTER Stratum A SCS soil type Lookup Soil Parameters	ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum B SCS soil type Lookup Soil Parameters	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum C SCS soil type Lookup Soil Parameters	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)
C	1.43	0.459	0.215								

MORE
↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP (g/cm-s^2)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)	ENTER Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)
10	40	1000	1000	366	0.1	0.5	5

MORE
↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	25	25	250	1.0E-05	1

END

Used to calculate risk-based
groundwater concentration.

DATA ENTRY SHEET

Diffusivity in air, D_a (cm ² /s)	Diffusivity in water, D_w (cm ² /s)	Henry's law constant at reference temperature, H (atm-m ³ /mol)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm ³ /g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	1.55E+02	2.00E+02	2.6E-07	4.0E-02

END

DATA ENTRY SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm ³ /cm ³)	Stratum B soil air-filled porosity, θ_a^B (cm ³ /cm ³)	Stratum C soil air-filled porosity, θ_a^C (cm ³ /cm ³)	Stratum A effective total fluid saturation, S_e (cm ³ /cm ³)	Stratum A soil intrinsic permeability, k_i (cm ²)	Stratum A soil relative air permeability, k_{rg} (cm ²)	Stratum A soil effective vapor permeability, k_v (cm ²)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm ³ /cm ³)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm ³ /cm ³)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm ³ /cm ³)	Floor-wall seam perimeter, X_{crack} (cm)
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7.88E+08	108	0.244	ERROR	ERROR	0.324	2.26E-09	0.821	1.86E-09	81.52	0.459	0.047	0.412	4,000
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Bldg. ventilation rate, $Q_{building}$ (cm ³ /s)	Area of enclosed space below grade, A_B (cm ²)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} (atm-m ³ /mol)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, D_{A}^{eff} (cm ² /s)	Stratum B effective diffusion coefficient, D_{B}^{eff} (cm ² /s)	Stratum C effective diffusion coefficient, D_{C}^{eff} (cm ² /s)	Capillary zone effective diffusion coefficient, D_{cz}^{eff} (cm ² /s)	Total overall effective diffusion coefficient, D_T^{eff} (cm ² /s)	Diffusion path length, L_d (cm)
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5.08E+04	1.80E+06	2.22E-04	200	9,553	7.81E-03	3.36E-01	1.75E-04	3.12E-03	0.00E+00	0.00E+00	1.91E-05	2.53E-05	108
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Convection path length, L_p (cm)	Source vapor conc., C_{source} (μg/m ³)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm ³ /s)	Crack effective diffusion coefficient, D^{crack} (cm ² /s)	Area of crack, A_{crack} (cm ²)	Exponent of equivalent foundation Peclet number, $\exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (μg/m ³)	Unit risk factor, URF (μg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
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200	3.36E+02	0.10	8.33E+01	3.12E-03	4.00E+02	1.67E+290	8.24E-06	2.77E-03	2.6E-07	4.0E-02
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END

DATA ENTRY SHEET

RISK-BASED GROUNDWATER CONCENTRATION CALCULATIONS:

Indoor exposure groundwater conc., carcinogen (µg/L)	Indoor exposure groundwater conc., noncarcinogen (µg/L)	Risk-based indoor exposure groundwater conc., (µg/L)	Pure component water solubility, S (µg/L)	Final indoor exposure groundwater conc., (µg/L)
5.68E+04	2.11E+04	2.11E+04	2.00E+05	2.11E+04

INCREMENTAL RISK CALCULATIONS:

21.08

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)

MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL
DOWN
TO "END"

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES ☒

Reset to
Defaults

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION (enter "X" in "YES" box and initial groundwater conc. below)

YES ☐

ENTER Chemical CAS No. (numbers only, no dashes)		ENTER Initial groundwater conc., C_w ($\mu\text{g/L}$)		Chemical	
127184		4.37E+03		Tetrachloroethylene	

ENTER Average soil/ groundwater temperature, T_s ($^{\circ}\text{C}$)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28)			ENTER Soil stratum directly above water table, (Enter A, B, or C)	ENTER SCS soil type directly above water table	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
10	200	308	308			A	C	C		

MORE
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ENTER Stratum A SCS soil type Lookup Soil Parameters	ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum B SCS soil type Lookup Soil Parameters	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum C SCS soil type Lookup Soil Parameters	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)
C	1.43	0.459	0.215								

MORE
↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP (g/cm-s^2)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)	ENTER Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)
10	40	1000	1000	366	0.1	0.5	5

MORE
↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	30	30	350	1.0E-05	1

END

Used to calculate risk-based
groundwater concentration.

DATA ENTRY SHEET

Diffusivity in air, D_a (cm ² /s)	Diffusivity in water, D_w (cm ² /s)	Henry's law constant at reference temperature, H (atm-m ³ /mol)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm ³ /g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	1.55E+02	2.00E+02	2.6E-07	4.0E-02

END

DATA ENTRY SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm ³ /cm ³)	Stratum B soil air-filled porosity, θ_a^B (cm ³ /cm ³)	Stratum C soil air-filled porosity, θ_a^C (cm ³ /cm ³)	Stratum A effective total fluid saturation, S_e (cm ³ /cm ³)	Stratum A soil intrinsic permeability, k_i (cm ²)	Stratum A soil relative air permeability, k_{rg} (cm ²)	Stratum A soil effective vapor permeability, k_v (cm ²)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm ³ /cm ³)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm ³ /cm ³)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm ³ /cm ³)	Floor-wall seam perimeter, X_{crack} (cm)
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9.46E+08	108	0.244	ERROR	ERROR	0.324	2.26E-09	0.821	1.86E-09	81.52	0.459	0.047	0.412	4,000
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Bldg. ventilation rate, $Q_{building}$ (cm ³ /s)	Area of enclosed space below grade, A_B (cm ²)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} (atm-m ³ /mol)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, D_{A}^{eff} (cm ² /s)	Stratum B effective diffusion coefficient, D_{B}^{eff} (cm ² /s)	Stratum C effective diffusion coefficient, D_{C}^{eff} (cm ² /s)	Capillary zone effective diffusion coefficient, D_{cz}^{eff} (cm ² /s)	Total overall effective diffusion coefficient, D_T^{eff} (cm ² /s)	Diffusion path length, L_d (cm)
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5.08E+04	1.80E+06	2.22E-04	200	9,553	7.81E-03	3.36E-01	1.75E-04	3.12E-03	0.00E+00	0.00E+00	1.91E-05	2.53E-05	108
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Convection path length, L_p (cm)	Source vapor conc., C_{source} (μg/m ³)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm ³ /s)	Crack effective diffusion coefficient, D^{crack} (cm ² /s)	Area of crack, A_{crack} (cm ²)	Exponent of equivalent foundation Peclet number, $\exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (μg/m ³)	Unit risk factor, URF (μg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
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200	3.36E+02	0.10	8.33E+01	3.12E-03	4.00E+02	1.67E+290	8.24E-06	2.77E-03	2.6E-07	4.0E-02
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END

DATA ENTRY SHEET

RISK-BASED GROUNDWATER CONCENTRATION CALCULATIONS:

INCREMENTAL RISK CALCULATIONS:

15.06

Indoor exposure groundwater conc., carcinogen (µg/L)	Indoor exposure groundwater conc., noncarcinogen (µg/L)	Risk-based indoor exposure groundwater conc., (µg/L)	Pure component water solubility, S (µg/L)	Final indoor exposure groundwater conc., (µg/L)	Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
3.38E+04	1.51E+04	1.51E+04	2.00E+05	1.51E+04	NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)

MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL
DOWN
TO "END"

END

DATA ENTRY SHEET

SCS Soil Type	Soil Properties Lookup Table						Bulk Density			SCS Soil Name
	K _s (cm/h)	α ₁ (1/cm)	N (unitless)	M (unitless)	n (cm ³ /cm ³)	θ _r (cm ³ /cm ³)	Mean Grain Diameter (cm)	(g/cm ³)	θ _w (cm ³ /cm ³)	
C	0.61	0.01496	1.253	0.2019	0.459	0.098		0.0092	1.43	0.215 Clay
CL	0.34	0.01581	1.416	0.2938	0.442	0.079		0.016	1.48	0.168 Clay Loam
L	0.50	0.01112	1.472	0.3207	0.399	0.061		0.020	1.59	0.148 Loam
LS	4.38	0.03475	1.746	0.4273	0.390	0.049		0.040	1.62	0.076 Loamy Sand
S	26.78	0.03524	3.177	0.6852	0.375	0.053		0.044	1.66	0.054 Sand
SC	0.47	0.03342	1.208	0.1722	0.385	0.117		0.025	1.63	0.197 Sandy Clay
SCL	0.55	0.02109	1.330	0.2481	0.384	0.063		0.029	1.63	0.146 Sandy Clay Loam
SI	1.82	0.00658	1.679	0.4044	0.489	0.050		0.0046	1.35	0.167 Silt
SIC	0.40	0.01622	1.321	0.2430	0.481	0.111		0.0039	1.38	0.216 Silty Clay
SICL	0.46	0.00839	1.521	0.3425	0.482	0.090		0.0056	1.37	0.198 Silty Clay Loam
SIL	0.76	0.00506	1.663	0.3987	0.439	0.065		0.011	1.49	0.180 Silt Loam
SL	1.60	0.02667	1.449	0.3099	0.387	0.039		0.030	1.62	0.103 Sandy Loam

CAS No.	Chemical	Chemical Properties Lookup Table												URF extrapolated (X)	RfC extrapolated (X)
		Organic carbon partition coefficient, K _{oc} (cm ³ /g)	Diffusivity in air, D _a (cm ² /s)	Diffusivity in water, D _w (cm ² /s)	Pure component water solubility, S (mg/L)	Henry's law constant H' (unitless)	Henry's law constant at reference temperature, H (atm-m ³ /mol)	Henry's law constant reference temperature, T _R (°C)	Normal boiling point, T _B (°K)	Critical temperature, T _C (°K)	Enthalpy of vaporization at the normal boiling point, ΔH _{v,b} (cal/mol)	Unit risk factor, URF (μg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)		
127184	Tetrachloroethylene	1.55E+02	7.20E-02	8.20E-06	2.00E+02	7.53E-01	1.84E-02	25	394.40	620.20	8,288	2.6E-07	4.0E-02		