APPENDIX 4

EXAMPLE PRINTOUTS OF INDOOR AIR IMPACT MODELS

1. Groundwater to indoor air, highly-permeable soils, residential exposure scenario.
2. Groundwater to indoor air, low/moderately permeable soils, residential exposure scenario.
3. Soil to indoor air, highly-permeable soils, residential exposure scenario.
4. Soil to indoor air, low/moderately permeable soils, residential exposure scenario.
5. Soil to indoor air, highly-permeable soils, industrial/commercial exposure scenario.
6. Soil to indoor air, low/moderately permeable soils, industrial/commercial exposure scenario.

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

GW-ADV
Version 2.3; 03/01

YES | X

OR

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

YES

GROUNDWATER VOC EMISSIONS TO INDOOR AIR
RESIDENTIAL EXPOSURE SCENARIO
HIGH-PERMEABILITY (SANDY) SOILS

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial groundwater conc., C_W (µg/L)	Chemical
127184		Tetrachloroethylene

ENTER Average soil/ groundwater temperature, T_S (°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 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)
			Totals must add up to value of L_{WT} (cell D28)							
15	15	300	100	200		B	CL	S		

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 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 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)
1.5	0.43	0.15	1.5	0.43	0.3			

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP ($g/cm\text{-}s^2$)	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)
15	40	961	961	244	0.1	1

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-06	0.2

Used to calculate risk-based groundwater concentration.

ND

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm \cdot m^3/mol$)	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 ($(\mu g/m^3)^{-1}$)	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	5.9E-06	6.0E-01

END

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm³/cm³)	Stratum B soil air-filled porosity, θ_a^B (cm³/cm³)	Stratum C soil air-filled porosity, θ_a^C (cm³/cm³)	Stratum A effective total fluid saturation, S_{te} (cm³/cm³)	Stratum A soil intrinsic permeability, k_i (cm²)	Stratum A soil relative air permeability, k_{rg} (cm²)	Stratum A soil effective vapor permeability, k_v (cm²)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm³/cm³)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm³/cm³)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm³/cm³)	Floor-wall seam perimeter, X_{crack} (cm)
9.46E+08	285	0.280	0.130	ERROR	0.257	1.00E-07	0.703	7.04E-08	46.88	0.43	0.055	0.375	3,844

Bldg. ventilation rate, $Q_{building}$ (cm³/s)	Area of enclosed space below grade, A_B (cm²)	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-m³/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 (cm²/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm²/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm²/s)	Capillary zone effective diffusion coefficient, D^{eff}_{cz} (cm²/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm²/s)	Diffusion path length, L_d (cm)
6.26E+04	9.24E+05	4.16E-04	15	9,502	1.05E-02	4.46E-01	1.77E-04	5.62E-03	4.38E-04	0.00E+00	2.85E-05	1.42E-04	285

Convection path length, L_p (cm)	Source vapor conc., C_{source} (μg/m³)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm³/s)	Crack effective diffusion coefficient, D^{crack} (cm²/s)	Area of crack, A_{crack} (cm²)	Exponent of equivalent foundation Peclet number, $\exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (μg/m³)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m³)
15	4.46E+02	0.10	6.74E+01	5.62E-03	3.84E+02	2.22E+203	7.29E-06	3.25E-03	5.9E-06	6.0E-01

END

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)
1.27E+02	3.85E+04	1.27E+02	2.00E+05	1.27E+02

INCREMENTAL RISK CALCULATIONS:

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

Soil Properties Lookup Table

SCS Soil Type	K_s (cm/h)	α (1/cm)	N (unitless)	M (unitless)	θ_s (cm³/cm³)	θ_r (cm³/cm³)	Mean Grain Diameter (cm)
C	0.61	0.0150	1.253	0.2019	0.459	0.098	0.0092
CL	0.34	0.0158	1.416	0.2938	0.442	0.079	0.016
L	0.50	0.0111	1.472	0.3207	0.399	0.061	0.02
LS	4.38	0.0348	1.746	0.4273	0.39	0.049	0.04
S	26.78	0.0352	3.177	0.6852	0.375	0.053	0.044
SC	0.47	0.0334	1.208	0.1722	0.385	0.117	0.025
SCL	0.55	0.0211	1.33	0.2481	0.384	0.063	0.029
SI	1.82	0.0066	1.679	0.4044	0.489	0.05	0.0046
SIC	0.40	0.0162	1.321	0.243	0.481	0.111	0.0039
SICL	0.46	0.0084	1.521	0.3425	0.482	0.09	0.0056
SIL	0.76	0.0051	1.663	0.3987	0.439	0.065	0.011
SL	1.60	0.0267	1.449	0.3099	0.387	0.039	0.03

Chemical Properties Lookup Table

CAS No.	Chemical	Organic carbon partition coefficient, K_{oc} (cm³/g)	Diffusivity in air, D_a (cm²/s)	Diffusivity in water, D_w (cm²/s)	Pure component water solubility, S (mg/L)	Henry's law constant H' (unitless)	Henry's law constant at reference temperature, H (atm-m³/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, $\Delta H_{v,b}$ (cal/mol)	Unit risk factor, URF (μg/m³)⁻¹	Reference conc., RfC (mg/m³)	Molecular weight, MW (g/mol)	URF extrapolated (X)	RfC extrapolated (X)	
56235	Carbon tetrachloride	1.74E+02	7.80E-02	8.80E-06	7.93E+02	1.25E+00	3.04E-02	25	349.90	556.60	7,127	4.2E-05	2.5E-03	153.82		+	Cal EPA URF
67641	Acetone	5.75E-01	1.24E-01	1.14E-05	1.00E+06	1.59E-03	3.88E-05	25	329.20	508.10	6,955	0.0E+00	3.5E-01	58.08		X	
67663	Chloroform	3.98E+01	1.04E-01	1.00E-05	7.92E+03	1.50E-01	3.67E-03	25	334.32	536.40	6,988	5.3E-06	3.0E-03	119.38		+	Cal EPA URF
71432	Benzene	5.90E+01	8.80E-02	9.80E-06	1.75E+03	2.28E-01	5.56E-03	25	353.24	562.16	7,342	2.9E-05	6.0E-03	78.11		+	Cal EPA URF
71556	1,1,1-Trichloroethane	1.10E+02	7.80E-02	8.80E-06	1.33E+03	7.05E-01	1.72E-02	25	347.24	545.00	7,136	0.0E+00	2.2E+00	133.41			No Cal EPA URF
74839	Methyl bromide (bromomethan	9.00E+00	7.28E-02	1.21E-05	1.52E+04	2.56E-01	6.24E-03	25	276.71	467.00	5,714	0.0E+00	4.9E-03	94.94			
74873	Chloromethane	3.50E+01	1.10E-01	6.50E-06	8.20E+03	9.84E-01	2.40E-02	25	248.94	416.80	5,147	1.8E-06	3.0E-01	51.00		X	No Cal EPA URF
75003	Chloroethane	1.47E+01	1.04E-01	1.15E-05	5.70E+03	4.51E-01	1.10E-02	25	285.00	460.00	5,892	8.3E-07	1.0E+01	65.00		X	No Cal EPA URF
75014	Vinyl chloride (chloroethene)	1.86E+01	1.06E-01	1.23E-06	2.76E+03	1.11E+00	2.70E-02	25	259.25	432.00	5,250	7.8E-05	0.0E+00	62.50			Cal EPA URF
75092	Methylene chloride	1.11E+01	1.01E-01	1.17E-05	1.32E+04	8.98E-02	2.19E-03	25	313.00	510.00	6,706	1.0E-06	3.0E+00	84.93			Cal EPA URF
75274	Bromodichloromethane	5.50E+01	2.98E-02	1.06E-05	6.74E+03	6.56E-02	1.60E-03	25	363.15	585.85	7,000	3.7E-05	7.0E-02	163.83	X	+	Cal EPA URF
75343	1,1-Dichloroethane	3.16E+01	7.42E-02	1.05E-05	5.06E+03	2.30E-01	5.62E-03	25	330.55	523.00	6,895	1.6E-06	5.0E-01	98.96			Cal EPA URF
75354	1,1-Dichloroethylene	5.89E+01	9.00E-02	1.04E-05	2.25E+03	1.07E+00	2.61E-02	25	304.75	576.05	6,247	0.0E+00	2.0E-01	96.94			No Cal EPA URF
78875	1,2-Dichloropropane	4.37E+01	7.82E-02	8.73E-06	2.80E+03	1.15E-01	2.80E-03	25	369.52	572.00	7,590	1.0E-05	4.0E-03	112.99			Cal EPA URF
78933	Methyl Ethyl Ketone	4.50E+00	8.95E-02	9.80E-06	2.68E+05	1.12E-03	2.74E-05	25	353.00	535.00	34,920	0.0E+00	1.0E+00	71.00			
79005	1,1,2-Trichloroethane	5.01E+01	7.80E-02	8.80E-06	4.42E+03	3.74E-02	9.13E-04	25	386.15	602.00	8,322	1.6E-05	1.4E-02	133.41			No Cal EPA URF
79016	Trichloroethylene	1.66E+02	7.90E-02	9.10E-06	1.10E+03	4.22E-01	1.03E-02	25	360.36	544.20	7,505	2.0E-06	3.5E-02	131.39			Cal EPA URF
79345	1,1,2,2-Tetrachloroethane	9.37E+01	7.10E-02	7.90E-06	2.97E+03	1.41E-02	3.45E-04	25	419.60	661.15	8,996	5.8E-05	2.1E-01	167.85		+	Cal EPA URF = USEPA
83329	Acenaphthene	4.90E+03	4.21E-02	7.69E-06	4.24E+00	6.36E-03	1.55E-04	25	550.54	803.15	12,155	0.0E+00	2.1E-01	154.21		X	
86737	Fluorene	1.38E+04	6.08E-02	7.88E-06	1.90E+00	3.16E-03	7.70E-05	25	570.44	870.00	12,666	0.0E+00	1.4E-01	166.22		X	
90120	1-(2-) Methylnaphthalene	7.20E+02	5.90E-02	7.50E-06	2.60E+01	1.19E-02	2.90E-04	25	514.70	772.00	11,190	0.0E+00	1.4E-01	142.00			
91203	Naphthalene	1.19E+03	5.90E-02	7.50E-06	3.10E+01	1.98E-02	4.83E-04	25	491.14	748.40	10,373	0.0E+00	3.0E-03	128.18			USEPA
95501	1,2-Dichlorobenzene	6.17E+02	6.90E-02	7.90E-06	1.56E+02	7.79E-02	1.90E-03	25	453.57	705.00	9,700	0.0E+00	2.0E-01	147.00			No Cal EPA URF
95578	2-Chlorophenol	3.98E+02	5.01E-01	9.46E-06	2.20E+04	1.60E-02	3.91E-04	25	447.53	675.00	9,572	0.0E+00	1.8E-02	128.56		X	
95954	2,4,5-Trichlorophenol	8.90E+01	2.91E-02	7.03E-06	1.19E+03	8.94E-03	2.18E-04	25	526.15	759.13	13,000	0.0E+00	3.5E-01	197.45		X	
100414	Ethylbenzene	3.63E+02	7.50E-02	7.80E-06	1.69E+02	3.23E-01	7.88E-03	25	409.34	617.20	8,501	1.1E-06	1.0E+00	106.17			USEPA IX PRGs
100425	Styrene	7.76E+02	7.10E-02	8.00E-06	3.10E+02	1.13E-01	2.75E-03	25	418.31	636.00	8,737	0.0E+00	1.0E+00	104.15			
105679	2,4-Dimethylphenol	4.00E+01	5.84E-02	8.69E-06	7.87E+03	6.97E-04	1.70E-05	25	484.13	707.60	11,329	0.0E+00	7.0E-02	122.17		X	
106467	1,4-Dichlorobenzene	6.17E+02	6.90E-02	7.90E-06	7.38E+01	9.96E-02	2.43E-03	25	447.21	684.75	9,271	1.1E-05	8.0E-01	147.00			Cal EPA URF
106934	1,2-dibromoethane	2.81E+01	7.33E-02	8.06E-06	3.40E+03	1.31E-02	3.20E-04	25	404.00	582.80	9,986	7.1E-05	2.0E-04	188.00			Cal EPA URF
107062	1,2-Dichloroethane	1.74E+01	1.04E-01	9.90E-06	8.52E+03	4.01E-02	9.79E-04	25	356.65	561.00	7,643	2.1E-05	4.9E-03	98.96			Cal EPA URF
108101	Methyl Isobutyl Ketone	1.34E+02	7.50E-02	7.80E-06	1.90E+04	5.74E-03	1.40E-04	25	389.00	575.00	40,610	0.0E+00	8.1E-02	100.00			
108383	Xylene (m)	4.07E+02	7.00E-02	7.80E-06	1.61E+02	3.01E-01	7.34E-03	25	412.27	617.05	8,523	0.0E+00	1.0E-01	106.17		X	USEPA Region IX
108883	Toluene	1.82E+02	8.70E-02	8.60E-06	5.26E+02	2.72E-01	6.64E-03	25	383.78	591.79	7,930	0.0E+00	4.0E-01	92.14			
108907	Chlorobenzene	2.19E+02	7.30E-02	8.70E-06	4.72E+02	1.52E-01	3.70E-03	25	404.87	632.40	8,410	0.0E+00	6.0E-02	112.56			USEPA Region IX
111444	Bis(2-chloroethyl)ether	7.60E+01	6.92E-02	7.53E-06	1.72E+04	7.38E-04	1.80E-05	25	451.15	659.79	9,000	7.1E-04	0.0E+00	143.11			CAEPA URF
120127	Anthracene	2.35E+04	3.24E-02	7.74E-06	4.34E-02	2.67E-03	6.50E-05	25	615.18	873.00	13,121	0.0E+00	1.1E+00	178.24		X	
120821	1,2,4-Trichlorobenzene	1.78E+03	3.00E-02	8.23E-06	3.00E+02	5.82E-02	1.42E-03	25	486.15	725.00	10,471	0.0E+00	2.0E-01	181.45			No Cal EPA URF
124481	Dibromochloromethane	4.68E+02	9.60E-02	1.00E-05	4.40E+03	3.49E-02	8.50E-04	25	416.14	678.20	8,000	2.7E-05	7.0E-02	208.28	X		Cal EPA URF
127184	Tetrachloroethylene	1.55E+02	7.20E-02	8.20E-06	2.00E+02	7.54E-01	1.84E-02	25	394.40	620.20	8,288	5.9E-06	6.0E-01	165.83			Cal EPA URF
129000	Pyrene	1.05E+05	2.72E-02	7.24E-06	1.35E-01	4.51E-04	1.10E-05	25	667.95	936.00	14,370	0.0E+00	1.1E-01	202.26		X	
156592	cis-1,2-Dichloroethylene	3.55E+01	7.36E-02	1.13E-05	3.50E+03	1.67E-01	4.08E-03	25	333.65	544.00	7,192	0.0E+00	3.5E-02	96.94		X	No Cal EPA URF
156605	trans-1,2-Dichloroethylene	5.25E+01	7.07E-02	1.19E-05	6.30E+03	3.85E-01	9.38E-03	25	320.85	516.50	6,717	0.0E+00	7.0E-02	96.94		X	No Cal EPA URF
542756	1,3-Dichloropropene	4.57E+01	6.26E-02	1.00E-05	2.80E+03	7.26E-01	1.77E-02	25	381.15	587.38	7,000	1.6E-05	2.0E-02	110.97			Cal EPA URF
1634044	Methy tert Butyl Ether	6.00E+00	8.00E-02	1.00E-05	1.50E+05	2.41E-02	5.87E-04	25	328.00	497.10	6,678	2.6E-07	3.0E+00	98.00			Cal EPA URF

Notes:
URFs from CalEPA if available: Criteria for Carcinogens: California Environmental Protection Agency, Office of Environmental Health Hazard Assessment, Standards and Criteria Work Group, January 2003 (CalEPA 2003).
"+" Additional RfC extrapolated from RfD-inhalation factor presented in USEPA Region IX Preliminary Remediation Goals document (USEPA 2002).
Default physio-Chemical constants included in spreadsheet replaced with constants from USEPA Region IX Preliminary Remediation Goals document (USEPA 2002) when available.
Additional physio-chemical constants from NIST 2001.

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

GW-ADV
Version 2.3; 03/01

YES [X]

OR

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

YES

GROUNDWATER VOC EMISSIONS TO INDOOR AIR
RESIDENTIAL EXPOSURE SCENARIO
LOW-PERMEABILITY (SILTY) SOILS

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial groundwater conc., C_W (μg/L)	Chemical
127184		Tetrachloroethylene

ENTER Average soil/ groundwater temperature, T_S (°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 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 (cm²)
			Totals must add up to value of L_{WT} (cell D28)							
15	15	300	100	200		B	SI	LS		

ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm³)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm³/cm³)	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm³)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm³/cm³)	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm³)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm³/cm³)
1.5	0.43	0.15	1.5	0.43	0.3			

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP (g/cm-s²)	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)
15	40	961	961	244	0.1	1

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-06	0.2

Used to calculate risk-based groundwater concentration.

ND

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm\text{-}m^3/mol$)	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 ($(\mu g/m^3)^{-1}$)	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	5.9E-06	6.0E-01

END

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_{te} (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)
9.46E+08	285	0.280	0.130	ERROR	0.265	1.64E-08	0.824	1.35E-08	163.04	0.43	0.048	0.382	3,844

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} ($atm \cdot m^3/mol$)	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)
6.26E+04	9.24E+05	4.16E-04	15	9,502	1.05E-02	4.46E-01	1.77E-04	5.62E-03	4.38E-04	0.00E+00	2.02E-05	3.48E-05	285

Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	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., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF ($(\mu g/m^3)^{-1}$)	Reference conc., RfC (mg/m^3)
15	4.46E+02	0.10	1.29E+01	5.62E-03	3.84E+02	9.74E+38	1.79E-06	7.98E-04	5.9E-06	6.0E-01

END

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)
5.17E+02	1.57E+05	5.17E+02	2.00E+05	5.17E+02

INCREMENTAL RISK CALCULATIONS:

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

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

GW-ADV
Version 2.3; 03/01

YES | X

OR

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

YES

GROUNDWATER VOC EMISSIONS TO INDOOR AIR
COMMERCIAL/INDUSTRIAL EXPOSURE SCENARIO
HIGH-PERMEABILITY (SANDY) SOILS

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial groundwater conc., C_W (μg/L)	Chemical
127184		Tetrachloroethylene

ENTER Average soil/ groundwater temperature, T_S (°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 Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, Enter value or C 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)
			Totals must add up to value of L_{WT} (cell D28)							
15	15	300	100	200		B	CL	S		

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 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 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)
1.5	0.43	0.15	1.5	0.43	0.3			

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)
15	40	961	961	244	0.1	2

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-06	0.2

Used to calculate risk-based groundwater concentration.

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm\cdot m^3/mol$)	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 ($(\mu g/m^3)^{-1}$)	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	5.9E-06	6.0E-01

END

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_{te} (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)
7.88E+08	285	0.280	0.130	ERROR	0.257	1.00E-07	0.703	7.04E-08	46.88	0.43	0.055	0.375	3,844

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} ($atm \cdot m^3/mol$)	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)
1.25E+05	9.24E+05	4.16E-04	15	9,502	1.05E-02	4.46E-01	1.77E-04	5.62E-03	4.38E-04	0.00E+00	2.85E-05	1.42E-04	285

Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	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., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
15	4.46E+02	0.10	6.74E+01	5.62E-03	3.84E+02	2.22E+203	3.65E-06	1.63E-03	5.9E-06	6.0E-01

END

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)
4.26E+02	1.08E+05	4.26E+02	2.00E+05	4.26E+02

INCREMENTAL RISK CALCULATIONS:

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

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

GW-ADV
Version 2.3; 03/01

YES [X]

OR

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

YES [ ]

GROUNDWATER VOC EMISSIONS TO INDOOR AIR
COMMERCIAL/INDUSTRIAL EXPOSURE SCENARIO
LOW-PERMEABILITY (SILTY) SOILS

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial groundwater conc., C_W (μg/L)	Chemical
127184		Tetrachloroethylene

ENTER Average soil/ groundwater temperature, T_S (°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 D28) 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)
15	15	300	100	200		B	SI	LS		

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 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 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)
1.5	0.43	0.15	1.5	0.43	0.3			

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)
15	40	961	961	244	0.1	2

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-06	0.2

Used to calculate risk-based groundwater concentration.

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm \cdot m^3/mol$)	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 ($(\mu g/m^3)^{-1}$)	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	5.9E-06	6.0E-01

END

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_{te} (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)
7.88E+08	285	0.280	0.130	ERROR	0.265	1.64E-08	0.824	1.35E-08	163.04	0.43	0.048	0.382	3,844

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} ($atm{\cdot}m^3/mol$)	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)
1.25E+05	9.24E+05	4.16E-04	15	9,502	1.05E-02	4.46E-01	1.77E-04	5.62E-03	4.38E-04	0.00E+00	2.02E-05	3.48E-05	285

Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	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., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
15	4.46E+02	0.10	1.29E+01	5.62E-03	3.84E+02	9.74E+38	8.94E-07	3.99E-04	5.9E-06	6.0E-01

END

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)
1.74E+03	4.39E+05	1.74E+03	2.00E+05	1.74E+03

INCREMENTAL RISK CALCULATIONS:

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

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

YES [X]

OR

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

YES [ ]

SL-ADV
Version 2.3; 03/01

SOIL VOC EMISSIONS TO INDOOR AIR
RESIDENTIAL EXPOSURE SCENARIO
HIGH-PERMEABILITY (SANDY) SOILS

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial soil conc., C_R (μg/kg)	Chemical
127184		Tetrachloroethylene

MORE ↓

ENTER Average soil temperature, T_S (°C)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to top of contamination, L_t (cm)	ENTER Depth below grade to bottom of contamination, (enter value of 0 if value is unknown) L_b (cm)	ENTER Totals must add up to value of L_t (cell D28) 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 A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm²)
20	15	15	215	15			S		

MORE ↓

ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm³)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm³/cm³)	ENTER Stratum A soil organic carbon fraction, f_{oc}^A (unitless)	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm³)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm³/cm³)	ENTER Stratum B soil organic carbon fraction, f_{oc}^B (unitless)	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm³)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm³/cm³)	ENTER Stratum C soil organic carbon fraction, f_{oc}^C (unitless)
1.5	0.43	0.15	0.006								

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP (g/cm-s²)	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)
15	40	961	961	244	0.1	1

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-06	0.2

Used to calculate risk-based soil concentration.

END

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm \cdot m^3/mol$)	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 ($(\mu g/m^3)^{-1}$)	Reference conc., RfC (mg/m^3)	Physical state at soil temperature, (S,L,G)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	1.55E+02	2.00E+02	5.9E-06	6.0E-01	1.7E+02

END

Exposure duration, τ (sec)	Source-building separation, LT (cm)	Stratum A soil air-filled porosity, θαA (cm3/cm3)	Stratum B soil air-filled porosity, θαB (cm3/cm3)	Stratum C soil air-filled porosity, θαX (cm3/cm3)	Stratum A effective total fluid saturation, Ste (cm3/cm3)	Stratum A soil intrinsic permeability, ki (cm2)	Stratum A soil relative air permeability, krg (cm2)	Stratum A soil effective vapor permeability, kv (cm2)	Floor-wall seam perimeter, Xcrack (cm)	Initial soil concentration used, CR (mg/kg)	Bldg. ventilation rate, Qbuilding (cm3/s)
9.46E+08	1	0.280	ERROR	ERROR	0.257	1.01E-07	0.703	7.10E-08	3,844	1.00E+00	6.26E+04

Area of enclosed space below grade, AB (cm2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Zcrack (cm)	Enthalpy of vaporization at ave. soil temperature, ΔHϖ,ΤΣ (cal/mol)	Henry's law constant at ave. soil temperature, HTS (atm-m3/mol)	Henry's law constant at ave. soil temperature, H'TS (unitless)	Vapor viscosity at ave. soil temperature, μΤΣ (g/cm-s)	Stratum A effective diffusion coefficient, DeffA (cm2/s)	Stratum B effective diffusion coefficient, DeffB (cm2/s)	Stratum C effective diffusion coefficient, DeffC (cm2/s)	Total overall effective diffusion coefficient, DeffT (cm2/s)	Diffusion path length, Ld (cm)	Convection path length, Lp (cm)
9.24E+05	4.16E-04	15	9,451	1.40E-02	5.83E-01	1.78E-04	5.62E-03	0.00E+00	0.00E+00	5.62E-03	1	15

Soil-water partition coefficient, Kd (cm3/g)	Source vapor conc., Csource (mg/m3)	Crack radius, rcrack (cm)	Average vapor flow rate into bldg., Qsoil (cm3/s)	Crack effective diffusion coefficient, Dcrack (cm2/s)	Area of crack, Acrack (cm2)	Exponent of equivalent foundation Peclet number, exp(Pef) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., Cbuilding (mg/m3)	Finite source β τερμ (unitless)	Finite source ψ τερμ (sec)-1	Time for source depletion, τΔ (sec)	Exposure duration > time for source depletion (YES/NO)
9.30E-01	5.12E+02	0.10	6.74E+01	5.62E-03	3.84E+02	2.23E+203	NA	NA	7.80E+01	1.92E-03	1.86E+07	YES

Finite source indoor attenuation coefficient, <a> (unitless)	Mass limit bldg. conc., Cbuilding (mg/m3)	Finite source bldg. conc., Cbuilding (mg/m3)	Final finite source bldg. conc., Cbuilding (mg/m3)	Unit risk factor, URF (mg/m3)-1	Reference conc., RfC (mg/m3)
NA	4.68E-03	NA	4.68E-03	5.9E-06	6.0E-01

END

RISK-BASED SOIL CONCENTRATION CALCULATIONS:

Indoor exposure soil conc., carcinogen (μg/kg)	Indoor exposure soil conc., noncarcinogen (μg/kg)	Risk-based indoor exposure soil conc., (μg/kg)	Soil saturation conc., C_{sat} (μg/kg)	Final indoor exposure soil conc., (μg/kg)
8.82E+01	2.67E+04	8.82E+01	2.28E+05	8.82E+01

INCREMENTAL RISK CALCULATIONS:

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

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

SL-ADV
Version 2.3; 03/01

YES | X

OR

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

YES |

SOIL VOC EMISSIONS TO INDOOR AIR
COMMERCIAL/INDUSTRIAL EXPOSURE SCENARIO
HIGH-PERMEABILITY (SANDY) SOILS

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial soil conc., C_R (μg/kg)	Chemical
127184		Tetrachloroethylene

MORE ↓

ENTER Average soil temperature, T_S (°C)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to top of contamination, L_t (cm)	ENTER Depth below grade to bottom of contamination, (enter value of 0 if value is unknown) L_b (cm)	ENTER 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 A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
20	15	15	215	15			S		

Totals must add up to value of L_t (cell D28) (applies to thickness of soil strata A, B and C)

MORE ↓

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 A soil organic carbon fraction, f_{oc}^A (unitless)	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 B soil organic carbon fraction, f_{oc}^B (unitless)	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)	ENTER Stratum C soil organic carbon fraction, f_{oc}^C (unitless)
1.5	0.43	0.15	0.006								

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)
15	40	961	961	244	0.1	2

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-06	0.2

Used to calculate risk-based soil concentration.

END

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H $(atm\text{-}m^3/mol)$	Henry's law constant reference temperature, T_R (^oC)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (^oK)	Critical temperature, T_C (^oK)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)	Physical state at soil temperature, (S,L,G)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	1.55E+02	2.00E+02	5.9E-06	6.0E-01	1.7E+02

END

Exposure duration, τ (sec)	Source-building separation, LT (cm)	Stratum A soil air-filled porosity, θαA (cm3/cm3)	Stratum B soil air-filled porosity, θαB (cm3/cm3)	Stratum C soil air-filled porosity, θαX (cm3/cm3)	Stratum A effective total fluid saturation, Ste (cm3/cm3)	Stratum A soil intrinsic permeability, ki (cm2)	Stratum A soil relative air permeability, krg (cm2)	Stratum A soil effective vapor permeability, kv (cm2)	Floor-wall seam perimeter, Xcrack (cm)	Initial soil concentration used, CR (mg/kg)	Bldg. ventilation rate, Qbuilding (cm3/s)
7.88E+08	1	0.280	ERROR	ERROR	0.257	1.01E-07	0.703	7.10E-08	3,844	1.00E+00	1.25E+05

Area of enclosed space below grade, AB (cm2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Zcrack (cm)	Enthalpy of vaporization at ave. soil temperature, ΔHϖ,TΣ (cal/mol)	Henry's law constant at ave. soil temperature, HTS (atm-m3/mol)	Henry's law constant at ave. soil temperature, H'TS (unitless)	Vapor viscosity at ave. soil temperature, μTΣ (g/cm-s)	Stratum A effective diffusion coefficient, DeffA (cm2/s)	Stratum B effective diffusion coefficient, DeffB (cm2/s)	Stratum C effective diffusion coefficient, DeffC (cm2/s)	Total overall effective diffusion coefficient, DeffT (cm2/s)	Diffusion path length, Ld (cm)	Convection path length, Lp (cm)
9.24E+05	4.16E-04	15	9,451	1.40E-02	5.83E-01	1.78E-04	5.62E-03	0.00E+00	0.00E+00	5.62E-03	1	15

Soil-water partition coefficient, Kd (cm3/g)	Source vapor conc., Csource (mg/m3)	Crack radius, rcrack (cm)	Average vapor flow rate into bldg., Qsoil (cm3/s)	Crack effective diffusion coefficient, Dcrack (cm2/s)	Area of crack, Acrack (cm2)	Exponent of equivalent foundation Peclet number, exp(Pef) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., Cbuilding (mg/m3)	Finite source β τερμ (unitless)	Finite source ψ τερμ (sec)-1	Time for source depletion, τΔ (sec)	Exposure duration > time for source depletion (YES/NO)
9.30E-01	5.12E+02	0.10	6.74E+01	5.62E-03	3.84E+02	2.23E+203	NA	NA	7.80E+01	1.92E-03	1.86E+07	YES

Finite source indoor attenuation coefficient, <a> (unitless)	Mass limit bldg. conc., Cbuilding (mg/m3)	Finite source bldg. conc., Cbuilding (mg/m3)	Final finite source bldg. conc., Cbuilding (mg/m3)	Unit risk factor, URF (mg/m3)-1	Reference conc., RfC (mg/m3)
NA	2.81E-03	NA	2.81E-03	5.9E-06	6.0E-01

END

RISK-BASED SOIL CONCENTRATION CALCULATIONS:

Indoor exposure soil conc., carcinogen (μg/kg)	Indoor exposure soil conc., noncarcinogen (μg/kg)	Risk-based indoor exposure soil conc., (μg/kg)	Soil saturation conc., C_{sat} (μg/kg)	Final indoor exposure soil conc., (μg/kg)
2.47E+02	6.24E+04	2.47E+02	2.28E+05	2.47E+02

INCREMENTAL RISK CALCULATIONS:

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

SOIL VOC EMISSIONS TO INDOOR AIR
RESIDENTIAL EXPOSURE SCENARIO
HIGH-PERMEABILITY (SANDY) SOILS
SOIL GAS:INDOOR AIR ATTENUATION FACTOR = 0.001

Soil Gas Concentration Data

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Soil gas conc., C_R (μg/m^3)	OR	ENTER Soil gas conc., C_R (ppmv)	Chemical
127184	3.88E+02			Tetrachloroethylene

Enter soil gas concentration in only one set of units.

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Soil gas sampling depth below grade, L_s (cm)	ENTER Average soil temperature, T_S (°C)	ENTER 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 A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
15	15	10	15			S		

Totals must add up to value of Ls (cell C24)

MORE ↓

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 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 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)
1.5	0.43	0.15						

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)
15	40	961	961	244	0.1	1

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)
70	30	30	350

END

Diffusivity in air, Da (cm2/s)	Diffusivity in water, Dw (cm2/s)	Henry's law constant at reference temperature, H (atm-m3/mol)	Henry's law constant reference temperature, TR (oC)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, TB (oK)	Critical temperature, TC (oK)	Molecular weight, MW (g/mol)	Unit risk factor, URF (mg/m3)-1	Reference conc., RfC (mg/m3)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	165.83	5.9E-06	6.0E-01

END

Exposure duration, t (sec)	Source-**building** separation, LT (cm)	Stratum A **air-filled** porosity, qaA (cm3/cm3)	Stratum B soil air-filled porosity, qaB (cm3/cm3)	Stratum C air-filled porosity, qaC (cm3/cm3)	Stratum A effective total fluid saturation, Ste (cm3/cm3)	Stratum A soil intrinsic permeability, ki (cm2)	Stratum A soil relative air permeability, krg (cm2)	Stratum A soil effective vapor permeability, kv (cm2)	Floor-wall seam perimeter, Xcrack (cm)	Soil gas conc. (mg/m3)	Bldg. ventilation rate, Qbuilding (cm3/s)
9.5E+08	1	0.28	ERROR	ERROR	0.25729443	9.92425E-08	0.703228129	6.97901E-08	3844	388.1	62594.20111

Area of enclosed space **below** grade, AB (cm2)	Crack-**to-total** area ratio, h (unitless)	Crack **depth** below grade, Zcrack (cm)	Enthalpy of **vaporization at** ave. soil temperature, DHv,TS (cal/mol)	Henry's law **constant at** ave. soil temperature, HTS (atm-m3/mol)	Henry's law **constant at** ave. soil temperature, H'TS (unitless)	Vapor **viscosity at** ave. soil temperature, mTS (g/cm-s)	Stratum A **effective** diffusion coefficient, DeffA (cm2/s)	Stratum B effective diffusion coefficient, DeffB (cm2/s)	Stratum C **effective** diffusion coefficient, DeffC (cm2/s)	Total overall effective diffusion coefficient, DeffT (cm2/s)	Diffusion path length, Ld (cm)
923521	0.000416233	15	9552.934617	7.83E-03	0.337067044	0.000175414	5.62E-03	0	0	0.0056163	1

Convectior path length, **Lp** (cm)	Source vapor **conc.,** Csource (mg/m3)	Crack **radius,** rcrack (cm)	Average vapor flow rate **into bldg.,** Qsoil (cm3/s)	Crack effective diffusion **coefficient,** Dcrack (cm2/s)	Area of **crack,** Acrack (cm2)	Exponent of equivalent foundation Peclet **number,** exp(Pef) (unitless)	Infinite source indoor attenuation **coefficient,** a (unitless)	Infinite source bldg. **conc.,** Cbuilding (mg/m3)	Unit risk **factor,** URF (mg/m3)-1	Reference **conc.,** RfC (mg/m3)
15	388.1	0.1	67.38925148	0.005616299	384.4	2.211E+203	0.001062797	0.412471487	0.0000059	0.6

END

Qsoil (L/min)
4.0

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
1.0E-06	6.6E-04

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

SCROLL DOWN TO "END"

END

SG-ADV
Version 1.0; 03/01

SOIL VOC EMISSIONS TO INDOOR AIR
COMMERCIAL/INDUSTRIAL EXPOSURE SCENARIO
HIGH-PERMEABILITY (SANDY) SOILS
SOIL GAS:INDOOR AIR ATTENUATION FACTOR = 0.0005

Soil Gas Concentration Data

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Soil gas conc., C_R ($\mu g/m^3$)	OR	ENTER Soil gas conc., C_R (ppmv)	Chemical
127184	1.30E+03			Tetrachloroethylene

Enter soil gas concentration in only one set of units.

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Soil gas sampling depth below grade, L_s (cm)	ENTER Average soil temperature, T_S (°C)	ENTER 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 A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm²)
			Totals must add up to value of Ls (cell C24)					
15	15	10	15			S		

MORE ↓

ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm³)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm³/cm³)	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm³)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm³/cm³)	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm³)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm³/cm³)
1.5	0.43	0.15						

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP (g/cm-s²)	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)
15	40	961	961	244	0.1	2

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)
70	25	25	250

END

Diffusivity in air, Da (cm2/s)	Diffusivity in water, Dw (cm2/s)	Henry's law constant at reference temperature, H (atm-m3/mol)	Henry's law constant reference temperature, TR (oC)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, TB (oK)	Critical temperature, TC (oK)	Molecular weight, MW (g/mol)	Unit risk factor, URF (mg/m3)-1	Reference conc., RfC (mg/m3)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	165.83	5.9E-06	6.0E-01

END

Exposure duration, t (sec)	Source-building separation, LT (cm)	Stratum A air-filled porosity, qaA (cm3/cm3)	Stratum B soil air-filled porosity, qaB (cm3/cm3)	Stratum C air-filled porosity, qaC (cm3/cm3)	Stratum A effective total fluid saturation, Ste (cm3/cm3)	Stratum A soil intrinsic permeability, ki (cm2)	Stratum A soil relative air permeability, krg (cm2)	Stratum A soil effective vapor permeability, kv (cm2)	Floor-wall seam perimeter, Xcrack (cm)	Soil gas conc. (mg/m3)	Bldg. ventilation rate, Qbuilding (cm3/s)
7.9E+08	1	0.28	ERROR	ERROR	0.25729443	9.92425E-08	0.703228129	6.97901E-08	3844	1304	125188.4022

Area of enclosed space below grade, AB (cm2)	Crack-to-total area ratio, h (unitless)	Crack depth below grade, Zcrack (cm)	Enthalpy of vaporization at ave. soil temperature, DHv,TS (cal/mol)	Henry's law constant at ave. soil temperature, HTS (atm-m3/mol)	Henry's law constant at ave. soil temperature, H'TS (unitless)	Vapor viscosity at ave. soil temperature, mTS (g/cm-s)	Stratum A effective diffusion coefficient, DeffA (cm2/s)	Stratum B effective diffusion coefficient, DeffB (cm2/s)	Stratum C effective diffusion coefficient, DeffC (cm2/s)	Total overall effective diffusion coefficient, DeffT (cm2/s)	Diffusion path length, Ld (cm)
923521	0.000416233	15	9552.934617	7.83E-03	0.337067044	0.000175414	5.62E-03	0	0	0.0056163	1

Convection path length, Lp (cm)	Source vapor conc., Csource (mg/m3)	Crack radius, rcrack (cm)	Average vapor flow rate into bldg., Qsoil (cm3/s)	Crack effective diffusion coefficient, Dcrack (cm2/s)	Area of crack, Acrack (cm2)	Exponent of equivalent foundation Peclet number, exp(Pef) (unitless)	Infinite source indoor attenuation coefficient, a (unitless)	Infinite source bldg. conc., Cbuilding (mg/m3)	Unit risk factor, URF (mg/m3)-1	Reference conc., RfC (mg/m3)
15	1304	0.1	67.38925148	0.005616299	384.4	2.211E+203	0.000531398	0.692943596	0.0000059	0.6

END

Qsoil (L/min)
4.0

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
1.0E-06	7.9E-04

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

SCROLL DOWN TO "END"

END

APPENDIX 5

DEVELOPMENT OF SOIL LEACHING SCREENING LEVELS

The method used by the Ontario Ministry of Environment and Energy (MOEE 1996) to develop soil screening levels for leaching concerns was adopted from guidance published by the Massachusetts Department of Environment Protection (MADEP). This appendix provides relevant sections and appendices from the 1994 MADEP publication entitled "Background Documentation for the Development of the Massachusetts Contingency Plan Numerical Standards".

BACKGROUND DOCUMENTATION

FOR THE DEVELOPMENT OF THE

MCP NUMERICAL STANDARDS

Massachusetts Department of Environmental Protection
Bureau of Waste Site Cleanup
and
Office of Research and Standards

April 1994

MCP APPENDIX F

DEVELOPMENT OF

DILUTION/ATTENUATION FACTORS (DAFs)

FOR THE LEACHING-BASED

SOIL STANDARDS

DEVELOPMENT OF DILUTION/ATTENUATION FACTORS (DAFs) FOR THE LEACHING-BASED SOIL STANDARDS

INTRODUCTION

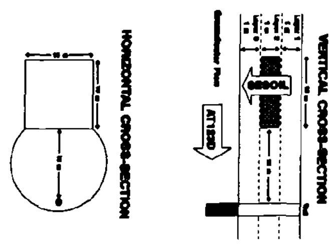
The Massachusetts Department of Environmental Protection has developed dilution attenuation factors (DAFs) in order to establish soil cleanup criteria for the protection of groundwater from leaching of residual contaminants in soil. DEP has adopted the modeling approach utilized by the State of Oregon in a similar process. This report describes the model and its application toward the development of DAFs for Massachusetts for a limited number of compounds of concern, and the subsequent development of one regression algorithm that relates DAFs developed by Oregon to those applicable in Massachusetts, and another algorithm that relates DAFs to chemical specific parameters. The pathway to groundwater is only one consideration in the final determination of an acceptable soil cleanup level.

THE OREGON MODEL

The Oregon model (Anderson, 1992) assumes a generic setting for a release of contaminant in the unsaturated zone and then applies the combination of SESOIL and AT123D models to estimate impact of the initial soil loading on a receptor assumed directly downgradient of the site via the groundwater pathway. The SESOIL and AT123D models, while previously individually developed (see References, Bonazountas, 1984 and Yeh, 1981), are a part of the risk assessment Graphical Exposure Modeling System (GEMS) developed by USEPA. A pc-based version of this (PCGEMS) was developed for USEPA by General Sciences Corporation (1989). The two models can now be linked so that SESOIL can pass leachate loadings to the saturated zone AT123D model.

The Oregon model's site setting (see Figure 1) assumes a 3-meter thick unsaturated zone, divided into three 1-meter layers. Contamination is initially released in the middle layer, as might occur for a leaking tank or for a residual contaminant remaining after some remedial excavation with clean cover backfill, and is uniformly distributed in this layer over a 10 meter by 10 meter area. The unsaturated zone and aquifer are assumed to be the same sandy soil with uniform properties. The upper and lower unsaturated zone layers are initially clean, as is the aquifer.

FIGURE 1
CONCEPTUAL SETTING



Source: Anderson (1991)

SESOIL inputs include the soil type parameters, chemical properties, application rates, and the climatic conditions of the area. The model is run as a transient monthly estimator of leachate volumes and concentrations. Initially, no other transport mechanisms other than leaching, partitioning, and volatilization were considered. Oregon used default values in SESOIL for Portland Oregon climatic conditions, but distributed total precipitation uniformly over the year.

SESOIL was initially found to overestimate losses via volatilization. A parameter, the volatilization fraction (VOLF), was introduced to allow adjustment of losses through this pathway and allow a site-specific calibration. This factor may be varied in time and space. The Oregon study used a uniform VOLF factor of 0.2, based on consultation with a panel of experts. One other soil-related parameter is the disconnectedness index. This parameter varies for and within soil types. Two values are given as SESOIL defaults, and the larger, 7.5, has been used in the simulations. An increase in this parameter appears to result in a higher soil moisture, lower leachate rates, and somewhat lower DAFs (i.e., is more conservative) for the compounds run.

AT123D inputs include general aquifer properties, source configuration, loadings to groundwater, soil partition coefficients, and dispersivity values. The aquifer is assumed to be infinitely wide and thick. The pc-based version of AT123D accepts monthly transient loading rates calculated by SESOIL, and also provides a preprocessor for input file preparation and editing. In utilizing the model, the center of the 10 by 10 meter source area is assumed to be at coordinates 0,0,0. The positive x-axis is in the direction of flow. Calculated concentrations are maximum along the x-axis (y=0) and at the water table surface (z=0). Since the receptor is assumed to be 10 meters from the downgradient edge of the source area, the concentration at x=15, y=0, and z=0 represents the receptor location. Oregon used longitudinal, transverse, and vertical dispersivities of 20m, 2m, and 2m, respectively. These values seem high for a sandy aquifer, but the values have been retained to be consistent with the Oregon base values and to be protective of the Commonwealth's sensitive aquifers on Cape Cod. DAFs are proportional to the dispersivities, particularly sensitive to the vertical dispersivity.

Oregon ran the model for 10 indicator compounds and then developed a multiple linear regression model relating the DAF to the organic partition coefficient (K_{oc}) and the Henry's Law constant (H) to provide preliminary DAFs for sixty other organic compounds. Soil cleanup levels were generated based on the regression algorithm and a safe drinking water level for each compound. In some cases, risk based levels determined by other pathways were lower than the levels required to protect groundwater. In these instances, the lower value was selected as the soil target level. A similar approach was taken to develop the MCP Method 1 Standards, as described in Section 5.3.

SIMULATIONS FOR MASSACHUSETTS

The approach taken to develop DAFs for Massachusetts was to determine the effect that varying the location (changing the climatic conditions from Portland, Oregon to Boston, Massachusetts in SESOIL) would have on the Oregon calculated DAFs. If the model system was essentially linear with respect to loading, then DAFs already calculated for Oregon would be directly related to DAFs appropriate for Massachusetts, and the general algorithm developed by Oregon (with coefficients adjusted) could also be used to estimated DAFs for other compounds. To this end, model runs were made using the Oregon input values for SESOIL and AT123D with the exception of climate parameter values. Eight indicator compounds were selected: benzene, toluene, ethylbenzene, o-xylene, trichloroethene, tetrachloroethene, 1,1,1-trichloroethane, and naphthalene.

The input values for SESOIL are shown in Tables F-1 through F-4, and those for AT123D are shown on Table F-5. Depending on the mobility of the compound through the transport pathway, model runs varied from 2 years to 6 years as necessary to determine the maximum concentration attained at the receptor location for a specific compound. A point to consider in the adoption of the Oregon values, or adjustments to them, is the need to agree with the physio-chemical parameters that were used to generate the DAFs. Even in the eight indicator compounds selected, various accepted databases provide some widely varying values for S, H and K_{oc}. For example, for PCE, H is reported with an order of magnitude difference, and values of K_{oc} and solubility differing by a factor of 2 are reported for ethylbenzene in the literature.

Output concentrations at the selected receptor location demonstrated a cyclical nature due to seasonal variations in precipitation and net recharge. Maximum concentrations were not always attained in the first cycle due to seasonal variability. However, the model output appeared to be linear with respect to the initial loading, allowing soil cleanup levels to be estimated based on the linear DAF approach. Table F-6 shows the model-based DAFs for Oregon and Massachusetts, and also, based on listed safe drinking water levels and the estimated DAFs for Massachusetts, what soil target levels would be for the eight indicator compounds run.

TABLE F-1
CLIMATE PARAMETER VALUES
FOR THE SESOIL MODEL

Default climate values for Boston as contained in the SESOIL model. Latitude = 42 degrees.

TABLE F-2
SOIL PARAMETER VALUES
FOR THE SESOIL MODEL

Intrinsic permeability =$1x10^{-7}$ cm^2
Source area=1,000,000 cm^2
Porosity =0.3
Disconnectedness index = 7.5
Soil bulk density = 1.5 gm/cm^3
Soil organic carbon = 0.1%

Layer 1 thickness = 100 cm
Layer 2 thickness = 100 cm
Layer 3 thickness = 100 cm
No further sublayering specified

Clay content = 0%

All other parameters set to zero except those to indicate uniform parameters in all layers.

TABLE F-3
APPLICATIONS DATA
FOR SESOIL MODEL

Application month = October only
layer = 2
rate = 1500 microgm/cm^2
year = 1 only

Based on the area, thickness and bulk density, this produces an initial concentration of 10 ppm. No other sources are added.

Volatile fraction (VOLF) = 0.2

Uniform in time and space.

All other parameter values set to zero.

TABLE F-4
CHEMICAL DATA FOR SESOIL MODEL

Compound	MW	K_{oc} ml/g	S mg/L	H atm-m^3/mol	DA cm^2/sec
benzene	78	83	1780	0.0055	0.109
ethylbenzene	106	575	161	0.00343	0.093
toluene	92	270	535	0.00668	0.100
o-xylene	106	302	171	0.00527	0.093
TCE	131	124	1100	0.00912	0.083
PCE	166	468	200	0.00204	0.075
1,1,1-TCA	133	157	730	0.0231	0.080
naphthalene	128	1288	31	0.00118	0.085

MW = molecular weight
K_{oc} = organic carbon partition coefficient
S = solubility in water
H = Henry's Law constant
DA = diffusion coefficient in air

TABLE F-5
AT123D MODEL INPUT PARAMETER VALUES

Soil bulk density	= 1.5 g/cc
Porosity	= 0.3
Hydraulic conductivity	= 0.5 m/hr
Hydraulic gradient	= 0.005
Longitudinal dispersivity	= 20.0 m
Transverse dispersivity	= 2.0 m
Vertical dispersivity	= 2.0 m

Loading (kg/hr) passed by SESOIL link program
Distribution coefficient = K_{oc} * fraction organic carbon
Source area = 10 m by 10 m, centered at 0,0
initial z penetration = 0

Degradation rates initially zero

TABLE F-6
MODEL OUTPUT DRAFT DAFS
COMPARISON AND SOIL LEVELS

Oregon Compound	Mass DAF	DAF	DRINKING WATER LEVEL mg/L	SOIL TARGET LEVEL ppm
benzene	44.4	56.5	0.005	0.28
ethylbenzene	103.5	121.1	0.700	84.8
toluene	64.5	80.6	1.000	80.6
o-xylene	65.4	83.3	10.000	833.3
TCE	65.4	76.3	0.005	0.38
PCE	73.0	86.2	0.005	0.43
1,1,1-TCA	133.2	169.2	0.200	33.8
naphthalene	207.0	222.2	0.280	62.2

STATISTICAL RELATIONSHIPS

A linear regression was run on the eight DAF data pairs with DAFs for Oregon as the independent variable. The model was :

$$DAF_{Mass} = A + B*DAF_{Oregon}$$

That is, the regression was not forced through the origin. For the eight data pairs, the equation was

$$DAF_{Mass} = 12.39 + 1.053*DAF_{Oregon}$$

with an r of 0.9913. Thus, over the range of data spanned by these eight compounds, the correlation appears good. Table F-7 shows a comparison of the DAFs calculated by the model and those by the linear regression equation above for the eight indicator compounds. Differences between the two methods are less than 10 percent.

A multiple linear regression algorithm for DAF(Mass) as a function of K_{oc} and H was also developed along the same lines as that developed by Oregon. This allows the calculation of DAFs for compounds for which Oregon did not consider, and which also may be used exclusively from the linear regression cited above. Two models were considered:

(a) $DAF = A + B*H + C*K_{oc}$, and
(b) $DAF = B*H + C*K_{oc}$.

where A, B, and C are regression coefficients. As with the Oregon analysis, it proved that the constant term was not statistically different from zero, and the simpler second model was adopted. Regression analysis yielded:

$$\boxed{DAF = 6207 * H + 0.166 * K_{oc}}$$

The fit here is somewhat better than the r-squared value of .956 for the Oregon model in that one compound with a large residual (carbon tetrachloride with a residual of 30) was not used here, and the average difference is much smaller with the eight compounds than for Oregon's ten. Table F-8 shows the relationship between the model DAFs and the regression expression predicted values. Only one compound varies more than 10 percent while six of the eight have percent differences less than five.

TABLE F-7
COMPARISON BETWEEN MODEL DAFS AND LINEAR REGRESSION DAFS BASED ON OREGON DAFS

Compound	Model DAF	Regr. DAF	%Diff.
benzene	56.5	59.1	4.60
ethylbenzene	121.1	121.4	0.25
toluene	80.6	80.3	-0.37
o-xylene	83.3	81.3	-2.40
TCE	76.3	81.3	6.55
PCE	86.2	89.3	3.60
1,1,1-TCA	169.2	152.6	-9.81
naphthalene	222.2	230.4	3.69

TABLE F-8
RESULTS OF THE MULTIPLE LINEAR REGRESSION EQUATION FOR H AND KOC

Compound	Model DAF	Predicted	% Diff.
benzene	56.5	47.9	-15.2
ethylbenzene	121.1	116.7	- 3.6
toluene	80.6	86.3	7.1
o-xylene	83.3	82.8	- 0.5
TCE	76.3	77.2	1.2
PCE	86.2	90.4	4.9
1,1,1-TCA	169.2	169.4	0.1
naphthalene	222.2	221.1	- 0.5

BIODEGRADATION

It is intuitive that biodegradation may play an important role in attenuating the potential impact of residual contaminants in soils on groundwater. However, there are a great many site-specific conditions that will determine actual biodegradation rates. Further, literature values cover a wide range and the exact conditions under which they were estimated are rarely known. Literature values should be applied only with great caution to any estimation of contaminant fate and transport. In order to evaluate the potential effect of biodegradation, rate constants cited by Howard et al (1991) were input to the model for the five compounds of the eight indicator compounds known to degrade aerobically. This eliminated the chlorinated compounds TCE, PCE, and 1,1,1-TCA. In addition, one additional rate for benzene (0.002/day from the California LUFT guidance) was also run. Four runs were made for benzene as the most critical compound, at the California rate, at the high and low rates cited by Howard and at the geometric mean of the Howard high and low rates. Only one rate, the low Howard value, was used for each of the other four compounds. The reason for this will be seen shortly.

The degradation rates in Howard appear to be high, with half lives for the BTEX compounds on the order of days. This implies that within a year, residual concentrations in soil would be reduced by biodegradation several (three to six) orders of magnitude. Table F-9 presents the results of the model runs.

For all situations except for the two lowest rates for benzene, the DAFs become huge. In essence, this indicates that only trace amounts of the contaminants ever reach the groundwater table. Soil target level estimation using large DAFs and the linear approach should be done only with extreme caution. A contaminant in the subsurface will attempt to reach equilibrium concentrations in the air, moisture and sorbed to soil. At some total concentration, equilibrium solubility in moisture would be exceeded, indicating the probable presence of free product. In this case, the linearity and basic assumptions in the model may be violated. Of further consideration are the potential toxic effects on the biological population as concentrations of the compounds increase. For these circumstances, estimation of soil target levels considering biodegradation is very difficult.

TABLE F-9
RESULTS OF THE BIODEGRADATION RUNS

Compound	Rate in Soil 1/day	Rate in Water 1/day	DAF
benzene	0.002	0.001 *	84.7
benzene	0.0433	0.000963	2178.
benzene	0.0775	0.00817	1.5×10^{4}
benzene	0.1386	0.0693	5.7×10^{7}
toluene	0.0315	0.02475	8.7×10^{6}
ethylbenzene	0.0693	0.00304	1.8×10^{13}
o-xylene	0.02475	0.001899	2.8×10^{5}
naphthalene	0.01444	0.00269	8.6×10^{10}

* Note: Odencrantz's article on the California LUFT parameter values did not cite a rate for water. This was assumed here to be half that in soil. Note that not much more degradation occurs in the aquifer due to the rapid travel time to the receptor of about 11 to 12 days (large longitudinal dispersivity and low retardation).

SENSITIVITY

A detailed sensitivity analysis was not done at this point in time. However, Oregon did perform some sensitivity analyses, and sensitivity of these models as applied in California's LUFT program is discussed in another article (Odencrantz, et al, 1992)

REFERENCES

Anderson, M. 1992. Development of Generic Soil Cleanup Levels Based on Analysis of the Leachate Pathway. Environmental Cleanup Division, Department of Environmental Quality, State of Oregon, May 12, 1992.

Bonazountas, M. and J. Wagner. 1984. SESOIL. A Seasonal Soil Compartment Model. A.D. Little for USEPA.

General Sciences Corporation. 1989. PCGEMS User's Guide. Release 1.0. Prepared for U.S. Environmental Protection Agency Office of Pesticides and Toxic Substances Exposure Evaluation Division

Howard, P. et al. 1991. Handbook of Environmental Degradation Rates Lewis Publishers, Chelsea, Michigan.

Odencrantz, J., et al. 1992. Transport Model Parameter Sensitivity for Soil Cleanup Level Determinations Using SESOIL and AT123D in the Context of the California Leaking Underground Fuel Tank Field Manual. Journal of Soil Contamination 1(2):159-182.

Yeh, G. 1981. AT123D: Analytical Transient One-, Two-, and Three- Dimensional Simulation of Waste Transport in the Aquifer System. Oak Ridge National Laboratory. ORNL-5602.

APPENDIX 6

RATIONAL FOR MOEE ECOTOXICITY-BASED SOIL CRITERIA

ISNB: 0-7778-2818-9

RATIONALE FOR THE DEVELOPMENT AND APPLICATION OF GENERIC SOIL, GROUNDWATER AND SEDIMENT CRITERIA FOR USE AT CONTAMINATED SITES IN ONTARIO

Report prepared by:

Standards Development Branch
Ontario Ministry of Environment and Energy

December 1996

Report prepared for:

Ontario Ministry of Environment and Energy

Version 1.1

Acknowledgements

This document was prepared by the Criteria Development Subgroup (A. L. Kuja, Chair) under the direction of the Criteria Development, Site Assessment and Site Specific Risk Assessment Work Group (R.G. Pearson, Chair). Following consultation, all modifications were made by the document editors: A. L. Kuja and R. G. Pearson, Phytotoxicology Section, Standards Development Branch.

The efforts of the following individuals are greatfully acknowledged:

Standards Development Branch:	Richard Aucoin Tim Fletcher Bill Gizyn Lee Hofmann Goff Jenkins Randy Jones	Bryan Leece Angela Li-Muller Marius Marsh Pavel Muller Doug Spry Franca Ursitti
Central Regional Office:	Ron Lall	
Ottawa District Office:	Andy Lewis	
Cambridge District Office:	Bill Bardswick	
Security Account Office:	Patrick Leung	
Environmental Monitoring and Reporting Branch:	Mike Scafe Sam Singer	
Science and Technology Branch:	Ulo Sibul	
Waterfront Regeneration Trust:	Beth Benson	

The Criteria Development Subgroup would also like to recognize and thank the Massachusetts Department of Environmental Protection, Bureau of Waste Site Clean-up and the Office of Research and Standards for their co-operation in providing the committee with the MCP Standards Approach background document and databases.

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

This document describes the rationale behind the development of effects-based generic soil, groundwater and sediment quality criteria, to be used in place of the 1989 soil clean-up levels in the remediation of contaminated sites in Ontario. This rationale document replaces the document entitled "Soil Clean-up Guidelines for Decommissioning of Industrial Lands: Background and Rationale for Development". The use and application of these criteria are described in the "Guideline for Use at Contaminated Sites in Ontario" (1996) which replaces the MOE 1989 "Guideline for the Decommissioning and Clean-up of Sites in Ontario" and the 1993 "Interim Guidelines for the Assessment and Management of Petroleum Contaminated Sites in Ontario".

This introduction is the first of four sections comprising the rationale document. Section 2 provides an overview of the environmental approach, guiding principles, and remediation options and their linkage with the criteria development process. Section 3 describes in detail, the process and assumptions used in the development of the soil and groundwater criteria. This includes a full description of the Massachusetts methodology that was adopted for use in Ontario, as well as the modifications and additional components that were utilized. All references utilized in this document are listed in Section 4. The criteria tables, on which decisions relating to site remediation will be based, are found in Appendix A. Also provided in Appendix A are summary tables of all criteria components. Additional scientific documents and supporting information for the development of the criteria are found in Appendix B.

2 OVERVIEW OF THE APPROACH, GUIDING PRINCIPLES AND MAJOR ASPECTS OF THE CRITERIA DEVELOPMENT PROCESS.

2.1 General Approach

The revision of the Ministry's 1989 guideline for the decommissioning and clean-up of contaminated sites is predicated on providing a more flexible, environmentally protective approach which will be applicable to a greater number of environmental contaminants and provide an increased level of guidance and remediation options to proponents. From an environmental aspect, this flexibility was achieved by more closely matching receptors and exposure pathways to land and groundwater use categories, and to the extent possible, to site conditions which affect contaminant transport and exposure.

The MOEE has participated in the development of a protocol for setting effects-based soil quality criteria under the National Contaminated Sites Remediation Program of the Canadian Council of Ministers of Environment (CCME). These protocols are summarized in the CCME document entitled "A Protocol for the Derivation of Ecological Effects Based and Human Health Based Soil Quality Criteria for Contaminated Sites." (1994). However, as the development of soil clean-up criteria based on CCME criteria documents will take several years, the MOEE explored other options to provide effects-based criteria.

The Department of Environmental Protection, Bureau of Waste Site Cleanup and the Office of Research and Standards for the Commonwealth of Massachusetts, have jointly produced chemical-specific standards for use under their revised Massachusetts Contingency Plan (MCP) which was promulgated in October 1993. Generic criteria for 106 inorganic/organic contaminants were developed using a risk characterization approach to provide protection to human and environmental health.

After a review of the general assumptions and multi-media components of the MCP approach, a decision was made to adopt and modify this approach for generic soil and groundwater "risk-based" site remediation criteria in Ontario. The MCP approach was selected as it appeared to best meet Ontario's needs for a large number of effects-based soil and groundwater criteria which address most potential human health and aquatic exposure pathways. It was also chosen because both the toxicological assessments and exposure scenarios carried out by the Massachusetts Department of Environmental Protection (DEP) had been subjected to extensive public consultation and had been promulgated as standards.

All assumptions for risk characterization, dose-response and toxicity information, methods, calculations and data inputs to the MCP standards development process are detailed in the Massachusetts document entitled "Background Documentation for the Development of the MCP Numerical Standards" (1994). The relevant portions of this document have been included in Appendix B.5. Modifications were made to various inputs into the MCP spreadsheets so that the criteria for the 106 chemicals would better represent the Ontario situation.

3.2.3 Additional Soil Criteria Components Incorporated by MOEE

3.2.3.1 Terrestrial Ecological Soil Criteria Component

The MCP approach addresses primarily human-health effects with some consideration of indirect ecological effects (aquatic) through the soil/groundwater leaching-based concentrations (GW-3). However, there is no consideration for direct soil contact exposure for terrestrial ecological receptors. As MOEE is also committed to providing ecological protection, ecotoxicity criteria were included in the development process for soil criteria. Ontario ecological effects-based criteria for inorganics were incorporated into the process to develop surface restoration criteria for soils. The decision was made that terrestrial ecological protection for direct contact below the 1.5 meter depth, was not appropriate. Therefore, only human health and indirect ecological effects through leaching (via groundwater to surface water) were considered for sub-surface soil criteria (>1.5m depth).

The Netherlands have also developed ecosystem toxicity-based soil criteria for several inorganic and organic contaminants. These concentrations were utilized in the process when Ontario ecological criteria did not already exist. The Massachusetts DEP developed soil and groundwater criteria (based on human health) for 106 inorganic and organic chemicals. The integration of additional criteria for metals and inorganic parameters, based on ecological data, increased the soil chemical list to 115.

The following inorganic parameters were added to the soil criteria development process: barium, boron, chromium (total), cobalt, copper, molybdenum, electrical conductivity (mS/cm), nitrogen (total), and sodium absorption ratio (SAR).

The Massachusetts DEP chose to develop a human health risk-based criterion for chromium III and VI but not for total chromium. MOEE has ecological effects-based criteria for total chromium. Therefore, the committee decided to include total chromium on the chemical list. The Phytotoxicology Section of the MOEE Standards Development Branch has recently developed soil quality criteria for boron based on phytotoxicity effects data. Boron has been included in the chemical list; however, the boron criteria, which address the 'available' boron in soil are based on a 'hot water extract' rather than bulk soil analysis. The development of the boron criteria is described in detail in Appendix B.3.

3.2.3.1.1 Exposure Pathways and Protection of Ecological Receptors at Various Land Uses

In determining numerical criteria for soil based on potential ecological effects, it was necessary to make judgements as to what receptors should be protected and what level of protection was required for each land use category. A full range of philosophies exist, from protection against the earliest detectable effects to any species that could potentially occur on a site, or be affected by contamination at a site, to protection against the most severe of effects to very common species which normally occur on sites of a particular land use category. The philosophy that is adopted can, therefore, strongly influence the final generic criteria derived. This section outlines the level of ecological protection which forms the basis for the development of the ecological criteria for each of the three land use categories: agricultural, residential/parkland and industrial/commercial.

To the extent permitted by available scientific evidence, these types of protection were incorporated into the criteria development process for each land use category. However, it must be stressed that in many cases, the lack of scientific evidence prohibited the development of an ecological component.

Agricultural Land Use Category

Soils that are to be used for agricultural purposes should be able to support the growth of a wide range of commercial crops as well as the raising of livestock. Contamination due to anthropogenic activities should not result in noticeable yield reductions of commercial crops that cannot be remedied through normal farming practices. Soil concentrations of chemical parameters also should be sufficiently low that there are no known or suspected adverse impacts on domestic grazing animals, including migratory and transitory wildlife, through both direct soil ingestion or through ingestion of plants grown on the soil. Since soil invertebrates and microorganisms provide important functions for the overall health of a soil, and the plants supported by the soil, these populations should not be adversely affected to the point where functions such as nutrient cycling, soil:root symbiotic relationships and decomposition are significantly reduced or impaired.

A consideration of all of the above factors also must recognize that in certain situations, agricultural chemicals are utilized because they are capable of selective toxicological action against undesirable plants and soil organisms. In these situations, a case specific approach will be necessary in the soil remediation process.

Residential/Parkland Land Use Category

The need for protection of commercial crops in the residential/parkland land use category is not as apparent as for agriculture; nevertheless, the common practice of growing backyard vegetable gardens and allotment gardens results in there being little practical difference between the plant species to be protected at residential sites and those at agricultural sites. Since parkland is included with residential land use in this category, it is also necessary to protect migratory and transitory species that may utilize such sites. The major difference from agricultural sites is that, for residential/parkland sites, the protection of domestic grazing animals such as sheep and cattle is not an important consideration.

Industrial/Commercial Land Use Category

It is not necessary to require as high a degree of protection for on-site ecological receptors at an industrial or commercial site as it is for agricultural or residential/parkland sites. The soil at industrial sites should be capable of supporting the growth of some native and ornamental trees, shrubs and grasses, but, it is not as important to protect against yield or growth reductions to the same extent as for residential and agricultural properties, nor to protect as wide a range of species. Since it would be highly undesirable to have transitory or migratory species being affected by utilizing any specific industrial or commercial property, criteria should be sufficiently protective to prevent such adverse effects on these species.

3.2.3.1.2 Existing MOEE Soil Clean-up/Decommissioning Guidelines (SCUGs)

The rationale on which the 1989 guidelines was based was described in the MOE publication "Soil Clean-up Guidelines for Decommissioning of Industrial Lands: Background and Rationale for Development" (MOE, 1991). This publication has been replaced and relevant information applicable to those parameters that were utilized in the 1995 criteria development process can be found in Appendix B.3.

Soil clean-up criteria were developed for the following parameters: As, Cd, Cr (total), CrVI, Co, Cu, Pb, Hg, Mo, Ni, Se, Ag, Zn, soil pH range, Electrical Conductivity and Sodium Absorption Ratio. However, in the case of Cd, Pb, and Hg, the 1989 criteria were influenced more by human health considerations rather than ecological effects, and accordingly these criteria were discarded (with the exception of Cd for the agricultural land use category).

Re-examination of the rationale for the 1989 ecological criteria indicated that although the process was much less rigorous than the most recent CCME protocol for the development of ecological criteria, it did offer several important features:

- the criteria have been utilized in Ontario for 15 years without any evidence to indicate that protection was not provided

- the criteria have been widely adopted for use in other jurisdictions including the CCME without any evidence of problems

- early evidence from the new CCME process which has been applied to a limited number of parameters indicates that the 1989 ecological criteria are in reasonable agreement with the results from this process

- a thorough review of the available literature combined with an experimental program by the Phytotoxicology Section has confirmed that in the case of copper, the 1989 values are fully in line with values that emerge from this type of analysis

Based on this assessment, a decision was made to incorporate the 1989 ecological criteria. The following additional considerations were utilized.

A strong argument can be made that the 1989 SCUGs for Cd (i.e. 3 ppm for coarse-textured soils and 4 ppm for medium/fine textured soils) are still valid for the agricultural use category. Cd is an element that is not readily eliminated in mammals, and it is known to bio-accumulate in tissue. Grazing animals that are ingesting Cd accumulated in plants growing on contaminated soils and from the soils themselves may be more at risk from Cd accumulation than is accounted for by any criterion higher than the current MOEE SCUG of 3 ppm (e.g. the Netherlands ecotoxicity criterion for Cd is 12 ug/g). It is known that wild ungulates grazing on lands with natural background Cd concentrations can accumulate Cd in the kidneys to the point where the kidneys are unfit for consumption. Some species of food plants (i.e. spinach and lettuce) have been observed to accumulate Cd in the edible portions of the plant to levels that would be of concern, even at relatively low soil Cd concentrations. Although the change of the Cd guideline from 3 μg/g to 12 ug may be suitable for residential purposes, there is little evidence that it takes the above factors into consideration for agricultural land uses.

The CCME draft document "A Protocol for the Derivation of Ecological Effects Based and Human-Health Based Soil Quality Criteria" (1994) contains some equations that are useful for estimating guidelines based on food ingestion and soil ingestion by animals utilizing the land. Using these equations and data presented in the draft CCME assessment document on Cadmium (Canadian Soil Quality Criteria for Contaminated Sites: Cadmium), a guideline of 3 μg Cd/g is indicated to be appropriate for agricultural use. These equations are presented below. For these reasons, it was decided to continue using the 3 μg/g guideline for cadmium for agricultural use unless and until there is substantial justification to indicate that it too should be changed. The following is a CCME calculation of soil quality criteria based on food ingestion by animals (e.g. cattle):

EDFI = DTED x BW/FIR
= 0.0028 mg Cd kg-1BW x day-1 x 100kg / 3kg day-1
= 0.093 mg/kg dw food

SQCfi = EDFI x AFfi/BCF
= 0.093 mg/kg x 0.85/0.025
= 3.16 mg/kg

CCME calculation of soil quality criteria based on soil ingestion by animals

EDFI = DTED x BW/SIR

$= 0.0028$ mg Cd kg-1BW x day-1 x 100kg / 0.54kg day-1
$= 0.519$ mg/kg dw soil

SQCsi = EDSI x AFsi/ BF
$= 0.519$ mg/kg x 0.18/ 0.025
$= 3.74$ mg/kg

Where:

SQCfi =	Soil Quality Criteria for Food Ingestion
SQCsi =	Soil Quality Criteria for Soil Ingestion
EDFI =	Estimated dose for Food Ingestion
DTED =	Daily Threshold Effects Dose
BW =	Body Weight
FIR =	Food Ingestion Rate
SIR =	Soil Ingestion Rate
AFfi =	Apportionment factor for Food ingestion
AFsi =	Apportionment Factor for Soil Ingestion
BCF =	Bioconcentration Factor
BF =	Bioavailability Factor

The 1989 Cu, Mo, and Se SCUG criteria for agricultural/residential/parkland land uses were developed to protect grazing livestock. The industrial/commercial SCUG criteria for these three parameters provided protection to vegetation only. For this reason, the industrial/commercial SCUG criteria (for coarse-textured and medium-fine textured soils) were selected for both the residential/parkland and industrial/commercial land use categories where grazing animals are not likely to occur. The Cu, Mo and Se SCUG values that were based on protection of grazing livestock will apply to the agricultural land use category only.

The electrical conductivity of soil is essentially a measurement of the total concentration of soluble salts in the soil solution and can have a large osmotic influence on plant growth, as well as on soil organisms. The existing MOEE SCUGs for electrical conductivity (E.C.) of a soil required the use of a saturated extract. This procedure is time consuming and results are subjective; i.e. the end point of saturation is determined by the technician's expert opinion.

A fixed 2:1 water:soil procedure eliminates this uncertainty and provides a more rapid and reliable test. Both MOEE (Phytotoxicology Section) and Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) now use the 2:1 procedure for most routine samples. The water:soil ratio used for the extract affects the resultant electrical conductivity; hence, the existing SCUG of 2.0 mS/cm (agricultural/residential/parkland) and 4.0 mS/cm (commercial/industrial) were adjusted to account for the change in water:soil ratio for this criterion.

Data in Extension Bulletin E-1736 (Michigan State University, 1983) made available to the committee by the Department of Land Resource Science, University of Guelph, show that for a given E.C., in saturation extract, the expected E.C. in a 2:1 water:soil ratio would be one third of the former. The appropriate E.C. for both agricultural and residential/parkland land use categories is 0.667 mS/cm. When rounded to 0.7 mS/cm, this value corresponds with the boundary between what McKeague (1978) states "may result in a slightly stunted condition in most plants" and "slight to severe burning of most plants". This is a reasonable concentration at which to establish the E.C. SCUG and confirmed the use of the divisor of 3 as a conversion factor. Using this conversion factor, the industrial/commercial SCUG for E.C. becomes 1.4 mS/cm.

Provisional soil clean-up guidelines were also produced in 1989 for Sb, Ba, Be and V for which the knowledge of their potential adverse phytotoxic effects was more limited than for the other inorganic parameters. These provisional criteria were also incorporated into the current modified criteria development process.

In all cases, MOE SCUG criteria values for coarse-textured soils, as well as medium and fine textured soils have been adopted from the 1989 guidelines for use in the current criteria development process. Coarse-textured soils are defined here as greater than 70% sand. The medium and fine textured soil SCUGs are 20-25% higher than the corresponding values for coarse-textured soils.

3.2.3.1.3 The Netherlands "C Level" Ecotoxicity Criteria

The Dutch government published soil and groundwater clean up guidelines, "ABC values", in 1983. These guidelines have undergone revision over the last 7 years to include both human health and ecological effects-based data. A new set of C-values has been proposed (Vegter, 1993). The final integrated C-value includes a human health component, as well as the ecological component, and includes risk management adjustments. The ecological component of the C-value is derived by taking the geometric mean or the average value of the logarithm of the No Observable Adverse Effect Concentration (NOEC) (Denneman and van Gestel, 1990). This means that the C-value represents the chemical concentration at which the NOEC for 50% of the ecological species has been exceeded.

For the purposes of this guideline, the ecotoxicity component of the C-value was incorporated into the soil criteria development process in all cases where a 1989 MOE SCUG value was not available. In addition to the references listed above, more information on the Dutch guidelines can be found in the following references: van den Berg and Roels (1993); van den Berg et al. (1993); and Denneman and Robberse (1990).

Appendix B.3: Rationale for MOEE Ecotoxicity-Based Soil Criteria.

(IN: *Rational For The Development And Application Of Generic Soil Groundwater, And Sediment Criteria For Use At Contaminated Sites In Ontario,* Standards Development Branch, Ontario Ministry of Environment and Energy, December 1996 (ISNB: 0-7778-2818-9)

Appendix B.3

This appendix replaces the rationale which was the basis for the 1989 ecotoxicity-based soil remediation criteria. The original rationale is described in the 1991 MOE publication entitled "Soil Clean-up Guidelines for Decommissioning of Industrial Lands: Background and Rationale for Development". Those parameters in the original rationale, which were based on human health effects, have been removed. A rationale for a boron soil criterion (hot water extract), based on protection of vegetation and grazing animals, has been added.

All relevant information applicable to MOEE ecotoxicity-based soil values utilized in the 1995 soil remediation criteria development process are contained in the following sections. As more information on these and other soil parameters becomes available, the information will be included in this appendix as part of the rationale for deriving ecotoxicity criteria for soil remediation.

APPENDIX B.3 TABLE OF CONTENTS

1 BACKGROUND

In February, 1984, the Phytotoxicology Section was requested by the Halton-Peel District Office of the MOE to provide input into the development of soil criteria for the decommissioning of certain oil refinery lands. Proposed land uses made it desirable to have separate criteria for residential and industrial redevelopment. Monenco Consultants, on behalf of one of the oil companies, undertook a large-scale literature survey in an attempt to relate contaminant concentrations in soil to toxic effects on vegetation and animals. As a result of this effort, Monenco recommended site-specific ecotoxicity-based soil criteria for a number of contaminants (Monenco Ontario Ltd., 1984a & 1984b).

Subsequent to the above-described exercise, the Phytotoxicology Section was asked to recommend soil clean-up criteria for additional contaminants. Provisional criteria for these additional elements were developed, based on literature reviews. The Phytotoxicology Section was requested by the MOE Waste Management Branch to develop clean-up levels for agricultural land use. This request was brought to the attention of the Sludge and Waste Utilization Committee. It was the opinion of this Committee that the residential/parkland clean-up levels previously developed were, with minor modifications/qualifications, also suitable for application to agricultural situations.

2 RATIONALES FOR ECOTOXCITY-BASED SOIL CRITERIA

The recommended ecotoxicity-based soil remediation criteria are shown in Section 5.1 (Table 5.1). The rationales for their development include considerations of phytotoxicity and animal health. In general, the most conservative of these considerations was used to established agricultural and residential soil criteria. Redevelopment as parkland also was felt to warrant this conservative approach, because parkland often is used by children at play, and occasionally is used for allotment gardening.

Different industrial/commercial remediation levels (normally set at twice the residential levels) were recommended where the residential and industrial criteria were both set on the same basis but where phytotoxic concerns were judged to be considerably less significant in the industrial/commercial environment. For two elements (molybdenum and selenium), residential soil remediation levels were established to prevent toxicity to grazing animals, whereas a higher industrial level was established to prevent toxicity to vegetation.

Provisional ecotoxicity-based soil remediation criteria recommended for four additional contaminants are shown in Section 5.2 (Table 5.2). Because knowledge of potential adverse effects of these elements in soil is generally more limited than for the Table 1 criteria, the provisional criteria were purposefully established in an even more conservative vein.

Since the mobility and availability of metals in soils may be highly dependent on form of the metal, soil texture, pH and organic matter content, site-specific considerations of these parameters may reveal the suitability of different criteria. For example, where metals are known to be present in specific forms of very limited availability, higher levels may be considered. Furthermore, in researching the clean-up criteria, Monenco Consultants utilized data from studies on medium to fine textured soils (i.e. sandy soils excluded), in which mobility (availability) of metals would be lower than in coarse-textured sand (hence, metals are less likely to accumulate in sand than in clay). Therefore, it is recommended that the remediation levels for the metals and metalloids be reduced in the case of coarse-textured (greater than 70% sand) mineral soils (less than 17% organic matter). This recommendation is reflected in the remediation levels shown in Tables 5.1 and 5.2.

The rationales for individual parameters are summarized in the following sections (RATIONAL FOR As, B, Cr, co, Cu, Mo, Ni, Ag, Zin, SAR, Sb, Ba, Be, V; NOT INCLUDED IN THIS APPENDIX).

APPENDIX 7

SUMMARY OF MADEP CARBON RANGE AND TOTAL PETROLEUM HYDROCARBON RISK-BASED SCREENING LEVELS

SUMMARY OF MADEP CARBON RANGE AND TOTAL PETROLEUM HYDROCARBON TOXICITY AND PHYSIO-CHEMICAL SURROGATES

CARBON RANGE	Human Toxicity Surrogate	Aquatic Life Protection Surrogate	Organic Carbon Coefficient (Koc) (cm^3/g)	Henry's Law Constant (H) ($atm\text{-}m^3/mol$)
Aliphatics				
C5 to C8	n-hexane	n-hexane	2.27E+03	1.29E+00
C9 to C12	10 x n-hexane	decane	1.50E+05	1.56E+00
C9 to C18	10 x n-hexane	decane	6.80E+05	1.66E+00
C19 to C36	100 x n-hexane	cyclododecane	-	-
Aromatics				
C9 to C10	xylenes	ethylbenzene	1.78E+03	7.92E-03
C11 to C22	naphthalene /pyrene	PAHs	5.00E+03	7.20E-04
**Total Petroleum Hydrocarbon (TPH)	naphthalene/ pyrene	PAHs	5.00E+03	7.20E-04

* MADEP referred to both naphthalene & pyrene for the C11 to C22 range RfD in their original documents. Both have an Oral RfD of 0.03 mg/kg-d and inhalation RFC of 0.071 mg/m^3 (0.02 mg/kg-d) in MADEP guidance.

**TPH conservatively assumed to be 100% C11 to C22 aromatic compounds (major component of diesel#2, #3-#6 fuel oil, JP-4).

Reference:

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Public Hearing Draft: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, January 17, 1997.

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Redline/Strikeout Version: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, October 31, 1997, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000, Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, November 7, 1997, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

MADEP, 1999, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Spreadsheet Detailing VPH/EPH Standards Derivation: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, May 25, 1999, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

Summary of Massachusetts DEP Carbon Range/TPH Risk-Based Screening Levels (RBSLs) (mg/kg)

***RESIDENTIAL SURFACE SOIL (S-1) - Drinking Water Resource Threatened (GW-1)**

Carbon Range		Final S-1/GW-1 RBSL	Direct Exposure	Leaching	Nuisance Ceiling	Upper Concentration Level
Aliphatics	C5 to C8	100	730	3400	**100**	5000
	C9 to C12	1000	15000	140000	**1000**	20000
	C9 to C18	1000	15000	490000	**1000**	20000
	C19 to C36	2500	230000	-	**2500**	20000
Aromatics	C9 to C10	100	810	**69**	100	5000
	C11 to C22	200	810	**170**	1000	10000
TPH-general	-	200	800	**200**	1000	10000

*See Massachusetts DEP MCP for full description S-1, S-2 and S-3 soils.

RESIDENTIAL SURFACE SOIL (S-1) - Groundwater Discharge to Surface Water (GW-3)

Carbon Range		Final S-1/GW-3 RBSL	Direct Exposure	Leaching	Nuisance Ceiling	Upper Concentration Level
Aliphatics	C5 to C8	100	730	34000	**100**	5000
	C9 to C12	1000	15000	690000	**1000**	20000
	C9 to C18	1000	15000	2500000	**1000**	20000
	C19 to C36	2500	230000	-	**2500**	20000
Aromatics	C9 to C10	100	810	1400	**100**	5000
	C11 to C22	800	**810**	25000	1000	10000
TPH-general	-	800	**800**	25000	1000	10000

References:

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Public Hearing Draft: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, January 17, 1997.

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Redline/Strikeout Version: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, October 31, 1997, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000, Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, November 7, 1997, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

MADEP, 1999, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Spreadsheet Detailing VPH/EPH Standards Derivation: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, May 25, 1999, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

Summary of Massachusetts DEP Carbon Range/TPH Risk-Based Screening Levels (RBSLs) (mg/kg)

*OCCUPATIONAL SURFACE SOIL (S-2) - Drinking Water Resource Threatened (GW-1)

Carbon Range		Final S-1/GW-1 RBSL	Direct Exposure	Leaching	Nuisance Ceiling	Upper Concentration Level
Aliphatics	**C5 to C8**	500	1500	3400	**500**	5000
	C9 to C12	2500	36000	140000	**2500**	20000
	C9 to C18	2500	36000	490000	**2500**	20000
	C19 to C36	5000	670000	-	**5000**	20000
Aromatics	**C9 to C10**	100	2000	**69**	500	5000
	C11 to C22	200	2000	**170**	2500	10000
TPH-general	-	200	2000	**200**	2500	10000

*See Massachusetts DEP MCP for full description S-1, S-2 and S-3 soils.

OCCUPATIONAL SURFACE SOIL (S-2) - Groundwater Discharge to Surface Water (GW-3)

Carbon Range		Final S-1/GW-3 RBSL	Direct Exposure	Leaching	Nuisance Ceiling	Upper Concentration Level
Aliphatics	**C5 to C8**	500	1500	34000	**500**	5000
	C9 to C12	2500	36000	690000	**2500**	20000
	C9 to C18	2500	36000	2500000	**2500**	20000
	C19 to C36	5000	670000	-	**5000**	20000
Aromatics	**C9 to C10**	500	2000	1400	**500**	5000
	C11 to C22	2000	**2000**	25000	2500	10000
TPH-general	-	2000	**2000**	25000	2500	10000

References:

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Public Hearing Draft: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, January 17, 1997.

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Redline/Strikeout Version: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, October 31, 1997, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000, Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, November 7, 1997, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

MADEP, 1999, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Spreadsheet Detailing VPH/EPH Standards Derivation: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, May 25, 1999, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

Summary of Massachusetts DEP Carbon Range/TPH Risk-Based Screening Levels (RBSLs) (mg/kg)

***ISOLATED SUBSURFACE SOIL (S-3) - Drinking Water Resource Threatened (GW-1)**

Carbon Range		Final S-1/GW-1 RBSL	Direct Exposure	Leaching	Nuisance Ceiling	Upper Concentration Level
Aliphatics	C5 to C8	500	7100	3400	**500**	5000
	C9 to C12	5000	170000	140000	**5000**	20000
	C9 to C18	5000	170000	490000	**5000**	20000
	C19 to C36	5000	3100000	-	**5000**	20000
Aromatics	C9 to C10	100	9300	**69**	500	5000
	C11 to C22	200	9300	**170**	5000	10000
TPH-general	-	200	9300	**200**	5000	10000

*See Massachusetts DEP MCP for full description S-1, S-2 and S-3 soils.

ISOLATED SUBSURFACE SOIL (S-3) - Groundwater Discharge to Surface Water (GW-3)

Carbon Range		Final S-1/GW-3 RBSL	Direct Exposure	Leaching	Nuisance Ceiling	Upper Concentration Level
Aliphatics	C5 to C8	500	7100	34000	**500**	5000
	C9 to C12	5000	170000	690000	**5000**	20000
	C9 to C18	5000	170000	2500000	**5000**	20000
	C19 to C36	5000	3100000	-	**5000**	20000
Aromatics	C9 to C10	500	9300	1400	**500**	5000
	C11 to C22	5000	9300	25000	**5000**	10000
TPH-general	-	5000	9300	25000	**5000**	10000

References:

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Public Hearing Draft: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, January 17, 1997.

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Redline/Strikeout Version: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, October 31, 1997, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000, Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, November 7, 1997, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

MADEP, 1999, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Spreadsheet Detailing VPH/EPH Standards Derivation: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, May 25, 1999, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

Summary of Massachusetts DEP Carbon Range/TPH Risk-Based Screening Levels (RBSLs) (ug/L)

*GROUNDWATER - Drinking Water (GW-1)

Carbon Range		Final GW-1 RBSL	Human Consumption	Nuisance Ceiling	Upper Concentration Level
Aliphatics	C5 to C8	400	**420**	5000	100000
	C9 to C12	4000	**4200**	5000	100000
	C9 to C18	4000	**4200**	5000	100000
	C19 to C36	5000	42000	**5000**	100000
Aromatics	C9 to C10	200	**230**	5000	100000
	C11 to C22	200	**230**	5000	100000
TPH-general	-	200	**230**	5000	100000

*See Massachusetts DEP MCP for full description GW-1, GW-2 and GW-3 groundwater.

*GROUNDWATER - Discharge to Surface Water (GW-3)

Carbon Range		Final GW-3 RBSL	*Aquatic Life Protection	Nuisance Ceiling	Upper Concentration Level
Aliphatics	C5 to C8	4000	**3900**	50000	100000
	C9 to C12	20000	**18000**	50000	100000
	C9 to C18	20000	**18000**	50000	100000
	C19 to C36	20000	**21000**	50000	100000
Aromatics	C9 to C10	4000	**4300**	50000	100000
	C11 to C22	30000	**30000**	50000	100000
TPH-general	-	20000	**20000**	50000	100000

*** Aquatic Life Protection = aquatic life criteria x assumed ten-fold diuition factor.**

References:

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Public Hearing Draft: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, January 17, 1997.

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Redline/Strikeout Version: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, October 31, 1997, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000, Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, November 7, 1997, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

MADEP, 1999, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Spreadsheet Detailing VPH/EPH Standards Derivation: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, May 25, 1999, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

APPENDIX 8

SUMMARY OF JULY 2003 UPDATES TO DECEMBER 2001 RBSL DOCUMENT

Screening For Environmental Concerns At Sites With Contaminated Soil and Groundwater (July 2003)

Updates to: December 2001 Application of Risk-Based Screening Levels and Decision Making to Sites With Impacted Soil and Groundwater

Date: 6/19/02
Section: Volume 1, Tables A, B, C and D; Volume 2, Tables A, B, C, D and K series.
Update: Direct Exposure soil screening levels presented for cyanide revised:

Date: 2/1/02
Section: Volume 1, Section 3.3.3 Laboratory-Based Soil Leaching Tests
Update: Page 3-7, text revised."

Date: 02/01/02
Section: Volume 2, Appendix 1, Table E-series
Update: Addition of Indoor-Air Impact screening levels for MEK and MIK

Date: 02/01/02
Section: Volume 1, Table D; Volume 2, Appendix 1, Table D-1
Update: Final RBSL for Bromomethane, Subsurface Soils, Residential Exposure Scenario corrected.

Date: 02/11/02
Section: Volume 2, Appendix 1, Table E-series
Update: Correction of Indoor-Air Impact screening levels for chloroethane and chloromethane

Date: July 2003
Summary of Additional Updates To December 2001 Document

General: Document revised to reflect comments received during peer review by University of California in January 2003

Volume 1:
General: "Risk-Based Screening Levels" terminology changed to "Environmental Screening Levels" to better convey the scope of the screening levels and clarify that some screening levels are not "risk-based" in a strict toxicological sense of this term.
General: "Surface Soils" and "Subsurface Soils" terminology revised to "Shallow Soils" and "Deep Soils".
General: Toxaphene and tert Buytl Alcohol added to tables.
Table E: Screening levels for soil gas and indoor air added.
Table F: Screening levels for surface water added

Volume 2 - Appendix 1
Chapters 2 and 3: "Fine-grained soils" and "Coarse-grained soils" terminology revised to "Low-permeability soils" and "High-permeability soils".

Chapters 2 and 3: Models and screening levels for indoor-air impact concerns revised. Refer to of Appendix 1. Among other issues, screening levels for shallow soil gas and indoor air added, low-permeability and high-permeability vadose-zone soil models revised.
Chapter 2: Selection of aquatic habitat goals clarified.
Chapter 3, Table K-2: Soil direct exposure model for commercial/industrial land use revised to reflect soil ingestion rate of 100 mg/day.
Table A-D series: Background level of arsenic and total chromium substituted for direct-exposure screening level
Table E series: Screening levels for soil and groundwater revised; screening levels for soil gas and indoor air added.
Table F-2a, F-2b, F-2c: Screening levels for surface water added
Table F-6: USEPA Region IX Preliminary Remediation Goals for tapwater added
Table J. Toxicity Factors Updated (see highlights in electronic version of table)

<u>**Volume 2 - Appendix 3**</u>
Sensitivity analysis of Johnson & Ettinger model added

APPENDIX 9

SUMMARY OF UPDATES TO JULY 2003 ESL DOCUMENT (9/4/03)

Winston H. Hickox
Secretary for Environmental Protection

California Regional Water Quality Control Board

San Francisco Bay Regional Water Quality Control Board

Internet Address: http://www.swrcb.ca.gov
1515 Clay Street, Suite 1400, Oakland, California 94612
Phone (510) 622-2300 FAX (510) 622-2460

Gray Davis
Governor

TO: Interested Parties
FROM: Roger Brewer
Toxics Cleanup Division
DATE: September 4, 2003

SUBJECT: *Screening For Environmental Concerns at Sites With Contaminated Soil and Groundwater* (July 2003) - Updates and Corrections.

Following is a summary of revisions and updates to the July 2003 document *Screening For Environmental Concerns at Sites With Contaminated Soil and Groundwater* as of the above-noted date. These updates have been incorporated into the tables of the ESL document currently posted to the ESL web page at www.swrcb.ca.gov/rwqcb2/esl.htm.

This notice will updated and posted as needed. If you find an apparent error in the tables please notify Roger Brewer at rdb@rb2.swrcb.ca.gov.

ESL Updates (Most Recent Updates: September 4, 2003):
Date: 9/4/03
Section: Volume 1, Tables A, B, C and D; Volume 2, Tables A, B, C, D series and Table G.
Update: Leaching based soil screening levels for perchlorate added to Table G and affected tables updated. A different model was used to develop the leaching based soil screening levels for perchlorate and the results were inadvertently left out of the Table G spreadsheet. The correct screening levels are, however, discussed in Section 3.4 of Appendix 1 (page 3-9). Laboratory-based soil leaching tests are recommended for site-specific evaluation of leaching concerns (e.g., SPLP test, adjusted to remove laboratory method dilution effects). Refer to Section 3.3.3 of Volume 1.

Volume 1:

Table A

Chemical	Residential (mg/kg)	Commercial/Industrial (mg/kg)
Perchlorate	0.007	0.007

Table B

Chemical	Residential (mg/kg)	Commercial/Industrial (mg/kg)
Perchlorate	1.2	1.2

Table C

Chemical	Residential (mg/kg)	Commercial/Industrial (mg/kg)
Perchlorate	0.007	0.007

Table D

Chemical	Residential (mg/kg)	Commercial/Industrial (mg/kg)
Perchlorate	1.2	1.2

ESL Document Updates

Appendix 1:

Table A-1

Chemical	**Final ESL (mg/kg)**	**Soil Leaching (mg/kg)**
Perchlorate	0.007	0.007

Table A-2

Chemical	**Final ESL (mg/kg)**	**Soil Leaching (mg/kg)**
Perchlorate	0.007	0.007

Table B-1

Chemical	**Final ESL (mg/kg)**	**Soil Leaching (mg/kg)**
Perchlorate	1.2	1.2

Table B-2

Chemical	**Final ESL (mg/kg)**	**Soil Leaching (mg/kg)**
Perchlorate	1.2	1.2

Table C-1

Chemical	**Final ESL (mg/kg)**	**Soil Leaching (mg/kg)**
Perchlorate	0.007	0.007

Table C-2

Chemical	**Final ESL (mg/kg)**	**Soil Leaching (mg/kg)**
Perchlorate	0.007	0.007

Table D-1

Chemical	**Final ESL (mg/kg)**	**Soil Leaching (mg/kg)**
Perchlorate	1.2	1.2

Table D-2

Chemical	**Final ESL (mg/kg)**	**Soil Leaching (mg/kg)**
Perchlorate	1.2	1.2

Table G. Soil Screening Levels For Leaching Concerns

Chemical	**Drinking Water Resource Threatened (mg/kg)**	**NON-Drinking Water Resource Threatened (mg/kg)**
Perchlorate	0.007	1.2

ESL Document Updates

Date: 9/2/03
Section: Volume 1, Table E; Volume 2, Tables E-2 and E-3.
Update: Inhalation toxicity factors for carbon tetrachloride, 1,2 dibromo-3-dichloropropane and 1,1,22 Tetrachloroethane corrected. Indoor air screening levels (Table E-3) and correlative soil gas screening levels (Table E-2) were corrected. Soil and groundwater screening levels for vapor emission concerns were not affected.

Volume 1, Table E

	INDOOR AIR		SHALLOW SOIL GAS	
CHEMICAL	Residential Land Use (ug/m^3)	Commercial/ Industrial Land Use (ug/m^3)	Residential Land Use (ug/m^3)	Commercial/ Industrial Land Use (ug/m^3)
CARBON TETRACHLORIDE	5.8E-02	9.7E-02	5.8E+01	1.9E+02
1,2-DIBROMO-3-CHLOROPROPANE	1.2E-03	2.0E-3	1.2E+00	4.1E+00
TETRACHLOROETHANE, 1,1,1,2-	no change	7.0E-02	no change	1.4E+02

Volume 2, Table 2 - Shallow Soil Gas Screening Levels

	Residential Exposure		
CHEMICAL	Lowest Residential (ug/m^3)	Indoor Air Carcinogens (ug/m^3)	Indoor Air Noncarcinogens (ug/m^3)
CARBON TETRACHLORIDE	5.8E+01	5.8E+01	5.2E+02
1,2-DIBROMO-3-CHLOROPROPANE	1.2E+00	1.2E+00	4.2E+01
TETRACHLOROETHANE, 1,1,2,2-	4.2E+01	4.2E+01	4.4E+04

(**bold** - revised screening level)

Volume 2, Table E-2 - Shallow Soil Gas Screening Levels

	Commercial/Industrial Exposure		
CHEMICAL	Lowest C/I (ug/m^3)	Indoor Air Carcinogens (ug/m^3)	Indoor Air Noncarcinogens (ug/m^3)
CARBON TETRACHLORIDE	**1.9E+02**	**1.9E+02**	**1.5E+03**
1,2-DIBROMO-3-CHLOROPROPANE	**4.1E+00**	**4.1E+00**	**1.2E+02**
TETRACHLOROETHANE, 1,1,2,2-	**1.4E+02**	**1.4E+02**	**1.2E+05**

(**bold** - revised screening level)

ESL Document Updates

Volume 2, Table E-3 - Indoor Air Screening Levels

CHEMICAL	URF $(ug/m^3)^{-1}$	RFC $(ug/m^3)^{-1}$	Residential Exposure: Lowest Residential (ug/m^3)	Indoor Air Carcinogens (ug/m^3)	Indoor Air Noncarcinogens (ug/m^3)
CARBON TETRACHLORIDE	no change	2.5E+00	**5.8E-02**	5.8E-02	**5.2E-01**
1,2-DIBROMO-3-CHLOROPROPANE	2.0E-03	no change	**1.2E-03**	**1.2E-03**	4.2E-02
TETRACHLOROETHANE, 1,1,2,2-	no change	2.1E+02	4.2E-02	4.2E-02	**4.4E+01**

(**bold** - revised screening level)

Volume 2, Table E-3 - Indoor Air Screening Levels

CHEMICAL	URF $(ug/m^3)^{-1}$	RFC $(ug/m^3)^{-1}$	Commercial/Industrial Exposure: Lowest C/I (ug/m^3)	Indoor Air Carcinogens (ug/m^3)	Indoor Air Noncarcinogens (ug/m^3)
CARBON TETRACHLORIDE	no change	2.5E+00	**9.7E-02**	9.7E-02	**7.3E-01**
1,2-DIBROMO-3-CHLOROPROPANE	2.0E-03	no change	**2.0E-03**	**2.0E-03**	5.8E-02
TETRACHLOROETHANE, 1,1,2,2-	no change	2.1E+02	**7.0E-02**	7.0E-02	**6.1E+01**

(**bold** - revised screening level)

Date: 8/4/03
Section: Volume 1, Tables A, B, C and D; Volume 2, Tables A, B, C, D series and Table G.
Update: Leaching based soil screening levels for bis(2-ethylhexl)phthalate and pentachlorophenol corrected in Appendix 1, Table G. Corrections also made to affected tables of Volume 1 and Appendix 1 of Volume 2 as noted below. Note that final ESLs in Volume 1 were not affected in all cases.

Volume 1:

Table A

Chemical	Residential (mg/kg)	Commercial/Industrial (mg/kg)
Bis(2-ethylhexl)phthalate	66	66
Pentachlorophenol	4.4	5.0

Table B

Chemical	Residential (mg/kg)	Commercial/Industrial (mg/kg)
Bis(2-ethylhexl)phthalate	160	530
Pentachlorophenol	4.4	5.0

Table C

Chemical	Residential (mg/kg)	Commercial/Industrial (mg/kg)
Bis(2-ethylhexl)phthalate	66	66

Pentachlorophenol	5.3	5.3

Table D

Chemical	Residential (mg/kg)	Commercial/Industrial (mg/kg)
Bis(2-ethylhexl)phthalate	530	530
Pentachlorophenol	42	42

Appendix 1:

Table A-1

Chemical	Final ESL (mg/kg)	Soil Leaching (mg/kg)
Bis(2-ethylhexl)phthalate	66	66
Pentachlorophenol	4.4	5.3

Table A-2

Chemical	Final ESL (mg/kg)	Soil Leaching (mg/kg)
Bis(2-ethylhexl)phthalate	66	66
Pentachlorophenol	5.0	5.3

Table B-1

Chemical	Final ESL (mg/kg)	Soil Leaching (mg/kg)
Bis(2-ethylhexl)phthalate	160	530
Pentachlorophenol	4.4	42

Table B-2

Chemical	Final ESL (mg/kg)	Soil Leaching (mg/kg)
Bis(2-ethylhexl)phthalate	530	530
Pentachlorophenol	5.0	42

Table C-1

Chemical	Final ESL (mg/kg)	Soil Leaching (mg/kg)
Bis(2-ethylhexl)phthalate	66	66
Pentachlorophenol	5.3	5.3

Table C-2

Chemical	Final ESL (mg/kg)	Soil Leaching (mg/kg)
Bis(2-ethylhexl)phthalate	66	66
Pentachlorophenol	5.3	5.3

Table D-1

Chemical	Final ESL (mg/kg)	Soil Leaching (mg/kg)
Bis(2-ethylhexl)phthalate	530	530
Pentachlorophenol	42	42

ESL Document Updates

Table D-2

Chemical	Final ESL (mg/kg)	Soil Leaching (mg/kg)
Bis(2-ethylhexl)phthalate	530	530
Pentachlorophenol	42	42

Table G. Soil Screening Levels For Leaching Concerns

Chemical	Drinking Water Resource Threatened (mg/kg)	NON-Drinking Water Resource Threatened (mg/kg)
Bis(2-ethylhexl)phthalate	66	530
Pentachlorophenol	5.3	420