Appendix A

Calculation of Risk-Based Media Cleanup Standards

Appendix A-1: Media Cleanup Standards Calculations for Theoretical ILCR = 10^{-6} and HI = 1

APPENDIX A: GROUNDWATER AND SOIL MEDIA CLEANUP STANDARD CALCULATION SUMMARY

LAWRENCE BERKELEY NATIONAL LABORATORY HHRA

Input Parameters for all MCS Calculations	
Cancer Risk	1.00E-06
Hazard Quotient	1
η*	0.002
Depth to Groundwater (feet)	5
Depth to Soil Source (feet)	5

Risk Estimates

Groundwater COPCs	Groundwater				Soil COPCs	Soil	
	Indoor Workers		Intrusive Workers			Indoor Workers	
Compound	Calculated Target Cancer Risk Cw (µg/L)	Calculated Target Non-Cancer Risk Cw (µg/L)	cancer Cw (µg/L) [g/]	Non-cancer Cw (µg/L) [g/]		Calculated Target Cancer Risk Cs (mg/kg)	Calculated Target Non-Cancer Risk Cs (mg/kg)
Organic Compounds							
1,1,1-Trichloroethane	--	1,570,783	--	2,596,355	1,1,1-Trichloroethane	--	690
1,1,2-Trichloroethane	1,905	--	14,833	61,026			
1,1-Dichloroethane	3,663	1,025,767	277,640	2,260,781	1,1-Dichloroethane	1.3	364
1,1-Dichloroethene	--	28,873	--	639,607	1,1-Dichloroethene	--	7.9
1,2-Dichloroethane	1,030	3,088,688	53,714	1,081,945	1,2-Dichloroethane	0.23	8.5
1,2-Dichloroethene, cis-	--	98,405	--	199,358	1,2-Dichloroethene, cis-	--	38.1
1,2-Dichloroethene, trans-	--	94,405	--	320,269	1,2-Dichloroethene, trans-	--	49.6
1,2-Dichloropropane	1,071	15,302	27,688	--			
Benzene	175	108,838	8,092	46,238	Benzene	0.10	6.0
Carbon tetrachloride	27	1,004	3,084	4,625	Carbon tetrachloride	0.05	1.7
Chloroform	1,206	684,732	8,770	38,838	Chloroform	0.49	0.28
Methylene chloride	10,381	1,482,958	235,804	2,829,653	Methylene Chloride	1.8	1974
Tetrachloroethene	343	25,265	384	29,661	Tetrachloroethene	0.45	380
Trichloroethene	1,594	682,956	55,015	3,065	Trichloroethene	2.3	966
Vinyl chloride	12	33,798	7,236	83,736	Vinyl chloride	0.0035	9.7

*Areal fraction of cracks in foundations/walls (cm^2-cracks/cm^2-total area)

[a/] Refer to the Model Unit Definition table for all associated unit definitions.

Risk-Based MCS

APPENDIX A: GROUNDWATER RISK CALCULATIONS
MODELING VOLATILIZATION FROM GROUNDWATER INTO INDUSTRIAL/COMMERCIAL INDOOR AIR (ASTM MODEL)

LAWRENCE BERKELEY NATIONAL LABORATORY CMS

Equations	Input Parameter Definition[a]		Commercial Input Parameters
1i) Enclosed Space (Indoor) Air Concentration Due to Volatilization from Ground Water	Cair-indoor	Modeled COPC indoor air concentration (µg/m3)	Calculated (Eq. 1i)
Cair-indoor = CwVFwesp	Cw	Groundwater COPC concentration (µg/L)	Measured
	VFwesp	Cross-media groundwater-to-enclosed (indoor) space volatilization factor(mg/m3-air)/(mg/L-water)	Calculated (Eq. 2i)
2i) Cross-Media Groundwater-to-Enclosed (Indoor) Space Air Volatilization Factor	H	Henry's law constant (cm3-water)/(cm3-air)	Chemical-specific
	Deffws	Effective diffusion coefficient between ground water and soil surface (cm2/s)	Calculated (Eq. 3 on Page: Cair-gw outdoor)
	LGW	Depth to ground water = hcap + hv (cm)	152
	ER	Enclosed-space air exchange rate (1/sec)	0.00023
	LB	Enclosed-space volume/infiltration area ratio (cm)	300
	Deffcrack	Effective diffusion coefficient through foundation cracks (cm2/s)	Calculated (Eq. 3i)
3i) Effective Diffusion Through Foundation Cracks	Lcrack	Enclosed-space foundation or wall thickness (cm)	15
	η	Areal fraction of cracks in foundations/walls (cm2-cracks/cm2-total area)	0.002
	Dair	Diffusion coefficient in air (cm2/s)	Chemical-specific
	θ acrack	Volumetric air content in foundation/wall cracks (cm3-air/cm3 total volume)	0.26
	θ T	Total soil porosity (cm3/cm3-soil)	0.38
	θ wcrack	Volumetric water content in foundation/wall cracks (cm3-water/cm3 total volume)	0.12
	Dwat	Diffusion coefficient in water (cm2/s)	Chemical-specific
		Target Cancer Risk (user defined)	1.00E-06

$$VF_{wesp} = \frac{H\left[\frac{D^{eff}_{ws}/L_{GW}}{ER\,L_B}\right]}{1+\left[\frac{D^{eff}_{ws}/L_{GW}}{ER\,L_B}\right]+\left[\frac{D^{eff}_{ws}/L_{GW}}{\left(D^{eff}_{crack}/L_{crack}\right)\eta}\right]} x10^3 \frac{L}{m^3}$$

$$D^{eff}_{crack} = D^{air}\frac{\theta^{3.33}_{acrack}}{\theta^2_T} + D^{wat}\frac{1}{H}\frac{\theta^{3.33}_{wcrack}}{\theta^2_T}$$

Compound	Calculated Cw based on Target Cancer Risk (µg/L)	Calculated Cw based on Target Non-Cancer Risk (µg/L)	H	Dair (cm^2/s)	Dwat (cm^2/s)	Deffcrack (cm^2/s)	Deffws (cm^2/s)	VFwesp	Target Cancer Risk Cair-indoor (µg/m^3)	Target Non-Cancer Risk Cair-indoor (µg/m^3)
Organic Compounds										
1,1,1-Trichloroethane	--	1,570,783	7.05E-01	7.80E-02	8.80E-06	6.09E-03	3.59E-04	6.17E-03	--	9.69E+03
1,1,2-Trichloroethane	1,905	--	3.74E-02	7.80E-02	8.80E-06	6.09E-03	1.34E-03	4.03E-04	7.67E-01	--
1,1-Dichloroethane	3,663	1,025,767	2.30E-01	7.42E-02	1.05E-05	5.79E-03	5.14E-04	2.09E-03	7.67E+00	2.15E+03
1,1-Dichloroethene	--	28,873	1.07E+00	9.00E-02	1.04E-05	7.02E-03	3.90E-04	1.06E-02	--	3.07E+02
1,2-Dichloroethane	1,030	3,088,688	4.01E-02	1.04E-01	9.90E-06	8.12E-03	1.53E-03	5.68E-04	5.85E-01	1.75E+03
1,2-Dichloroethene, cis-	--	98,405	1.67E-01	7.36E-02	1.13E-05	5.74E-03	6.19E-04	1.56E-03	--	1.53E+02
1,2-Dichloroethene, trans-	--	94,405	3.85E-01	7.07E-02	1.19E-05	5.52E-03	4.27E-04	3.25E-03	--	3.07E+02
1,2-Dichloropropane	1,071	15,302	1.15E-01	7.82E-02	8.73E-06	6.10E-03	6.76E-04	1.15E-03	1.23E+00	1.75E+01
Benzene	175	108,838	2.28E-01	8.80E-02	9.80E-06	6.87E-03	5.54E-04	2.42E-03	4.23E-01	2.63E+02
Carbon tetrachloride	27	1,004	1.25E+00	7.80E-02	8.80E-06	6.09E-03	3.30E-04	1.07E-02	2.92E-01	1.07E+01
Chloroform	1,206	684,732	1.50E-01	1.04E-01	1.00E-05	8.12E-03	7.34E-04	1.92E-03	2.32E+00	1.32E+03
Methylene chloride	10,381	1,482,958	8.98E-02	1.01E-01	1.17E-05	7.88E-03	1.02E-03	1.18E-03	1.23E+01	1.75E+03
Tetrachloroethene	343	25,265	7.54E-01	7.20E-02	8.20E-06	5.62E-03	3.28E-04	6.07E-03	2.08E+00	1.53E+02
Trichloroethene	1,594	682,956	4.22E-01	7.90E-02	9.10E-06	6.16E-03	4.11E-04	3.85E-03	6.14E+00	2.63E+03
Vinyl chloride	12	33,798	1.11E+00	1.06E-01	1.23E-05	8.27E-03	4.57E-04	1.30E-02	1.57E-01	4.38E+02

[a] Refer to the Model Unit Definition table for all associated unit definitions.

APPENDIX A: GROUNDWATER RISK CALCULATIONS
INDOOR WORKER -- RME SCENARIO
CARCINOGENIC AND NONCARCINOGENIC RISK ESTIMATES - INHALATION OF VOLATILE COPCS IN INDOOR AIR FROM GROUNDWATER

LAWRENCE BERKELEY NATIONAL LABORATORY CMS

Exposure Assumptions			Risk and Hazard Equations
Receptor	Indoor Office Worker:	RME Scenario	Carcinogenic:
COPC Ambient Air Concentration (Cair-indoor)	chemical-specific	$\mu g/m^3$	$Risk = \frac{(C_{air-indoor})(EF)(ED)(ET)(URF)}{(AT_c)(365 days/year)}$
Exposure Frequency (EF)	250	days/yr	
Exposure Duration (ED)	25	yrs	
Fraction of EF breathing air at the site (ET)	0.333	unitless	Noncarcinogenic:
Averaging Time, Carcinogens (ATC)	70	yrs	$HQ = \frac{(C_{air-indoor})(EF)(ED)(ET)}{(RfC)(AT_{nc})(365 days/year)}$
Averaging Time, Noncarcinogens (ATNC)	25	yrs	
Inhalation Unit Risk Factor (URF)	chemical-specific	(µg/m3)-1	
Inhalation Reference Concentration (RfC)	chemical-specific	µg/m3	

COPC [a]	CAS Number [b]	Indoor Air Concentration for Target Cancer Risk ($\mu g/m^3$) [d]	Indoor Air Concentration for Target Non-Cancer Risk ($\mu g/m^3$) [d]	URF $(\mu g/m^3)^{-1}$	HHRA URF (if different)	RfC ($\mu g/m^3$)	Cancer Risk	Hazard Quotient
Organic Compounds								
1,1,1-Trichloroethane	71-55-6	--	9.69E+03	--		2.21E+03	1.00E-06	1.0
1,1,2-Trichloroethane	79-00-5	7.67E-01	--	1.60E-05		--	1.00E-06	1.0
1,1-Dichloroethane	75-34-3	7.67E+00	2.15E+03	1.60E-06		4.90E+02	1.00E-06	1.0
1,1-Dichloroethene	75-35-4	--	3.07E+02	--	5.00E-05	7.00E+01	1.00E-06	1.0
1,2-Dichloroethane	107-06-2	5.85E-01	1.75E+03	2.10E-05		4.00E+02	1.00E-06	1.0
1,2-Dichloroethene, cis-	156-59-2	--	1.53E+02	--		3.50E+01	1.00E-06	1.0
1,2-Dichloroethene, trans-	156-60-5	--	3.07E+02	--		7.00E+01	1.00E-06	1.0
1,2-Dichloropropane	78-87-5	1.23E+00	1.75E+01	1.00E-05		4.00E+00	1.00E-06	1.0
Benzene	71-43-2	4.23E-01	2.63E+02	2.90E-05		6.00E+01	1.00E-06	1.0
Carbon tetrachloride	56-23-5	2.92E-01	1.07E+01	4.20E-05		2.45E+00	1.00E-06	1.0
Chloroform	67-66-3	2.32E+00	1.32E+03	5.30E-06		3.00E+02	1.00E-06	1.0
Methylene chloride	75-09-2	1.23E+01	1.75E+03	1.00E-06		4.00E+02	1.00E-06	1.0
Tetrachloroethene	127-18-4	2.08E+00	1.53E+02	5.90E-06	5.80E-07	3.50E+01	1.00E-06	1.0
Trichloroethene	79-01-6	6.14E+00	2.63E+03	2.00E-06	1.70E-06	6.00E+02	1.00E-06	1.0
Vinyl chloride	75-1-4	1.57E-01	4.38E+02	7.80E-05		1.00E+02	1.00E-06	1.0

[a] COPC = chemical of potential concern.
[b] CAS = Chemical Abstracts Service number.
[c] Modeled indoor air concentrations are based on the COPC-specific cancer risk and hazard quotient
[d] $\mu g/m^3$ = micrograms per cubic meter.
-- = data not available.

APPENDIX A: GROUNDWATER RISK CALCULATIONS
MODELING VOLATILIZATION FROM GROUNDWATER TO SOIL SURFACE (ASTM MODEL)
LAWRENCE BERKELEY NATIONAL LABORATORY CMS

3) Effective Diffusion Coefficient Between Ground Water and Soil Surface

$$D_{ws}^{eff} = (h_{cap} + h_v)\left[\frac{h_{cap}}{D_{cap}^{eff}} + \frac{h_v}{D_s^{eff}}\right]^{-1}$$

$$D_{cap}^{eff} = D^{air}\frac{\theta_{acap}^{3.33}}{\theta_T^2} + D^{wat}\frac{1}{H}\frac{\theta_{wcap}^{3.33}}{\theta_T^2}$$

5) Effective Diffusion Coefficient in Soil Based on Vapor-Phase Concentration

$$D_s^{eff} = D^{air}\frac{\theta_{as}^{3.33}}{\theta_T^2} + D^{wat}\frac{1}{H}\frac{\theta_{ws}^{3.33}}{\theta_T^2}$$

Input Parameter Definition[a]		Input Parameters
H	Henry's law constant (cm3-water)/(cm3-air)	Chemical-specific
Deffws	Effective diffusion coefficient between ground water and soil surface (cm2/s)	Calculated (Eq. 3)
hcap	Thickness of capillary fringe (cm)	5
hv	Thickness of vadose zone (cm)	147
Deffcap	Effective diffusion coefficient through capillary fringe (cm2/s)	Calculated (Eq. 4)
Deffs	Effective diffusion coefficient in soil based on vapor-phase concentration (cm2/s)	Calculated (Eq. 5)
Dair	Diffusion coefficient in air (cm2/s)	Chemical-specific
θ acap	Volumetric air content in capillary fringe soils (cm3-air/cm3 total volume)	0.038
θ T	Total soil porosity (cm3/cm3-soil)	0.38
θ wcap	Volumetric water content in capillary fringe soils (cm3-water/cm3-soil)	0.342
Dwat	Diffusion coefficient in water (cm2/s)	Chemical-specific
θ as	Volumetric air content in vadose zone soils (cm3-air/cm3-soil)	0.26
θ ws	Volumetric water content in vadose zone soils (cm3-water/cm3-soil)	0.12

Compound	H	Dair (cm^2/s)	Dwat (cm^2/s)	Deffs (cm^2/s)	Deffcap (cm^2/s)	Deffws (cm^2/s)	VFwamb
1,1,1-Trichloroethane	7.05E-01	7.80E-02	8.80E-06	6.09E-03	1.25E-05	3.59E-04	4.32E-05
1,1,2-Trichloroethane	3.74E-02	7.80E-02	8.80E-06	6.09E-03	5.58E-05	1.34E-03	5.34E-06
1,1-Dichloroethane	2.30E-01	7.42E-02	1.05E-05	5.79E-03	1.85E-05	5.14E-04	1.82E-05
1,1-Dichloroethene	1.07E+00	9.00E-02	1.04E-05	7.02E-03	1.35E-05	3.90E-04	7.21E-05
1,2-Dichloroethane	4.01E-02	1.04E-01	9.90E-06	8.12E-03	6.14E-05	1.53E-03	7.06E-06
1,2-Dichloroethene, cis-	1.67E-01	7.36E-02	1.13E-05	5.74E-03	2.27E-05	6.19E-04	1.49E-05
1,2-Dichloroethene, trans-	3.85E-01	7.07E-02	1.19E-05	5.52E-03	1.51E-05	4.27E-04	2.62E-05
1,2-Dichloropropane	1.15E-01	7.82E-02	8.73E-06	6.10E-03	2.49E-05	6.76E-04	
Benzene	2.28E-01	8.80E-02	9.80E-06	6.87E-03	1.97E-05	5.54E-04	1.99E-05
Carbon tetrachloride	1.25E+00	7.80E-02	8.80E-06	6.09E-03	1.14E-05	3.30E-04	7.17E-05
Chloroform	1.50E-01	1.04E-01	1.00E-05	8.12E-03	2.64E-05	7.34E-04	1.68E-05
Methylene chloride	8.98E-02	1.01E-01	1.17E-05	7.88E-03	3.84E-05	1.02E-03	1.24E-05
Tetrachloroethene	7.54E-01	7.20E-02	8.20E-06	5.62E-03	1.14E-05	3.28E-04	4.23E-05
Trichloroethene	4.22E-01	7.90E-02	9.10E-06	6.16E-03	1.44E-05	4.11E-04	2.87E-05
Vinyl chloride	1.11E+00	1.06E-01	1.23E-05	8.27E-03	1.58E-05	4.57E-04	8.78E-05

[a] Refer to the Model Unit Definition table for all associated unit definitions.

APPENDIX A: GROUNDWATER RISK CALCULATIONS
CALCULATION OF DOSE ABSORBED PER UNIT AREA PER EVENT (DAevent)
INTRUSIVE WORKER -- RME SCENARIO

LAWRENCE BERKELEY NATIONAL LABORATORY HHRA

Equations	Input Parameter Definition		Input Parameters
Organics:	tevent	Duration of event (hr/event) [a]	0.25
If tevent < t*, then:	t*	Time it takes to reach steady state (hr/event)	Chemical-specific
	DAevent	Dose absorbed per unit area per event (mg/cm^2-event) [b]	Calculated
	Kp	Permeability coefficient from water (cm/hr) [c]	Chemical-specific
	Cw	Concentration of chemical in water (mg/cm^3) [d]	Measured
	τevent	Lag time per event (hr/event)	Chemical-specific
If tevent > t*, then:	B	Relative contribution of permeability coefficients in strateium corneum and viable epidermis (unitless)	Chemical-specific
	pi		3.141592654
		Target Cancer Risk (user defined)	1.00E-06

$$DA_{event} = 2K_p C_w \sqrt{\frac{6\tau_{event}\, t_{event}}{\pi}}$$

$$DA_{event} = K_p C_w \left[\frac{t_{event}}{1+B} + 2\tau_{event} \left(\frac{1+3B+3B^2}{(1+B)^2} \right) \right]$$

Inorganics:

$$DA_{event} = K_p C_w t_{event}$$

Preliminary COPC [e]	Type [f]	t*	Kp	cancer Cw (µg/L) [g]	cancer Cw (mg/cm^3) [h]	non-cancer Cw (µg/L) [g]	non-cancer Cw (mg/cm^3) [h]	τevent	B	cancer DAevent (organics)	non-cancer DAevent (organics)	DAevent (inorganics)	DAevent (all)
1,1,1-Trichloroethane	o	1.43E+00	1.30E-02	--	--	2,596,355.04	2.60E+00	6.00E-01	1.00E-01	--	3.61E-02		
1,1,2-Trichloroethane	o	1.43E+00	6.40E-03	14,833	1.48E-02	61,025.93	6.10E-02	6.00E-01	1.12E-02	1.02E-04	4.18E-04		
1,1-Dichloroethane	o	9.20E-01	6.70E-03	277,640	2.78E-01	2,260,780.63	2.26E+00	3.80E-01	6.17E-03	1.58E-03	1.29E-02		
1,1-Dichloroethene	o	8.90E-01	1.20E-02	--	--	639,606.58	6.40E-01	3.70E-01	1.35E-02	--	6.45E-03		
1,2-Dichloroethane	o	9.20E-01	4.20E-03	53,714	5.37E-02	1,081,945.02	1.08E+00	3.80E-01	3.02E-03	1.92E-04	3.87E-03		
1,2-Dichloroethene, cis-	o	8.90E-01	7.70E-03	--	--	199,357.89	1.99E-01	3.70E-01	7.24E-03	--	1.29E-03		5.93E-07
1,2-Dichloroethene, trans-	o	8.20E-01	1.00E-02	--	--	320,269.49	3.20E-01	3.40E-01	7.20E-03	--	2.58E-03		
1,2-Dichloropropane	o	1.00E+00	1.00E-02	27,688	2.77E-02	--	--	4.30E-01	1.00E-02	2.51E-04	--		
Benzene	o	7.00E-01	1.50E-02	8,092	8.09E-03	46,237.54	4.62E-02	2.90E-01	1.00E-01	9.03E-05	5.16E-04		1.34E-08
Carbon tetrachloride	o	1.86E+00	1.60E-02	3,084	3.08E-03	4,625.47	4.63E-03	7.80E-01	1.00E-01	6.02E-05	9.03E-05		
Chloroform	o	1.19E+00	6.80E-03	8,770	8.77E-03	38,838.38	3.88E-02	5.00E-01	9.33E-03	5.83E-05	2.58E-04		
Methylene chloride	o	7.60E-01	3.50E-03	235,804	2.36E-01	2,829,653.40	2.83E+00	3.20E-01	1.78E-03	6.45E-04	7.74E-03		
Tetrachloroethene	o	2.18E+00	3.30E-02	384	3.84E-04	29,661.31	2.97E-02	9.10E-01	2.00E-01	1.67E-05	1.29E-03		
Trichloroethene	o	1.39E+00	1.20E-02	55,015	5.50E-02	3,065.15	3.07E-03	5.80E-01	1.00E-01	6.95E-04	3.87E-05		
Vinyl chloride	o	5.10E-01	7.30E-03	7,236	7.24E-03	83,736.30	8.37E-02	2.10E-01	2.30E-03	3.35E-05	3.87E-04		1.38E-07

[a] hr/event = hours per event
[b] mg/cm^2-event = milligrams per centimeter-event
[c] cm/hr = centimeters per hour
[d] mg/cm^3 = milligrams per cubic centimeter
[e] Preliminary COPC = preliminary chemical of potential concern.
[f] "o" indicates an organic compound, "i" indicates an inorganic compound
[g] Cw is the maximum detected contaminant concentration; mg/L = micrograms per liter
[h] mg/cm^3 = milligrams per cubic centimeter

APPENDIX A: GROUNDWATER RISK CALCULATIONS
INTRUSIVE WORKER -- RME SCENARIO
CARCINOGENIC AND NONCARCINOGENIC RISK ESTIMATES -- DERMAL CONTACT WITH GROUNDWATER

LAWRENCE BERKELEY NATIONAL LABORATORY HHRA

Exposure Assumptions		
Receptor	Intrusive Worker: RME Scenario	
COPC Absorbed Dose per Event (DAevent)	chemical-specific	mg/cm2-event
Event Frequency (EV)	1	events/day
Exposure Frequency (EF)	60	days/yr
Fraction of EF in Contact with Ground Water (EC)	1.0	unitless
Exposure Duration (ED)	1	yrs
Exposed Body Surface Area (SA)	3300	cm2
Averaging Time, Carcinogens (ATC)	70	yrs
Averaging Time, Noncarcinogens (ATN)	1	yrs
Oral Slope Factor Adjusted for GI Absorption (SFd)	chemical-specific	(mg/kg-day)-1
Body Weight (BW)	70	kg
Oral Reference Dose Adjusted for GI Absorption (RfDd)	chemical-specific	µg/m3
where: RfDd = RfDoral*OAF		
Gastrointestinal (oral) Absorption Fraction (OAF)	chemical-specific	unitless

Risk and Hazard Equations

Carcinogenic:

$$Risk = \frac{(DA_{event})(EV)(EF)(EC)(ED)(SA)(SF_d)}{(BW)(AT_c)(365 days/\ year)}$$

Noncarcinogenic:

$$HQ = \frac{(DA_{event})(EV)(EF)(EC)(ED)(SA)}{(RfD_d)(BW)(AT_{nc})(365 days/\ year)}$$

Preliminary COPC [a]	CAS Number [b]	Cancer DAevent (mg/cm^2-event) [c]	Non-cancer DAevent (mg/cm^2-event) [c]	SFd $(mg/kg\text{-}day)^{-1}$ [d]	RfDd (mg/kg-day)	Cancer Risk	Hazard Quotient
1,1,1-Trichloroethane	71-55-6	--	3.61E-02	--	2.80E-01	1.00E-06	1.00E+00
1,1,2-Trichloroethane	79-00-5	1.02E-04	4.18E-04	8.89E-02	3.24E-03	1.00E-06	1.00E+00
1,1-Dichloroethane	75-34-3	1.58E-03	1.29E-02	5.70E-03	1.00E-01	1.00E-06	1.00E+00
1,1-Dichloroethene	75-35-4	--	6.45E-03	--	5.00E-02	1.00E-06	1.00E+00
1,2-Dichloroethane	107-06-2	1.92E-04	3.87E-03	4.70E-02	3.00E-02	1.00E-06	1.00E+00
1,2-Dichloroethene, cis-	156-59-2	--	1.29E-03	--	1.00E-02	1.00E-06	1.00E+00
1,2-Dichloroethene, trans-	156-60-5	--	2.58E-03	--	2.00E-02	1.00E-06	1.00E+00
1,2-Dichloropropane	78-87-5	2.51E-04	--	3.60E-02	--	1.00E-06	1.00E+00
Benzene	71-43-2	9.03E-05	5.16E-04	1.00E-01	4.00E-03	1.00E-06	1.00E+00
Carbon tetrachloride	56-23-5	6.02E-05	9.03E-05	1.50E-01	7.00E-04	1.00E-06	1.00E+00
Chloroform	67-66-3	5.83E-05	2.58E-04	1.55E-01	2.00E-03	1.00E-06	1.00E+00
Chloromethane	74-87-3	5.56E-04	--	1.63E-02	--	1.00E-06	1.00E+00
Methylene chloride	75-09-2	6.45E-04	7.74E-03	1.40E-02	6.00E-02	1.00E-06	1.00E+00
Tetrachloroethene	127-18-4	1.67E-05	1.29E-03	5.40E-01	1.00E-02	1.00E-06	1.00E+00
Trichloroethene	79-01-6	6.95E-04	3.87E-05	1.30E-02	3.00E-04	1.00E-06	1.00E+00
Vinyl chloride	75-1-4	3.35E-05	3.87E-04	2.70E-01	3.00E-03	1.00E-06	1.00E+00

[a] Preliminary COPC = preliminary chemical of potential concern.
[b] CAS = Chemical Abstracts Service number.
[c] mg/cm^2-event = milligram per square centimeter per event.
[d] mg/kg-day = milligram per kilogram per day.
"--" = Data unavailable.

APPENDIX A: SOIL RISK CALCULATIONS
MODELING VOLATILIZATION FROM SOILS (0 - 20 FT BGS) INTO INDOOR AIR (ASTM MODEL)

Equations	Input Parameter Definition[a]		Residential Input Parameters
	P_s	Soil bulk density (g-soil/cm^3-soil)	1.7
1i) Enclosed Space (Indoor) Air Concentration Due to Volatilization from Subsurface Soil	$C_{air\text{-}indoor}$	Modeled COPC indoor air concentration (µg/m^3)	Calculated (Eq. 1i)
$C_{air\text{-}indoor} = C_s VF_{sesp} \times 10^3$	C_s	Soil COPC concentration (mg/kg)	Measured
	VF_{sesp}	Cross-media subsurface soil-to-enclosed (indoor) space volatilization factor (mg/m3-air)/(mg/kg-soil)	Calculated (Eq. 2i)
2i) Cross-Media Subsurface Soil-to-Enclosed (Indoor) Space Air Volatilization Factor	H	Henry's law constant (cm^3-water)/(cm^3-air)	Chemical-specific
	θ_{ws}	Volumetric	0.12
	θ_{as}	Volumetric air content in vadose zone soils (cm^3-air/cm^3-soil)	0.26
	Ls	Depth to subsurface soil source (cm)	152.4
	ER	Enclosed-space air exchange rate (1/sec)	0.00023
	L_B	Enclosed-space volume/infiltration area ratio (cm)	300
	D^{eff}_{crack}	Effective diffusion coefficient through foundation cracks (cm^2/s)	Calculated (Eq. 3i)
3i) Effective Diffusion Through Foundation Cracks	L_{crack}	Enclosed-space foundation or wall thickness (cm)	15
	η	Areal fraction of cracks in foundations/walls (cm^2-cracks/cm^2-total area)	0.002
	D^{air}	Diffusion coefficient in air (cm^2/s)	Chemical-specific
	θ_{acrack}	Volumetric air content in foundation/wall cracks (cm^3-air/cm^3 total volume)	0.26
	θ_T	Total soil porosity (cm^3/cm^3-soil)	0.38
	θ_{wcrack}	Volumetric water content in foundation/wall cracks (cm^3-water/cm^3 total volume)	0.12
	D^{wat}	Diffusion	Chemical-specific
	K_s	coefficient in	$Ks = K_{oc} X f_{oc}$
	K_{oc}	water (cm^2/s)	Chemical-specific
	F_{oc}	Soil-water fraction of organic carbon	0.01
		Target Cancer Risk	1.00E-06

$$VF_{sesp} = \frac{\left[\dfrac{Hp_s}{\theta ws + k_s p_s + H\theta_{as}}\right]\left[\dfrac{D_s^{eff}/L_s}{ER\,L_B}\right]}{1+\left[\dfrac{D_s^{eff}/L_s}{ER\,L_B}\right]+\left[\dfrac{D_s^{eff}/L_s}{(D_{crack}^{eff}/L_{crack})\eta}\right]} x10^3 \frac{cm3-kg}{m^3-g}$$

$$D_{crack}^{eff} = D^{air}\frac{\theta_{acrack}^{3.33}}{\theta_T^2} + D^{wat}\frac{1}{H}\frac{\theta_{wcrack}^{3.33}}{\theta_T^2}$$

Compound	Koc (cm^{3}water-g-carbon)	Ks (cm^3-water/cm^3-soil)	Calculated Target Cancer Risk Cs (mg/kg)	Calculated Target Non-Cancer Risk Cs (mg/kg)	H	D^{air} (cm^2/s)	D^{wat} (cm^2/s)	D^{eff}_{crack} (cm^2/s)	D^{eff}_s (cm^2/s)	VF_{sesp}	Cair-indoor (µg/m^3) for Target Cancer Risk	Cair-indoor (µg/m^3) for Target Non-Cancer Risk
1,1,1-Trichloroethane	1.10E+02	1.10E+00	--	690.17	7.05E-01	7.80E-02	8.80E-06	6.09E-03	6.09E-03	6.35E-03	--	4.38E+03
1,1-Dichloroethane	3.13E+01	3.13E-01	1.27	364.20	2.30E-01	7.42E-02	1.05E-05	5.79E-03	5.79E-03	6.03E-03	7.67E+00	2.19E+03
1,1-Dichloroethene	5.82E+01	5.82E-01	--	7.92	1.07E+00	9.00E-02	1.04E-05	7.02E-03	7.02E-03	1.74E-02	--	1.38E+02
1,2-Dichloroethane	1.68E+01	1.68E-01	0.23	8.54	4.01E-02	1.04E-01	9.90E-06	8.12E-03	8.12E-03	2.52E-03	5.85E-01	2.15E+01
1,2-Dichloroethene, cis-	3.55E+01	3.55E-01	--	38.15	1.67E-01	7.36E-02	1.13E-05	5.74E-03	5.74E-03	4.02E-03	--	1.53E+02
1,2-Dichloroethene, trans-	5.21E+01	5.21E-01	--	49.65	3.85E-01	7.07E-02	1.19E-05	5.52E-03	5.52E-03	6.18E-03	--	3.07E+02
Benzene	5.82E+01	5.82E-01	0.10	6.04	2.28E-01	8.80E-02	9.80E-06	6.87E-03	6.87E-03	4.32E-03	4.23E-01	2.61E+01
Carbon tetrachloride	2.08E+02	2.08E+00	0.05	1.75	1.25E+00	7.80E-02	8.80E-06	6.09E-03	6.09E-03	6.14E-03	2.92E-01	1.07E+01
Chloroform	3.97E+01	3.97E-01	0.49	0.28	1.50E-01	1.04E-01	1.00E-05	8.12E-03	8.12E-03	4.70E-03	2.32E+00	1.32E+00
Methylene Chloride	1.17E+01	1.17E-01	1.84	1,974.09	8.98E-02	1.01E-01	1.17E-05	7.88E-03	7.88E-03	6.66E-03	1.23E+01	1.32E+04
Tetrachloroethene	1.56E+02	1.56E+00	0.45	379.96	7.54E-01	7.20E-02	8.20E-06	5.62E-03	5.62E-03	4.60E-03	2.08E+00	1.75E+03
Trichloroethene	1.67E+02	1.67E+00	2.25	966.19	4.22E-01	7.90E-02	9.10E-06	6.16E-03	6.16E-03	2.72E-03	6.14E+00	2.63E+03
Vinyl chloride	1.43E+01	1.43E-01	0.00	9.66	1.11E+00	1.06E-01	1.23E-06	8.27E-03	8.27E-03	4.54E-02	1.57E-01	4.38E+02

[a] Refer to the Model Unit Definition table for all associated unit definitions.

APPENDIX A: SOIL RISK CALCULATIONS
INDOOR WORKER -- RME SCENARIO
CARCINOGENIC AND NONCARCINOGENIC RISK ESTIMATES - INHALATION OF VOLATILE COPCS IN INDOOR AIR FROM SOILS (0-20 FT BGS)

LAWRENCE BERKELEY NATIONAL LABORATORY, CALIFORNIA

Exposure Assumptions		Risk and Hazard Equations
Receptor	Indoor Office Worker: RME Scenario	Carcinogenic:
COPC Ambient Air Concentration ($C_{air\text{-}indoor}$)	chemical-specific $\mu g/m^3$	$Risk = \frac{(C_{air-indoor})(EF)(ED)(ET)(URF)}{(AT_c)(365 days/year)}$
Exposure Frequency (EF)	250 days/yr	
Exposure Duration (ED)	25 yrs	
Fraction of EF breathing air at the site (ET)	0.333 unitless	Noncarcinogenic:
Averging Time, Carcinogens (AT_C)	70 yrs	$HQ = \frac{(C_{air-indoor})(EF)(ED)(ET)}{(RfC)(AT_{nc})(365 days/year)}$
Averging Time, Noncarcinogens (AT_{NC})	25 yrs	
Inhalation Unit Risk Factor (URF)	chemical-specific $(\mu g/m^3)^{-1}$	
Inhalation Reference Concentration (RfC)	chemical-specific $\mu g/m^3$	

Preliminary COPC [a]	CAS Number [b]	Indoor Air Concentration for Target Cancer Risk ($\mu g/m^3$) [d]	Indoor Air Concentration for Target Non-Cancer Risk ($\mu g/m^3$) [d]	URF $(\mu g/m^3)^{-1}$	RfC ($\mu g/m^3$)	Cancer Risk	Hazard Quotient
1,1,1-Trichloroethane	71-55-6	--	4.38E+03	--	1.00E+03	1.00E-06	1.00
1,1-Dichloroethane	75-34-3	7.67E+00	2.19E+03	1.60E-06	5.01E+02	1.00E-06	1.00
1,1-Dichloroethene	75-35-4	--	1.38E+02	--	3.15E+01	1.00E-06	1.00
1,2-Dichloroethane	107-06-2	5.85E-01	2.15E+01	2.10E-05	4.90E+00	1.00E-06	1.00
1,2-Dichloroethene, cis-	156-59-2	--	1.53E+02	--	3.50E+01	1.00E-06	1.00
1,2-Dichloroethene, trans-	156-60-5	--	3.07E+02	--	7.00E+01	1.00E-06	1.00
Benzene	71-43-2	4.23E-01	2.61E+01	2.90E-05	5.95E+00	1.00E-06	1.00
Carbon tetrachloride	56-23-5	2.92E-01	1.07E+01	4.20E-05	2.45E+00	1.00E-06	1.00
Chloroform	67-66-3	2.32E+00	1.32E+00	5.30E-06	3.01E-01	1.00E-06	1.00
Methylene Chloride	75-09-2	1.23E+01	1.32E+04	1.00E-06	3.00E+03	1.00E-06	1.00
Tetrachloroethene	127-18-4	2.08E+00	1.75E+03	5.90E-06	3.99E+02	1.00E-06	1.00
Trichloroethene	79-01-6	6.14E+00	2.63E+03	2.00E-06	6.00E+02	1.00E-06	1.00
Vinyl chloride	75-1-4	1.57E-01	4.38E+02	7.80E-05	1.00E+02	1.00E-06	1.00

[a] Preliminary COPC = preliminary chemical of potential concern.
[b] CAS = Chemical Abstracts Service number.
[c] Modeled indoor air concentrations (ASTM vapor intrusion model) were based on the exposure-point concentration of each COPC detected at the evaluated area.
[d] $\mu g/m^3$ = micrograms per cubic meter.
-- = data not available.