Appendix K

Migration to Groundwater Calculations

River Terrace Site Remedial Investigation

Migration to Groundwater Calculations
River Terrace Site
Lower Contaminant Plume
(Maximum GW Parameters)

A. Site-Specific Information

1. Default Values

θ_w - water-filled soil porosity	**0.284**	Default (ADEC, 1998)
θ_a - air-filled soil porosity (L/L)	**0.15**	Default (ADEC, 1998)
ρ_b - dry soil bulk density (kg/L)	**1.5**	Default (ADEC, 1998)

2. Measured Values

K (hydraulic conductivity (m/yr)	3115	High value for lower plume area
I (infiltration rate) (m/yr)	0.13	Default for under 40 inch zone
i (hydraulic gradient) =(m/m)	0.14	High for MW-4A to MW-10 area
d_a (aquifer thickness) (meters)	1.7	Average site aquifer thickness
L (Source Length) (meters)	32	length of soil contamination lying directly over groundwater; unknown
f_{oc} (decimal fraction) Soil organic carbon	0.0022	estimate of Site Average (based on analyses)

C. Equation Calculations

Mixing Zone Depth (m): **3.396074** $d\ (m) = (0.0112*L^2)^{0.5} + d_a*\{1-\exp[(-L*I)/(K*i*d_a)]\}$

$(0.0112*L^2)^{0.5}$	3.386562
(K*i*da)	741.37
(-L*I)	-4.16
(-L*I)/(K*i*da)	-0.005611
exp[(-L*I)/(K*i*da)]	0.994404
1-exp[(-L*I)/(K*i*da)]	0.005596
da*{1-exp[(-L*I)/(K*i*da)]	0.009512
$(0.0112*L^2)^{0.5}$ + da*{1-exp[(-L*I)/(K*i*da)]}	**3.396074**

Dilution Factor: **357.0163** $DF = 1 + [(K*i*d)/(I*L)]$

K*i*d=	1481.028
I*L=	4.16
(K*i*d)/(I*L)=	356.0163
DF=	**357.0163**

D. Chemical Specific Information

Parameter	Data Source	PCE-average Koc	PCE-low Koc	PCE-high Koc	PCE-average Koc	PCE-low Koc	PCE-high Koc
Target GW conc. (mg/L)	ADEC GW Cleanup Standard (1998) or EPA Region III RBC (1997)	0.84	0.84	0.84	0.035	0.05	0.03
K_{oc} - soil organic carbon/water part. coeff (L/kg)	Chemical-specific (ADEC, 1998)	265	155	364	265	155	364
S - solubility (mg/L)	Chemical-specific (ADEC, 1998)	150	200	200	150	200	200
H' - Henry's law constant (unitless)	Chemical-specific (ADEC, 1998)	0.754	0.754	0.754	0.754	0.754	0.754
k_d - Distribution Coefficient	calculated ($K_{oc}*f_{oc}$)	0.583	0.341	0.8008	0.583	0.341	0.8008
C_w - Target soil leachate conc.(mg/L)	calculated (Eq 11)	308.29	308.29	308.29	12.85	18.35	11.01

E. Calculated Soil Cleanup Value

Soil cleanup Level (mg/kg)= $C_w\{(K_{oc}*f_{oc}) + ((\theta_w + \theta_a*H')/\rho_b)\}$	**Equation 11 (ADEC, 1998) (mg/kg)**	**261.35**	**186.74**	**328.50**	**10.89**	**11.12**	**11.73**

For the "maximum" set of groundwater parameters, the site ACL of 11.5 mg/kg is protective of the groundwater ACL of 0.84 mg/L.

Migration to Groundwater Calculations
River Terrace Site
Lower Contaminant Plume
(Average GW Parameters)

A. Site-Specific Information

1. Default Values

θ_w - water-filled soil porosity	**0.284**	Default (ADEC, 1998)
θ_a - air-filled soil porosity (L/L)	**0.15**	Default (ADEC, 1998)
ρ_b - dry soil bulk density (kg/L)	**1.5**	Default (ADEC, 1998)

2. Measured Values

K (hydraulic conductivity (m/yr)	145	Average value for lower plume area
I (infiltration rate) (m/yr)	0.13	Default for under 40 inch zone
i (hydraulic gradient) =(m/m)	0.1	Average value for lower plume area
d_a (aquifer thickness) (meters)	1.7	Average site aquifer thickness
L (Source Length) (meters)	32	length of soil contamination lying directly over groundwater; unknown
f_{oc} (decimal fraction) Soil organic carbon	0.0022	estimate of Site Average (based on analyses)

C. Equation Calculations

Mixing Zone Depth (m): **3.650556** $d\ (m) = (0.0112*L^2)^{0.5} + d_a*\{1-\exp[(-L*I)/(K*i*d_a)]\}$

$(0.0112*L^2)^{0.5}$	3.386562
$(K*i*da)$	24.65
$(-L*I)$	-4.16
$(-L*I)/(K*i*da)$	-0.16876
$\exp[(-L*I)/(K*i*da)]$	0.844709
$1-\exp[(-L*I)/(K*i*da)]$	0.155291
$da*\{1-\exp[(-L*I)/(K*i*da)]$	0.263994
$(0.0112*L^2)^{0.5} + da*\{1-\exp[(-L*I)/(K*i*da)]\}$	**3.650556**

Dilution Factor: **13.72429** $DF = 1 + [(K*i*d)/(I*L)]$

$K*i*d=$	52.93306
$I*L=$	4.16
$(K*i*d)/(I*L)=$	12.72429
$DF=$	**13.72429**

D. Chemical Specific Information

Parameter	Data Source	PCE-average Koc	PCE-low Koc	PCE-high Koc	PCE-average Koc	PCE-low Koc	PCE-high Koc
Target GW conc. (mg/L)	ADEC GW Cleanup Standard (1998) or EPA Region III RBC (1997)	0.84	0.84	0.84	0.57	0.79	0.45
K_{oc} - soil organic carbon/water part. coeff (L/kg)	Chemical-specific (ADEC, 1998)	265	155	364	265	155	364
S - solubility (mg/L)	Chemical-specific (ADEC, 1998)	150	200	200	150	200	200
H' - Henry's law constant (unitless)	Chemical-specific (ADEC, 1998)	0.754	0.754	0.754	0.754	0.754	0.754
k_d - Distribution Coefficient	calculated ($K_{oc}*f_{oc}$)	0.583	0.341	0.8008	0.583	0.341	0.8008
C_w - Target soil leachate conc.(mg/L)	calculated (Eq. 11)	19.93	19.93	19.93	13.52	18.74	10.68

E. Calculated Soil Cleanup Value

Soil cleanup Level (mg/kg)= $C_w\{(K_{oc}*f_{oc}) + ((\theta_w + \theta_a*H')/\rho_b)\}$	**Equation 11 (ADEC, 1998) (mg/kg)**	**16.89**	**12.07**	**21.23**	**11.46**	**11.35**	**11.38**

For the "average" set of groundwater parameters, the site ACL of 11.5 mg/kg is protective of the groundwater ACL of 0.84 mg/L.

Migration to Groundwater Calculations
River Terrace Site
Lower Contaminant Plume
(Minimum GW Parameters)

A. Site-Specific Information

1. Default Values

θ_w - water-filled soil porosity	**0.284**	Default (ADEC, 1998)
θ_a - air-filled soil porosity (L/L)	**0.15**	Default (ADEC, 1998)
ρ_b - dry soil bulk density (kg/L)	**1.5**	Default (ADEC, 1998)

2. Measured Values

K (hydraulic conductivity (m/yr)	10	Low value for lower plume area
I (infiltration rate) (m/yr)	0.13	Default for under 40 inch zone
i (hydraulic gradient) =(m/m)	0.06	Low value for lower plume area
d_a (aquifer thickness) (meters)	1.7	Average site aquifer thickness
L (Source Length) (meters)	32	length of soil contamination lying directly over groundwater; unknown
f_{oc} (decimal fraction) Soil organic carbon	0.0022	estimate of Site Average (based on analyses)

C. Equation Calculations

Mixing Zone Depth (m) **5.057774** $d\ (m) = (0.0112*L^2)^{0.5} + d_a*\{1-\exp[(-L*I)/(K*i*d_a)]\}$

$(0.0112*L^2)^{0.5}$	3.386562
$(K*i*da)$	1.02
$(-L*I)$	-4.16
$(-L*I)/(K*i*da)$	-4.07843
$\exp[(-L*I)/(K*i*da)]$	0.016934
$1-\exp[(-L*I)/(K*i*da)]$	0.983066
$da*\{1-\exp[(-L*I)/(K*i*da)]$	1.671212
$(0.0112*L^2)^{0.5} + da*\{1-\exp[(-L*I)/(K*i*da)]\}$	**5.057774**

Dilution Factor **1.729487** $DF = 1 + [(K*i*d)/(I*L)]$

$K*i*d=$	3.034664
$I*L=$	4.16
$(K*i*d)/(I*L)=$	0.729487
$DF=$	**1.729487**

D. Chemical Specific Information

Parameter	Data Source	PCE-average Koc	PCE-low Koc	PCE-high Koc	PCE-average Koc	PCE-low Koc	PCE-high Koc
Target GW conc. (mg/L)	ADEC GW Cleanup Standard (1998) or EPA Region III RBC (1997)	0.84	0.84	0.84	1.13	1.58	0.9
K_{oc} - soil organic carbon/water part. coeff (L/kg)	Chemical-specific (ADEC, 1998)	265	155	364	265	155	364
S - solubility (mg/L)	Chemical-specific (ADEC, 1998)	150	200	200	150	200	200
H' - Henry's law constant (unitless)	Chemical-specific (ADEC, 1998)	0.754	0.754	0.754	0.754	0.754	0.754
k_d - Distribution Coefficient	calculated ($K_{oc}*f_{oc}$)	0.583	0.341	0.8008	0.583	0.341	0.8008
C_w - Target soil leachate conc.(mg/L)	calculated (Eq. 11)	9.85	9.85	9.85	13.25	18.53	10.56

E. Calculated Soil Cleanup Value

Soil cleanup Level (mg/kg)= $C_w\{(K_{oc}*f_{oc}) + ((\theta_w + \theta_a*H')/\rho_b)\}$	**Equation 11 (ADEC, 1998) (mg/kg)**	8.35	5.97	10.50	11.24	11.23	11.25

For the "minimum" set of groundwater parameters, the site ACL of 11.5 mg/kg is NOT protective of the groundwater ACL of 0.84 mg/L.
Assuming a Koc value of 265 L/kg, the soil ACL would have to be 8.35 mg/kg to be protective
Assuming a Koc value of 155 L/kg, the soil ACL would have to be 6 mg/kg to be protective
Assuming a Koc value of 265 L/kg, the soil ACL would have to be 10.5 mg/kg to be protective

Migration to Groundwater Calculations
River Terrace Site
Upper Contaminant Plume
(Maximum GW Parameters)

A. Site-Specific Information

1. Default Values

θ_w - water-filled soil porosity	**0.284**	Default (ADEC, 1998)
θ_a - air-filled soil porosity (L/L)	**0.15**	Default (ADEC, 1998)
ρ_b - dry soil bulk density (kg/L)	**1.5**	Default (ADEC, 1998)

2. Measured Values

K (hydraulic conductivity (m/yr)	50500	High value for upper plume area
I (infiltration rate) (m/yr)	0.13	Default for under 40 inch zone
i (hydraulic gradient) =(m/m)	0.02	High value for upper plume area
d_a (aquifer thickness) (meters)	1.7	Average site aquifer thickness
L (Source Length) (meters)	32	length of soil contamination lying directly over groundwater; unknown
f_{oc} (decimal fraction) Soil organic carbon	0.0022	estimate of Site Average (based on analyses)

C. Equation Calculations

Mixing Zone Depth (m) **3.390676** $d\ (m) = (0.0112*L^2)^{0.5} + d_a*\{1-\exp[(-L*I)/(K*i*d_a)]\}$

$(0.0112*L^2)^{0.5}$	3.386562
(K*i*da)	1717
(-L*I)	-4.16
(-L*I)/(K*i*da)	-0.00242
exp[(-L*I)/(K*i*da)]	0.99758
1-exp[(-L*I)/(K*i*da)]	0.00242
da*{1-exp[(-L*I)/(K*i*da)]	0.004114
$(0.0112*L^2)^{0.5}$ + da*{1-exp[(-L*I)/(K*i*da)]}	**3.390676**

Dilution Factor: **824.2169** $DF = 1 + [(K*i*d)/(I*L)]$

K*i*d=	3424.582
I*L=	4.16
(K*i*d)/(I*L)=	823.2169
DF=	**824.2169**

D. Chemical Specific Information

Parameter	Data Source	PCE-average Koc	PCE-low Koc	PCE-high Koc	PCE-average Koc	PCE-low Koc	PCE-high Koc
Target GW conc. (mg/L)	ADEC GW Cleanup Standard (1998) or EPA Region III RBC (1997)	0.84	0.84	0.84	0.016	0.022	0.012
K_{oc} - soil organic carbon/water part. coeff (L/kg)	Chemical-specific (ADEC, 1998)	265	155	364	265	155	364
S - solubility (mg/L)	Chemical-specific (ADEC, 1998)	150	200	200	150	200	200
H' - Henry's law constant (unitless)	Chemical-specific (ADEC, 1998)	0.754	0.754	0.754	0.754	0.754	0.754
k_d - Distribution Coefficient	calculated ($K_{oc}*f_{oc}$)	0.583	0.341	0.8008	0.583	0.341	0.8008
C_w - Target soil leachate conc.(mg/L)	calculated (Eq. 11)	700.74	700.74	700.74	13.35	18.35	10.01

E. Calculated Soil Cleanup Value

Soil cleanup Level (mg/kg)= $C_w\{(K_{oc}*f_{oc}) + ((\theta_w + \theta_a*H')/\rho_b)\}$	**Equation 11 (ADEC, 1998) (mg/kg)**	**594.04**	**424.46**	**746.66**	**11.32**	**11.12**	**10.67**

For the "maximum" set of groundwater parameters, the site ACL of 11.5 mg/kg is protective of the groundwater ACL of 0.84 mg/L.

Migration to Groundwater Calculations
River Terrace Site
Upper Contaminant Plume
(Average GW Parameters)

A. Site-Specific Information

1. Default Values

θ_w - water-filled soil porosity	**0.284**	Default (ADEC, 1998)
θ_a - air-filled soil porosity (L/L)	**0.15**	Default (ADEC, 1998)
ρ_b - dry soil bulk density (kg/L)	**1.5**	Default (ADEC, 1998)

2. Measured Values

K (hydraulic conductivity (m/yr)	9768	Low value for upper plume area
I (infiltration rate) (m/yr)	0.13	Default for under 40 inch zone
i (hydraulic gradient) =(m/m)	0.01	Low value for upper plume area
d_a (aquifer thickness) (meters)	1.7	Average site aquifer thickness
L (Source Length) (meters)	32	length of soil contamination lying directly over groundwater; unknown
f_{oc} (decimal fraction) Soil organic carbon	0.0022	estimate of Site Average (based on analyses)

C. Equation Calculations

Mixing Zone Depth (m): **3.428621** $d\ (m) = (0.0112*L^2)^{0.5} + d_a*\{1-\exp[(-L*I)/(K*i*d_a)]\}$

$(0.0112*L^2)^{0.5}$	3.386562
(K*i*da)	166.056
(-L*I)	-4.16
(-L*I)/(K*i*da)	-0.02505
exp[(-L*I)/(K*i*da)]	0.975259
1-exp[(-L*I)/(K*i*da)]	0.024741
da*{1-exp[(-L*I)/(K*i*da)]	0.042059
$(0.0112*L^2)^{0.5}$ + da*{1-exp[(-L*I)/(K*i*da)]}	**3.428621**

Dilution Factor: **81.50665** $DF = 1 + [(K*i*d)/(I*L)]$

K*i*d=	334.9077
I*L=	4.16
(K*i*d)/(I*L)=	80.50665
DF=	**81.50665**

D. Chemical Specific Information

D. Chemical Specific Information

Parameter	Data Source	PCE-average Koc	PCE-low Koc	PCE-high Koc	PCE-average Koc	PCE-low Koc	PCE-high Koc
Target GW conc. (mg/L)	ADEC GW Cleanup Standard (1998) or EPA Region III RBC (1997)	0.84	0.84	0.84	0.145	0.2	0.11
K_{oc} - soil organic carbon/water part. coeff (L/kg)	Chemical-specific (ADEC, 1998)	265	155	364	265	155	364
S - solubility (mg/L)	Chemical-specific (ADEC, 1998)	150	200	200	150	200	200
H' - Henry's law constant (unitless)	Chemical-specific (ADEC, 1998)	0.754	0.754	0.754	0.754	0.754	0.754
k_d - Distribution Coefficient	calculated ($K_{oc}*f_{oc}$)	0.583	0.341	0.8008	0.583	0.341	0.8008
C_w - Target soil leachate conc.(mg/L)	calculated (Eq. 11)	76.87	76.87	76.87	13.27	18.30	10.07

E. Calculated Soil Cleanup Value

Soil cleanup Level (mg/kg)= $C_w\{(K_{oc}*f_{oc}) + ((\theta_w + \theta_a*H')/\rho_b)\}$	**Equation 11 (ADEC, 1998) (mg/kg)**	**65.16**	**46.56**	**81.90**	**11.25**	**11.09**	**10.73**

For the "average" set of groundwater parameters, the site ACL of 11.5 mg/kg is protective of the groundwater ACL of 0.84 mg/L.

Migration to Groundwater Calculations
River Terrace Site
Upper Contaminant Plume
(Minimum GW Parameters)

A. Site-Specific Information

1. Default Values

θ_w - water-filled soil porosity	**0.284**	Default (ADEC, 1998)
θ_a - air-filled soil porosity (L/L)	**0.15**	Default (ADEC, 1998)
ρ_b - dry soil bulk density (kg/L)	**1.5**	Default (ADEC, 1998)

2. Measured Values

K (hydraulic conductivity (m/yr)	2000	Low value for upper plume area
I (infiltration rate) (m/yr)	0.13	Default for under 40 inch zone
i (hydraulic gradient) =(m/m)	0.01	Low value for upper plume area
d_a (aquifer thickness) (meters)	1.7	Average site aquifer thickness
L (Source Length) (meters)	32	length of soil contamination lying directly over groundwater; unknown
f_{oc} (decimal fraction) Soil organic carbon	0.0022	estimate of Site Average (based on analyses)

C. Equation Calculations

Mixing Zone Depth (m) **3.58234** $d\ (m) = (0.0112*L^2)^{0.5} + d_a*\{1-\exp[(-L*I)/(K*i*d_a)]\}$

Dilution Factor **18.22279** $DF = 1 + [(K*i*d)/(I*L)]$

$(0.0112*L^2)^{0.5}$	3.386562
(K*i*da)	34
(-L*I)	-4.16
(-L*I)/(K*i*da)	-0.122353
exp[(-L*I)/(K*i*da)]	0.884836
1-exp[(-L*I)/(K*i*da)]	0.115164
da*{1-exp[(-L*I)/(K*i*da)]	0.195779
$(0.0112*L^2)^{0.5}$ + da*{1-exp[(-L*I)/(K*i*da)]}	**3.58234**
K*i*d=	71.64681
I*L=	4.16
(K*i*d)/(I*L)=	17.22279
DF=	**18.22279**

D. Chemical Specific Information

D. Chemical Specific Information

Parameter	Data Source	PCE-average Koc	PCE-low Koc	PCE-high Koc	PCE-average Koc	PCE-low Koc	PCE-high Koc
Target GW conc. (mg/L)	ADEC GW Cleanup Standard (1998) or EPA Region III RBC (1997)	0.84	0.84	0.84	0.48	0.67	0.38
K_{oc} - soil organic carbon/water part. coeff (L/kg)	Chemical-specific (ADEC, 1998)	265	155	364	265	155	364
S - solubility (mg/L)	Chemical-specific (ADEC, 1998)	150	200	200	150	200	200
H' - Henry's law constant (unitless)	Chemical-specific (ADEC, 1998)	0.754	0.754	0.754	0.754	0.754	0.754
k_d - Distribution Coefficient	calculated ($K_{oc}*f_{oc}$)	0.583	0.341	0.8008	0.583	0.341	0.8008
C_w - Target soil leachate conc (mg/L)	calculated (Eq. 11)	23.71	23.71	23.71	13.55	18.91	10.72

E. Calculated Soil Cleanup Value

Soil cleanup Level (mg/kg)= $C_w\{(K_{oc}*f_{oc}) + ((\theta_w + \theta_a*H')/\rho_b)\}$	**Equation 11 (ADEC, 1998) (mg/kg)**	**20.10**	**14.36**	**25.26**	**11.48**	**11.45**	**11.43**

For the "minimum" set of groundwater parameters, the site ACL of 11.5 mg/kg is protective of the groundwater ACL of 0.84 mg/L.