APPENDIX L

MULTIMED MODEL SIMULATIONS (EQUIVALENCY DEMONSTRATION)

SCS ENGINEERS

February 7, 2010
File No. 01210155.00

MEMORANDUM

TO: Joe Miller
Ambrose McCready

FROM: Chris Heiny

SUBJECT: MULTIMED Model Summary (Base Liner Equivalency Demonstration): Sonoma County Central Disposal Site

The proposed and prescripted landfill liners for the expansion of Landfill-2 (LF-2) and the Rock Extraction Area (REA) were evaluated using the MULTIMED Model to estimate the contaminant concentration at a receptor (point of compliance). Below is a discussion of the model applications, input parameters, and results.

MULTIMED MODEL

MULTIMED (Multimedia Exposure Assessment Model) was created by the United States Environmental Protection Agency (USEPA) for exposure assessment by simulating the movement of contaminants leaching from a waste disposal site. MULTIMED utilizes analytical, semi-analytical, and numerical solution techniques to solve the mathematical equations describing flow and transport. MULTIMED is composed of four data groups: the general data group, the chemical data group, the source data group, and the aquifer data group. The aquifer data group is comprised of the unsaturated and saturated zone modules. With the exception of infiltration rate, all data used in each data group was either researched from previous site studies/documentation or, when specific data were not available at the site, were researched. The researched values used were industry-accepted values. The infiltration rate values were obtained from the HELP model. MULTIMED uses data from each group to estimate the contaminant concentration at the point of compliance, which is a point down-gradient of the theoretical release. A dilution-attenuation factor (DAF) is calculated by dividing the initial contaminant concentration from that estimated at the point of compliance. A DAF greater than 100 demonstrates that the liner system is acceptable.

MULTIMED was built in FORTRAN and designed to work in DOS. Using programs in DOS can be quite difficult as the user must be familiar with the DOS language. Allison Geoscience Consultants developed MULTIMED for Windows that uses the MULTIMED code, but in a user-friendly, Windows-based format. SCS performed the liner assessment using MULTIMED for Windows, version 1.50.

Prepared by: CH
Checked by: JJM/AAM

INPUT PARAMETERS

Many of the input parameters used in MULTIMED were obtained from site-specific data (i.e. field investigations, aquifer test, and/or historical data). Where site-specific data were not available (i.e. the parameter has not been evaluated/calculated during a field investigation), the parameters were obtained from researched values or from the Subtitle D Application Manual for MULTIMED. The researched parameters and those obtained from the Subtitle D Application Manual for MULTIMED (EPA, 1990) are considered to be industry-accepted values and are good approximations for use in place of site-specific data. The Data Source Group and Aquifer Data Source Group parameters are discussed below.

Data Source Group

The Data Source Group Parameters are summarized in the following table:

Data Source Group Parameters
Landfill-2 and Rock Extraction Area

Parameter	LF-2 Value	REA Value	Source/Remarks
Lined Area of Waste Disposal Unit	24,003 m^2 (~6 acres)	11,838 m^2 (~3 acres)	Site specific, total base liner area for each unit.
Recharge Rate	0 m/yr	0 m/yr	Worst case scenario. Prevents dilution of contaminants from surface water infiltration.
Initial Contaminant Concentration at Landfill	1.0 mg/l	1.0 mg/l	Section 6.2.6 of Subtitle D Application Manual for MULTIMED states that for Subtitle D facilities the initial concentration should be set at 1.0 mg/l

Any contaminant release that may occur from the lined waste units would most likely occur in the bottom 2.5% graded area of the lined unit and not the excavation cut slope area. The respective floor areas of the bottom of the lined units were calculated using AutoCAD software for LF-2 and the REA and are presented above. These areas were used for model inputs.

The recharge rate was estimated by RMC Geosciences (2008) to be 1.855 in/year. Recharge is defined as direct precipitation into soils of unfilled areas outside the waste management unit (less evaporation). Recharge will effectively dilute any contaminant released from the liner system. Therefore, to evaluate the worst-case scenario, the recharge was set to zero for each unit to eliminate the dilution-effect caused by recharge in the model.

Although the initial concentration of the leachate (contaminant) is not known, the Subtitle D Application for MULTIMED (EPA, 1990) states that an initial concentration of 1.0 mg/L should

be used to evaluate the fate of the contaminant down-gradient of the landfill. Therefore, this value was used in the MULTIMED simulation.

Aquifer Data Source Group

The Aquifer Data Source Group Parameters are composed of the unsaturated and saturated zones, and are presented below:

Aquifer Data Source Group Parameters
Landfill-2 and Rock Extraction Area

Parameter	LF-2 Value	REA Value	Source/Remarks
Porosity	0.20	0.20	Site specific, Pacific Geoscience DAR, 2005.
Bulk Density	1.76 g/cc	1.76 g/cc	Value for fine-grained sandstone from Table 6-11, Subtitle D Application Manual for MULTIMED
Aquifer Thickness	4.6 m	4.6 m	Site specific, approximated from boring logs.
Vadose Zone Thickness	0.0348 m	3.3 m	Worst case scenario, assumes groundwater level at maximum regulatory level.
Aquifer Hydraulic Conductivity	0.96 m/yr	96.12 m/yr	Site specific, aquifer slug tests (Pacific Geoscience, DAR, 2005)
Vadose Hydraulic Conductivity	0.011 cm/hr	1.09 cm/hr	Site specific, Pacific Geoscience DAR, 2005.
Hydraulic Gradient	0.01	0.01	Site specific, Pacific Geoscience Quarterly Reports.
Longitudinal Dispersivity, α_L	7.50 m	1.5 m	0.1*X_r, Table 6-12, Subtitle D Application Manual for MULTIMED
Transverse Dispersivity, α_T	2.50 m	0.5 m	0.333α_L, Table 6-12, Subtitle D Application Manual for MULTIMED
Vertical Dispersivity, α_V	0.42 m	0.084 m	0.056α_L, Table 6-12, Subtitle D Application Manual for MULTIMED
Aquifer Temperature	16.7° C	16.7° C	Site specific, Pacific Geoscience DAR, 2005.
pH	7.6	7.6	Site specific, Pacific Geoscience Monitoring Data
Fractional Organic Carbon Content, f_{oc}	0.003	0.003	Subtitle D Application Manual for MULTIMED: Table 6-7
Well Distance from Site (Receptor), X_r	74.89 m	96.86 m	Site specific, waste limit to F-17 Site specific, waste limit to F-2N

Site specific data were obtained from aquifer tests, quarterly monitoring data, and boring logs. Data from these sources were used determine the aquifer thickness, aquifer and vadose zone hydraulic conductivity, hydraulic gradient, aquifer temperature, and pH. For many of these parameters, multiple measurements exist, and the values used in MULTIMED were averages for each parameter that were believed to be representative of the LF-2 and REA.

Where site specific data were not available, parameter values were researched using either published reports or the Subtitle D Application Manual for MULTIMED (EPA, 1990). Site data (boring logs) indicate that the aquifer and vadose zone at the areas of interest lie within the Franciscan Group. The Franciscan Group is characterized as massively-bedded sandstones to siltstones that contain open fractures. The boring logs suggest that most of the groundwater occurrence lies within the open fractures. Based upon the cited lithology, values for porosity, bulk density, and fractional organic carbon content were obtained from the researched literature. These values are believed to be a good approximation of the actual values that exist for the site.

For each MULTIMED simulation, a receptor was chosen down-gradient of the landfill. For LF-2 and the REA, existing monitoring wells were chosen as receptors. The MULTIMED simulation would calculate the anticipated concentration of the contaminant in each monitoring well if a release occurred up-gradient of the receptor. For LF-2, existing groundwater monitoring well F-17 was chosen as the receptor (point of compliance well) as it lies directly down-gradient of the planned waste unit. For the REA, existing groundwater monitoring well F-2N was chosen as the receptor (point of compliance well) as it lies directly down-gradient of the planned waste unit. Distances from the receptor to the waste unit (X_r) were measured from the *Landfill No. 1 and 2 Expansion* drawings (SCS, 2011). From this distance X_r, the longitudinal, transverse, and vertical dispersivity parameters were calculated based on the equations in the Subtitle D Application Manual for MULTIMED (EPA, 1990).

RESULTS

MULTIMED simulations were performed for the following scenarios:

- LF-2 Proposed Engineered Alternative Liner System
- LF-2 Prescribed Liner System (CCR Title 27, Subtitle D)
- REA Proposed Engineered Alternative Liner System
- REA Prescribed Liner System

For each scenario, the estimated infiltration rate from the 2.5% base into the subsurface was imported from the HELP Model. The results for each scenario are presented below:

MULTIMED Model Simulation Results
Landfill-2 and the Rock Extraction Area

Bottom Liner System at 2 Percent Slope		Estimated Infiltration Rate from 2.5% Base into the Subsurface m/yr (in/yr)	Estimated Concentration at Point of Compliance mg/L	Dilution Attenuation Factor (DAF)
LF-2	Proposed Liner	$2.54x10^{-7}$ ($1.0x10^{-5}$)	$1.722x10^{-4}$	5,807
	Prescriptive Liner	$2.54x10^{-6}$ ($1.0x10^{-4}$)	$1.722x10^{-3}$	580
REA	Proposed Liner	$2.54x10^{-7}$ ($1.0x10^{-5}$)	$9.033x10^{-7}$	$1.107x10^{6}$
	Prescriptive Liner	$2.54x10^{-6}$ ($1.0x10^{-4}$)	$9.033x10^{-6}$	$1.107x10^{5}$

DAF=initial concentration/estimated concentration at Point of Compliance

Point of compliance: LF-2 - F-17; REA - F-2N

The infiltration rate estimated from the HELP model was an order of magnitude higher for the prescriptive liner versus the proposed liner for each area. The MULTIMED Model estimated concentrations at the point of compliance wells an order of magnitude higher for the prescriptive liner versus the proposed liner for each area. In all simulations, the DAF was greater than 100, which indicates the liner system is acceptable. The DAF for the prescriptive liners was an order of magnitude lower than the proposed liner.

LANDFILL – 2 PROPOSED LINER

MULTIMED MODEL

MULTIMED V1.01 DATE OF CALCULATIONS: 7-FEB-2011 TIME: 12:43:19

U. S. E N V I R O N M E N T A L P R O T E C T I O N A G E N C Y

E X P O S U R E A S S E S S M E N T

M U L T I M E D I A M O D E L

MULTIMED (Version 1.50, 2005)

Run options
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Sonoma County Central Disposal Site

LF-2 Proposed Liner
Chemical simulated is Chemical Name

Option Chosen Saturated and unsaturated zone models
Run was DETERMIN
Infiltration Specified By User: 2.540E-07 m/yr
Run was steady-state
Reject runs if Y coordinate outside plume
Reject runs if Z coordinate outside plume
Gaussian source used in saturated zone model

UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

NP	- Total number of nodal points	240
NMAT	- Number of different porous materials	1
KPROP	- Van Genuchten or Brooks and Corey	1
IMSHGN	- Spatial discretization option	1
NVFLAYR	- Number of layers in flow model	1

OPTIONS CHOSEN
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Van Genuchten functional coefficients
User defined coordinate system

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	0.04	1

DATA FOR MATERIAL 1

VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Saturated hydraulic conductivity	cm/hr	CONSTANT	0.110E-01	-999.	-999.	-999.
Unsaturated zone porosity	--	CONSTANT	0.200	-999.	-999.	-999.
Air entry pressure head	m	CONSTANT	0.000	-999.	-999.	-999.
Depth of the unsaturated zone	m	CONSTANT	0.350E-01	0.000	0.000	0.000

DATA FOR MATERIAL 1

VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Residual water content	--	CONSTANT	0.450E-01	-999.	-999.	-999.
Brook and Corey exponent,EN	--	CONSTANT	-999.	-999.	-999.	-999.
ALFA coefficient	1/cm	CONSTANT	0.145	-999.	-999.	-999.
Van Genuchten exponent, ENN	--	CONSTANT	2.68	-999.	-999.	-999.

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		1
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN

Stehfest numerical inversion algorithm
Nondecaying continuous source
Computer generated times for computing concentrations

DATA FOR LAYER 1

VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Thickness of layer	m	CONSTANT	0.350E-01	-999.	-999.	-999.
Longitudinal dispersivity of layer	m	DERIVED	-999.	-999.	-999.	-999.
Percent organic matter	--	CONSTANT	0.600	-999.	-999.	-999.
Bulk density of soil for layer	g/cc	CONSTANT	0.600	-999.	-999.	-999.
Biological decay coefficient	1/yr	CONSTANT	0.000	-999.	-999.	-999.

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Solid phase decay coefficient	1/yr	DERIVED	-999.	-999.	-999.	-999.
Dissolved phase decay coefficient	1/yr	DERIVED	-999.	-999.	-999.	-999.
Overall chemical decay coefficient	1/yr	DERIVED	-999.	-999.	-999.	-999.
Acid catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000	-999.	-999.	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000	-999.	-999.	-999.
Base catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000	-999.	-999.	-999.
Reference temperature	C	CONSTANT	25.0	-999.	-999.	-999.
Normalized distribution coefficient	ml/g	CONSTANT	0.000	-999.	-999.	-999.
Distribution coefficient	--	DERIVED	-999.	-999.	-999.	-999.
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000	-999.	-999.	-999.
Air diffusion coefficient	cm2/s	CONSTANT	-999.	-999.	-999.	-999.
Reference temperature for air diffusion	C	CONSTANT	-999.	-999.	-999.	-999.
Molecular weight	g/M	CONSTANT	-999.	-999.	-999.	-999.
Mole fraction of solute	--	CONSTANT	-999.	-999.	-999.	-999.
Vapor pressure of solute	mm Hg	CONSTANT	-999.	-999.	-999.	-999.
Henry`s law constant	atm-m^3/M	CONSTANT	-999.	-999.	-999.	-999.
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000	0.000	0.000	1.00
Not currently used		CONSTANT	0.000	0.000	0.000	0.000
Not currently used		CONSTANT	0.000	0.000	0.000	0.000

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Infiltration rate	m/yr	CONSTANT	0.254E-06	-999.	-999.	-999.
Area of waste disposal unit	m^2	CONSTANT	0.240E+05	-999.	-999.	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	-999.	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	-999.	-999.
Recharge rate	m/yr	CONSTANT	0.000	-999.	-999.	-999.
Source decay constant	1/yr	CONSTANT	0.000	0.000	0.000	0.000
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	-999.	-999.
Length scale of facility	m	DERIVED	-999.	-999.	-999.	-999.
Width scale of facility	m	DERIVED	-999.	-999.	-999.	-999.
Near field dilution		DERIVED	1.00	0.000	0.000	1.00

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Particle diameter	cm	CONSTANT	-999.	-999.	-999.	-999.
Aquifer porosity	--	CONSTANT	0.200	-999.	-999.	-999.
Bulk density	g/cc	CONSTANT	1.76	-999.	-999.	-999.
Aquifer thickness	m	CONSTANT	4.60	-999.	-999.	-999.
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	-999.	-999.
Conductivity (hydraulic)	m/yr	CONSTANT	0.960	-999.	-999.	-999.
Gradient (hydraulic)		CONSTANT	0.100	-999.	-999.	-999.
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	-999.	-999.
Retardation coefficient	--	DERIVED	-999.	-999.	-999.	-999.
Longitudinal dispersivity	m	CONSTANT	7.49	-999.	-999.	-999.
Transverse dispersivity	m	CONSTANT	2.50	-999.	-999.	-999.
Vertical dispersivity	m	CONSTANT	0.419	-999.	-999.	-999.
Temperature of aquifer	C	CONSTANT	16.5	-999.	-999.	-999.
pH	--	CONSTANT	7.40	-999.	-999.	-999.
Organic carbon content (fraction)		CONSTANT	0.300E-02	-999.	-999.	-999.
Well distance from site	m	CONSTANT	74.9	-999.	-999.	-999.
Angle off center	degree	CONSTANT	0.000	0.000	0.000	0.000
Well vertical distance	m	CONSTANT	0.000	0.000	0.000	0.000

CONCENTRATION AFTER SATURATED ZONE MODEL 0.1722E-03

$$\boldsymbol{DILUTION\ ATTENUATION\ FACTOR\ (DAF) = \frac{Initial\ Concentration}{Concentration\ at\ Point\ of\ Compliance}}$$

$$\boldsymbol{DAF = \frac{1.0\ mg/L}{1.722e^{-04}\ mg/L} = 5{,}807}$$

LANDFILL – 2 PRESCRIBED LINER

MULTIMED MODEL

MULTIMED V1.01 DATE OF CALCULATIONS: 7-FEB-2011 TIME: 13:41:12

U. S. E N V I R O N M E N T A L P R O T E C T I O N A G E N C Y

E X P O S U R E A S S E S S M E N T

M U L T I M E D I A M O D E L

MULTIMED (Version 1.50, 2005)

Run options
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Sonoma County Central Disposal Site

LF-2 Prescribed Liner
Chemical simulated is Chemical Name

Option Chosen Saturated and unsaturated zone models
Run was DETERMIN
Infiltration Specified By User: 2.540E-06 m/yr
Run was steady-state
Reject runs if Y coordinate outside plume
Reject runs if Z coordinate outside plume
Gaussian source used in saturated zone model

UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

NP	- Total number of nodal points	240
NMAT	- Number of different porous materials	1
KPROP	- Van Genuchten or Brooks and Corey	1
IMSHGN	- Spatial discretization option	1
NVFLAYR	- Number of layers in flow model	1

OPTIONS CHOSEN
------- ------
Van Genuchten functional coefficients
User defined coordinate system

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	0.04	1

DATA FOR MATERIAL 1

VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Saturated hydraulic conductivity	cm/hr	CONSTANT	0.110E-01	-999.	-999.	-999.
Unsaturated zone porosity	--	CONSTANT	0.200	-999.	-999.	-999.
Air entry pressure head	m	CONSTANT	0.000	-999.	-999.	-999.
Depth of the unsaturated zone	m	CONSTANT	0.350E-01	0.000	0.000	0.000

DATA FOR MATERIAL 1

VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Residual water content	--	CONSTANT	0.450E-01	-999.	-999.	-999.
Brook and Corey exponent,EN	--	CONSTANT	-999.	-999.	-999.	-999.
ALFA coefficient	1/cm	CONSTANT	0.145	-999.	-999.	-999.
Van Genuchten exponent, ENN	--	CONSTANT	2.68	-999.	-999.	-999.

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

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NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		1
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN

Stehfest numerical inversion algorithm
Nondecaying continuous source
Computer generated times for computing concentrations

DATA FOR LAYER 1

VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Thickness of layer	m	CONSTANT	0.350E-01	-999.	-999.	-999.
Longitudinal dispersivity of layer	m	DERIVED	-999.	-999.	-999.	-999.
Percent organic matter	--	CONSTANT	0.600	-999.	-999.	-999.
Bulk density of soil for layer	g/cc	CONSTANT	0.600	-999.	-999.	-999.
Biological decay coefficient	1/yr	CONSTANT	0.000	-999.	-999.	-999.

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Solid phase decay coefficient	1/yr	DERIVED	-999.	-999.	-999.	-999.
Dissolved phase decay coefficient	1/yr	DERIVED	-999.	-999.	-999.	-999.
Overall chemical decay coefficient	1/yr	DERIVED	-999.	-999.	-999.	-999.
Acid catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000	-999.	-999.	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000	-999.	-999.	-999.
Base catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000	-999.	-999.	-999.
Reference temperature	C	CONSTANT	25.0	-999.	-999.	-999.
Normalized distribution coefficient	ml/g	CONSTANT	0.000	-999.	-999.	-999.
Distribution coefficient	--	DERIVED	-999.	-999.	-999.	-999.
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000	-999.	-999.	-999.
Air diffusion coefficient	cm2/s	CONSTANT	-999.	-999.	-999.	-999.
Reference temperature for air diffusion	C	CONSTANT	-999.	-999.	-999.	-999.
Molecular weight	g/M	CONSTANT	-999.	-999.	-999.	-999.
Mole fraction of solute	--	CONSTANT	-999.	-999.	-999.	-999.
Vapor pressure of solute	mm Hg	CONSTANT	-999.	-999.	-999.	-999.
Henry`s law constant	atm-m^3/M	CONSTANT	-999.	-999.	-999.	-999.
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000	0.000	0.000	1.00
Not currently used		CONSTANT	0.000	0.000	0.000	0.000
Not currently used		CONSTANT	0.000	0.000	0.000	0.000

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Infiltration rate	m/yr	CONSTANT	0.254E-05	-999.	-999.	-999.
Area of waste disposal unit	m^2	CONSTANT	0.240E+05	-999.	-999.	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	-999.	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	-999.	-999.
Recharge rate	m/yr	CONSTANT	0.000	-999.	-999.	-999.
Source decay constant	1/yr	CONSTANT	0.000	0.000	0.000	0.000
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	-999.	-999.
Length scale of facility	m	DERIVED	-999.	-999.	-999.	-999.
Width scale of facility	m	DERIVED	-999.	-999.	-999.	-999.
Near field dilution		DERIVED	1.00	0.000	0.000	1.00

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Particle diameter	cm	CONSTANT	-999.	-999.	-999.	-999.
Aquifer porosity	--	CONSTANT	0.200	-999.	-999.	-999.
Bulk density	g/cc	CONSTANT	1.76	-999.	-999.	-999.
Aquifer thickness	m	CONSTANT	4.60	-999.	-999.	-999.
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	-999.	-999.
Conductivity (hydraulic)	m/yr	CONSTANT	0.960	-999.	-999.	-999.
Gradient (hydraulic)		CONSTANT	0.100	-999.	-999.	-999.
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	-999.	-999.
Retardation coefficient	--	DERIVED	-999.	-999.	-999.	-999.
Longitudinal dispersivity	m	CONSTANT	7.49	-999.	-999.	-999.
Transverse dispersivity	m	CONSTANT	2.50	-999.	-999.	-999.
Vertical dispersivity	m	CONSTANT	0.419	-999.	-999.	-999.
Temperature of aquifer	C	CONSTANT	16.5	-999.	-999.	-999.
pH	--	CONSTANT	7.40	-999.	-999.	-999.
Organic carbon content (fraction)		CONSTANT	0.300E-02	-999.	-999.	-999.
Well distance from site	m	CONSTANT	74.9	-999.	-999.	-999.
Angle off center	degree	CONSTANT	0.000	0.000	0.000	0.000
Well vertical distance	m	CONSTANT	0.000	0.000	0.000	0.000

CONCENTRATION AFTER SATURATED ZONE MODEL 0.1722E-02

$$\textit{DILUTION ATTENUATION FACTOR}\ (\textit{DAF}) = \frac{\textit{Initial Concentration}}{\textit{Concentration at Point of Compliance}}$$

$$\textit{DAF} = \frac{1.0\ mg/L}{1.7226e^{-03}\ mg/L} = 580$$

ROCK EXTRACTION AREA PROPOSED LINER

MULTIMED MODEL

MULTIMED V1.01 DATE OF CALCULATIONS: 7-FEB-2011 TIME: 12:46:41

U. S. E N V I R O N M E N T A L P R O T E C T I O N A G E N C Y

E X P O S U R E A S S E S S M E N T

M U L T I M E D I A M O D E L

MULTIMED (Version 1.50, 2005)

Run options
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Sonoma County Central Disposal Site

REA Proposed Liner
Chemical simulated is Chemical Name

Option Chosen Saturated and unsaturated zone models
Run was DETERMIN
Infiltration Specified By User: 2.540E-07 m/yr
Run was steady-state
Reject runs if Y coordinate outside plume
Reject runs if Z coordinate outside plume
Gaussian source used in saturated zone model

UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

NP	- Total number of nodal points	240
NMAT	- Number of different porous materials	1
KPROP	- Van Genuchten or Brooks and Corey	1
IMSHGN	- Spatial discretization option	1
NVFLAYR	- Number of layers in flow model	1

OPTIONS CHOSEN
------- ------
Van Genuchten functional coefficients
User defined coordinate system

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	3.30	1

DATA FOR MATERIAL 1

VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Saturated hydraulic conductivity	cm/hr	CONSTANT	1.09	-999.	-999.	-999.
Unsaturated zone porosity	--	CONSTANT	0.200	-999.	-999.	-999.
Air entry pressure head	m	CONSTANT	0.000	-999.	-999.	-999.
Depth of the unsaturated zone	m	CONSTANT	3.30	0.000	0.000	0.000

DATA FOR MATERIAL 1

VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Residual water content	--	CONSTANT	0.450E-01	-999.	-999.	-999.
Brook and Corey exponent,EN	--	CONSTANT	-999.	-999.	-999.	-999.
ALFA coefficient	1/cm	CONSTANT	0.145	-999.	-999.	-999.
Van Genuchten exponent, ENN	--	CONSTANT	2.68	-999.	-999.	-999.

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		1
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN

Stehfest numerical inversion algorithm
Nondecaying continuous source
Computer generated times for computing concentrations

DATA FOR LAYER 1

VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Thickness of layer	m	CONSTANT	3.30	-999.	-999.	-999.
Longitudinal dispersivity of layer	m	DERIVED	-999.	-999.	-999.	-999.
Percent organic matter	--	CONSTANT	0.600	-999.	-999.	-999.
Bulk density of soil for layer	g/cc	CONSTANT	0.600	-999.	-999.	-999.
Biological decay coefficient	1/yr	CONSTANT	0.000	-999.	-999.	-999.

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Solid phase decay coefficient	1/yr	DERIVED	-999.	-999.	-999.	-999.
Dissolved phase decay coefficient	1/yr	DERIVED	-999.	-999.	-999.	-999.
Overall chemical decay coefficient	1/yr	DERIVED	-999.	-999.	-999.	-999.
Acid catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000	-999.	-999.	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000	-999.	-999.	-999.
Base catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000	-999.	-999.	-999.
Reference temperature	C	CONSTANT	25.0	-999.	-999.	-999.
Normalized distribution coefficient	ml/g	CONSTANT	0.000	-999.	-999.	-999.
Distribution coefficient	--	DERIVED	-999.	-999.	-999.	-999.
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000	-999.	-999.	-999.
Air diffusion coefficient	cm2/s	CONSTANT	-999.	-999.	-999.	-999.
Reference temperature for air diffusion	C	CONSTANT	-999.	-999.	-999.	-999.
Molecular weight	g/M	CONSTANT	-999.	-999.	-999.	-999.
Mole fraction of solute	--	CONSTANT	-999.	-999.	-999.	-999.
Vapor pressure of solute	mm Hg	CONSTANT	-999.	-999.	-999.	-999.
Henry`s law constant	atm-m^3/M	CONSTANT	-999.	-999.	-999.	-999.
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000	0.000	0.000	1.00
Not currently used		CONSTANT	0.000	0.000	0.000	0.000
Not currently used		CONSTANT	0.000	0.000	0.000	0.000

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Infiltration rate	m/yr	CONSTANT	0.254E-06	-999.	-999.	-999.
Area of waste disposal unit	m^2	CONSTANT	0.118E+05	-999.	-999.	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	-999.	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	-999.	-999.
Recharge rate	m/yr	CONSTANT	0.000	-999.	-999.	-999.
Source decay constant	1/yr	CONSTANT	0.000	0.000	0.000	0.000
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	-999.	-999.
Length scale of facility	m	DERIVED	-999.	-999.	-999.	-999.
Width scale of facility	m	DERIVED	-999.	-999.	-999.	-999.
Near field dilution		DERIVED	1.00	0.000	0.000	1.00

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Particle diameter	cm	CONSTANT	-999.	-999.	-999.	-999.
Aquifer porosity	--	CONSTANT	0.200	-999.	-999.	-999.
Bulk density	g/cc	CONSTANT	1.76	-999.	-999.	-999.
Aquifer thickness	m	CONSTANT	4.60	-999.	-999.	-999.
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	-999.	-999.
Conductivity (hydraulic)	m/yr	CONSTANT	96.1	-999.	-999.	-999.
Gradient (hydraulic)		CONSTANT	0.100	-999.	-999.	-999.
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	-999.	-999.
Retardation coefficient	--	DERIVED	-999.	-999.	-999.	-999.
Longitudinal dispersivity	m	CONSTANT	9.69	-999.	-999.	-999.
Transverse dispersivity	m	CONSTANT	3.23	-999.	-999.	-999.
Vertical dispersivity	m	CONSTANT	0.540	-999.	-999.	-999.
Temperature of aquifer	C	CONSTANT	16.5	-999.	-999.	-999.
pH	--	CONSTANT	7.40	-999.	-999.	-999.
Organic carbon content (fraction)		CONSTANT	0.300E-02	-999.	-999.	-999.
Well distance from site	m	CONSTANT	96.9	-999.	-999.	-999.
Angle off center	degree	CONSTANT	0.000	0.000	0.000	0.000
Well vertical distance	m	CONSTANT	0.000	0.000	0.000	0.000

CONCENTRATION AFTER SATURATED ZONE MODEL 0.9033E-06

$$DILUTION\ ATTENUATION\ FACTOR\ (DAF) = \frac{Initial\ Concentration}{Concentration\ at\ Point\ of\ Compliance}$$

$$DAF = \frac{1.0\ mg/L}{9.033e^{-07}\ mg/L} = 1.107e^{6}$$

ROCK EXTRACTION AREA PRESCRIBED LINER

MULTIMED MODEL

MULTIMED V1.01 DATE OF CALCULATIONS: 7-FEB-2011 TIME: 13:41:45

U. S. E N V I R O N M E N T A L P R O T E C T I O N A G E N C Y

E X P O S U R E A S S E S S M E N T

M U L T I M E D I A M O D E L

MULTIMED (Version 1.50, 2005)

Run options
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Sonoma County Central Disposal Site

REA Prescribed Liner
Chemical simulated is Chemical Name

Option Chosen Saturated and unsaturated zone models
Run was DETERMIN
Infiltration Specified By User: 2.540E-06 m/yr
Run was steady-state
Reject runs if Y coordinate outside plume
Reject runs if Z coordinate outside plume
Gaussian source used in saturated zone model

UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

NP	- Total number of nodal points	240
NMAT	- Number of different porous materials	1
KPROP	- Van Genuchten or Brooks and Corey	1
IMSHGN	- Spatial discretization option	1
NVFLAYR	- Number of layers in flow model	1

OPTIONS CHOSEN
------- ------
Van Genuchten functional coefficients
User defined coordinate system

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	3.30	1

DATA FOR MATERIAL 1

VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Saturated hydraulic conductivity	cm/hr	CONSTANT	1.09	-999.	-999.	-999.
Unsaturated zone porosity	--	CONSTANT	0.200	-999.	-999.	-999.
Air entry pressure head	m	CONSTANT	0.000	-999.	-999.	-999.
Depth of the unsaturated zone	m	CONSTANT	3.30	0.000	0.000	0.000

DATA FOR MATERIAL 1

VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Residual water content	--	CONSTANT	0.450E-01	-999.	-999.	-999.
Brook and Corey exponent,EN	--	CONSTANT	-999.	-999.	-999.	-999.
ALFA coefficient	1/cm	CONSTANT	0.145	-999.	-999.	-999.
Van Genuchten exponent, ENN	--	CONSTANT	2.68	-999.	-999.	-999.

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		1
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN

Stehfest numerical inversion algorithm
Nondecaying continuous source
Computer generated times for computing concentrations

DATA FOR LAYER 1

VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Thickness of layer	m	CONSTANT	3.30	-999.	-999.	-999.
Longitudinal dispersivity of layer	m	DERIVED	-999.	-999.	-999.	-999.
Percent organic matter	--	CONSTANT	0.600	-999.	-999.	-999.
Bulk density of soil for layer	g/cc	CONSTANT	0.600	-999.	-999.	-999.
Biological decay coefficient	1/yr	CONSTANT	0.000	-999.	-999.	-999.

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Solid phase decay coefficient	1/yr	DERIVED	-999.	-999.	-999.	-999.
Dissolved phase decay coefficient	1/yr	DERIVED	-999.	-999.	-999.	-999.
Overall chemical decay coefficient	1/yr	DERIVED	-999.	-999.	-999.	-999.
Acid catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000	-999.	-999.	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000	-999.	-999.	-999.
Base catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000	-999.	-999.	-999.
Reference temperature	C	CONSTANT	25.0	-999.	-999.	-999.
Normalized distribution coefficient	ml/g	CONSTANT	0.000	-999.	-999.	-999.
Distribution coefficient	--	DERIVED	-999.	-999.	-999.	-999.
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000	-999.	-999.	-999.
Air diffusion coefficient	cm2/s	CONSTANT	-999.	-999.	-999.	-999.
Reference temperature for air diffusion	C	CONSTANT	-999.	-999.	-999.	-999.
Molecular weight	g/M	CONSTANT	-999.	-999.	-999.	-999.
Mole fraction of solute	--	CONSTANT	-999.	-999.	-999.	-999.
Vapor pressure of solute	mm Hg	CONSTANT	-999.	-999.	-999.	-999.
Henry`s law constant	atm-m^3/M	CONSTANT	-999.	-999.	-999.	-999.
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000	0.000	0.000	1.00
Not currently used		CONSTANT	0.000	0.000	0.000	0.000
Not currently used		CONSTANT	0.000	0.000	0.000	0.000

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Infiltration rate	m/yr	CONSTANT	0.254E-05	-999.	-999.	-999.
Area of waste disposal unit	m^2	CONSTANT	0.118E+05	-999.	-999.	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	-999.	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	-999.	-999.
Recharge rate	m/yr	CONSTANT	0.000	-999.	-999.	-999.
Source decay constant	1/yr	CONSTANT	0.000	0.000	0.000	0.000
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	-999.	-999.
Length scale of facility	m	DERIVED	-999.	-999.	-999.	-999.
Width scale of facility	m	DERIVED	-999.	-999.	-999.	-999.
Near field dilution		DERIVED	1.00	0.000	0.000	1.00

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS		LIMITS	
			MEAN	STD DEV	MIN	MAX
Particle diameter	cm	CONSTANT	-999.	-999.	-999.	-999.
Aquifer porosity	--	CONSTANT	0.200	-999.	-999.	-999.
Bulk density	g/cc	CONSTANT	1.76	-999.	-999.	-999.
Aquifer thickness	m	CONSTANT	4.60	-999.	-999.	-999.
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	-999.	-999.
Conductivity (hydraulic)	m/yr	CONSTANT	96.1	-999.	-999.	-999.
Gradient (hydraulic)		CONSTANT	0.100	-999.	-999.	-999.
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	-999.	-999.
Retardation coefficient	--	DERIVED	-999.	-999.	-999.	-999.
Longitudinal dispersivity	m	CONSTANT	9.69	-999.	-999.	-999.
Transverse dispersivity	m	CONSTANT	3.23	-999.	-999.	-999.
Vertical dispersivity	m	CONSTANT	0.540	-999.	-999.	-999.
Temperature of aquifer	C	CONSTANT	16.5	-999.	-999.	-999.
pH	--	CONSTANT	7.40	-999.	-999.	-999.
Organic carbon content (fraction)		CONSTANT	0.300E-02	-999.	-999.	-999.
Well distance from site	m	CONSTANT	96.9	-999.	-999.	-999.
Angle off center	degree	CONSTANT	0.000	0.000	0.000	0.000
Well vertical distance	m	CONSTANT	0.000	0.000	0.000	0.000

CONCENTRATION AFTER SATURATED ZONE MODEL 0.9033E-05

$$\textit{DILUTION ATTENUATION FACTOR}\ (\textit{DAF}) = \frac{\textit{Initial Concentration}}{\textit{Concentration at Point of Compliance}}$$

$$\textit{DAF} = \frac{1.0\ mg/L}{9.033e^{-06}\frac{mg}{L}} = 1.107e^{5}$$