EVALUATION OF METALS MIGRATION FROM CEMENT KILN DUST (CKD) PILES USING THE EPACMTP GROUNDWATER MODEL

Section 3001(b)(3)(A)(iii) of the Resource Conservation and Recovery Act (RCRA) excludes cement kiln dust (CKD) from regulation under Subtitle C of RCRA, pending completion of a Report to Congress required by §8002(o) and a determination by the EPA Administrator either to promulgate regulations under Subtitle C or that such regulations are unwarranted. EPA completed the Report to Congress in December 1993 and the subsequent regulatory determination in January 1995. Based on potential adverse effects resulting from documented damages to groundwater and modeled releases via the air pathway, EPA is undertaking a proposed rule-making to regulate the management of CKD.

In support of the Report to Congress and subsequent regulatory determination, EPA conducted screening-level groundwater modeling to determine whether constituents could leach from the CKD management units to the groundwater and then move to a receptor site. The modeling indicated limited potential for contaminants of concern to migrate downgradient to receptor locations at levels of concern. However, the alkaline conditions associated with CKD leachate suggest that additional modeling with more complex groundwater models may be appropriate. Thus, the Agency chose to conduct additional groundwater analyses using the more complex groundwater model, EPACMTP.

This report documents the results from this modeling effort and identifies additional limitations of this modeling effort. This report is separated into four sections: Section 1 discusses the modeling methodology; Section 2 describes the inputs for the data elements of the model; Section 3 presents the results; and Section 4 discusses the limitations of the modeling and identifies additional studies to improve the ground water modeling.

1.0 Modeling Methodology

A detailed discussion of the methodology for evaluating the potential for migration of constituents from a Cement Kiln Dust (CKD) waste management unit to a receptor location through the groundwater pathway is provided in the EPACMTP Background Document for Metals (U.S. EPA, 1995a). In general, the modeling procedure for metals combines a finite source methodology with a metal-specific procedure (using MINTEQA2) for handling geochemical interactions that affect the subsurface fate and transport of metals. The latter procedure has been developed at the EPA-ORD Environmental Research Laboratory in Athens, GA and has been adopted for incorporation into EPACMTP.

In this methodology, the MINTEQA2 metals speciation code is used to generate nonlinear adsorption isotherms for each individual metal species. The isotherms reflect the range in geochemical environments that are expected to be encountered at waste sites across the nation. A set of isotherms is selected for each model simulation, depending on selected values for four environmental variables that control the mobility of metals: (1) the leachate organic matter content, (2) the subsurface pH, (3) the subsurface concentration of amorphous iron oxide adsorbent, and (4) the subsurface organic matter content.

At present, nonlinear adsorption isotherms have been developed for 9 RCRA metals. In addition, beryllium is assumed to have the same isotherm as barium. Of these, barium, cadmium, beryllium, lead, and chromium are of concern in CKD. Three other metals of concern could not be modeled using MINTEQA2 because adsorption reactions describing the interaction of the metal with an adsorbing surface

are not reliably known. These metals are Arsenic(III), Thallium(I), and Antimony (V). Because MINTEQA2 could not be used, empirical relationships developed by Loux et al., (1990), which provide the adsorption distribution coefficient as a function of pH, were used.

The implementation of the metals methodology is based on the assumption that the nonlinearity of the metals sorption isotherms is most important in the unsaturated zone where concentrations are relatively high. Upon reaching the water table and mixing with ambient groundwater, the metals concentration is considered to be low enough that a linear isotherm can be used. The appropriate saturated zone retardation factor is determined based on the maximum groundwater concentration underneath the source leaving the unsaturated zone.

The fate and transport of metal species in the subsurface can be modeled using a conventional advection-dispersion equation. The EPACMTP methodology separates the subsurface domain into two zones: (1) the unsaturated zone above the water table, and (2) the saturated zone beneath the water table. Flow and transport of contaminants in the unsaturated zone beneath the landfill is assumed to be vertical only, while flow and transport beneath the water table in the saturated zone is three-dimensional. A mass conservative coupling of the two zones occurs at the water table-unsaturated zone interface.

Flow through the unsaturated zone is assumed to occur under steady state conditions representing an average infiltration over the transport simulation time scale. Solution of the unsaturated one-dimensional, steady state flow equation is obtained through analytical solution schemes and is detailed in the EPACMTP Background Document (U.S. EPA, 1995b). Transport through the unsaturated zone follows the finite-source methodology for EPACMTP. The retardation, for metals, is obtained from MINTEQA2 simulations, as discussed earlier. The equation for transient transport of metals is solved by analytical solution methods detailed in the EPACMTP Background Document (U.S. EPA, 1995b).

Flow in the saturated zone is affected by ambient groundwater gradients, recharge over the modeled area, and infiltration of water (leachate) beneath the landfill. A numerical finite element solution is used for the steady-state saturated flow equation and is described in the EPACMTP Background Document (U.S. EPA, 1995b). Contaminant transport in the saturated zone follows the conventional transient advective-dispersive transport equation in three dimensions, i.e., metal transport occurs due to advection, diffusion, and dispersion in the porous medium, subject to adsorption on the soil. Further, we assume that metal concentrations beneath the water table are fairly low, due to mixing of leachate with ambient groundwater, and therefore, the MINTEQA2 derived adsorption isotherm is linearized, since the nonlinearities associated with high metal concentrations are not present.

Data for the simulation of metal transport at the five facilities of interest include site specific information assimilated in EPA's Report to Congress on Cement Kiln Dust (EPA, 1993), recharge and unsaturated zone soil data from a location database developed for EPACMTP (U.S. EPA, 1995b), and data on adsorption isotherms for metals under various conditions. These data are presented in Section 2 of this document. Results from an EPACMTP simulation of metals include the concentrations at all receptor well locations at various times up to a simulation period of 128 years.

2.0 Description of Data Elements

A detailed list of EPACMTP modeling data-needs for simulating the migration of constituents at CKD disposal facilities is presented in Attachment A. The primary source of site-specific data is EPA's Report to Congress on Cement Kiln Dust (EPA, 1993), which includes EPA's data collected during site

visits to CKD facilities, data collected from respondents to a Portland Cement Association CKD survey, and environmental setting data collected previously on other facilities in similar geographical regions. Additional data needed to run EPACMTP is also identified, along with the sources from which these data were obtained.

The data required by EPACMTP can be divided into seven groups:

1. **Control parameters to guide the simulation**. This data set is the same for all sites and for every constituent examined. These data tell the code to perform a deterministic analysis of the transport of metals through the unsaturated zone and with the underlying groundwater flow.

2. **Control parameters for the use of EPACMTP with deterministic simulations**. These parameters define the decay from the source, the flow in the unsaturated and saturated zones, and number of calculations to be conducted at the receptor.

3. **Source and infiltration boundary data for the system**. These parameters describe the source from which leachate is generated and the infiltration of water in the vicinity of the source. Site-specific data include source dimensions, leachate concentrations, and rate of infiltration at the source.

4. **Chemical-specific data**. These data include chemical-specific information, as well as information on soil pH, iron hydroxide content and organic contents of leachate and soil to determine adsorption/precipitation of metals based on curves generated for low, high and medium values of these parameters using MINTEQA2.

5. **Unsaturated zone-specific data**. These parameters describe the unsaturated zone in terms of conductivity parameters, water content, thickness of the unsaturated zone, bulk density and dispersivity.

6. **Saturated zone-specific data**. These parameters describe the saturated zone in terms of porosity, bulk density, thickness, dispersivity, groundwater pH, conductivity, hydraulic gradient, and well location.

7. **Recharge and infiltration data**. These location-specific data describe the soil types and climate parameters. The climate parameters are selected from the EPACMTP data base of climate centers by matching the facility with the closest climate center.

3.0 Results

For the CKD Report to Congress (EPA 1993), groundwater modeling was conducted for five facilities using both best estimate and upper-bound estimates for a number of critical parameters using MMSOILS. These parameters include include the area of the disposal unit, the leachate concentration generated from the waste, the density of the waste, soil pH conditions, and hydraulic conductivity of the aquifer. For the purposes of this modeling the same best estimate and upper-bound assumptions were used for each facility. However for this exercise, EPACMTP was used to simulate leaching from the CKD unit, movement through the unsaturated zone, and dispersion in the saturated zone. Tables 1 through 10 present the results of the model runs for the best estimate and upper-bound estimates for each of the five landfill

facilities. Although results presented in the Report to Congress focused on concentrations at the nearest receptor location, concentrations measured at 10 meters, 20 meters, and 50 meters downstream from the landfill have been included in the tables for comparison purposes (i.e., few data were available at the nearest receptor locations). In addition, values are reported for the best estimate and upper-bound estimates for 130 years (the modeling time-frame) and 160 years (for comparative purposes).

Using the EPACMTP model, none of the metals reached the water table within by 160 years at landfills Facilities A and J (see Tables 1, 2, 9, and 10) for central tendency or high end simulations. In contrast, MMSOILS predicted that trace amounts of antimony, cadmium, and chromium may reach the water table at Facility A within 160 years. However, only chromium reached the nearest receptor location within 160 years, but even that concentration resulted in a hazard quotient for noncarcinogenic effects of less than $1x10^{-3}$. For Facility J, the best estimate MMSOILS modeling, likewise, did not predict any constituents to reach the water table. However, the upper-bound estimate predicted concentrations of antimony, arsenic, chromium, cadmium, and thallium to reach the water table and all but thallium to reach the receptor location within 160 years. The cancer risk from ingestion of arsenic was less than $1x10^{-8}$ and the noncancer hazard quotient for the other constituents were less than $1x10^{-3}$.

At Facilities O, F, and G (see Tables 3-8), EPACMTP predicted that leachate from the CKD pile would reach the water table within both 130 and 160 years. For Facility O (see Tables 3 and 4), EPACMTP predicts that antimony, beryllium, and barium may leach to the water table within 160 years for the best estimate simulation and antimony and arsenic may reach the water table using the upper-bound modeling assumptions. However, the modeling only indicates that trace amounts of barium and beryllium may reach the receptor location within 160 years. The concentrations predicted at the receptor locations, however, should be interpreted as trace amounts because concentrations below 10^{-7} are unreliable due to roundoff errors in the calculations and convergence tolerance limits. MMSOILS predicted elevated concentrations of antimony , arsenic, and chromium under the best estimated modeling scenario (Table 3); however, none of these constituents reached the reached location. Under the upper-bound scenario (Table 4), MMSOILS predicted elevated levels of antimony, arsenic, cadmium, chromium, and thallium. Only chromium reached the receptor location and the non-cancer hazard ratio associated with chromium was less than $1x10^{-4}$.

For Facility F, EPACMTP predicted elevated levels of barium and beryllium for the best estimate modeling scenario and elevated levels of antimony and arsenic for the upper-bound simulations. However, none of these constituents reached the receptor location and levels were generally trace amounts at 50 meters. MMSOILS predicted elevated levels of antimony, arsenic, and chromium in the groundwater for both the best estimate and upper-bound estimate, as well as elevated levels of cadmium in the upper-bound simulation. However, only chromium in the upper-bound simulation reached the receptor location; the non-cancer hazard ratio asssociated with chromium was less than $1x10^{-4}$.

For Facility G, EPACMTP predicted elevated concentrations of antimony, arsenic, barium, beryllium, cadmium, and thallium in the best estimate simulation (Table 7) and all of these except for cadmium in the upper-bound scenario. None of the constituents reached the receptor location for Facility G within 160 years. MMSOILS predicted that antimony, arsenic, barium, cadmium, chromium, lead, and thallium would reach the water table within 160 years for the best estimate modeling, and all of these but barium would reach the water table within 160 years in the upper-bound estimate. However, only chromium is predicted to reach the receptor location in other than trace amounts. The noncancer hazard

Table 1: Concentration of Metals at Various Distances along the Centerline from Landfill 1 (Facility A: Ashgrove Cement, Chanute, KS - Best Estimate)

Metal	MMSOILS Modeling Risk Results							EPACMTP Modeling Risk Results						
	Concentration at specified distance over 160 years				Concentration at specified distance over 130 years			Concentration at specified distance over 160 years				Concentration at specified distance over 130 years		
	10 m	20 m	50 m	483 m (GWW)	10 m	20 m	50 m	10 m	20 m	50 m	483 m (GWW)	10 m	20 m	50 m
Antimony	1.16 E-06	3.98 E-08	0.0	0.0	4.15 E-07	7.27 E-09	0.0	Did not reach water table within 160 yrs.						
Arsenic	2.03 E-07	0.0	0.0	0.0	7.29 E-08	0.0	0.0	Did not reach water table within 160 yrs.						
Barium	Did not reach water table within 160 yrs.							Did not reach water table within 160 yrs.						
Beryllium	Did not reach water table within 160 yrs.							Did not reach water table within 160 yrs.						
Cadmium	Did not reach water table within 160 yrs.							Did not reach water table within 160 yrs.						
Chromium	2.93 E-04	2.31 E-04	8.20 E-05	0.0	2.41 E-04	1.79 E-04	4.91 E-05	Did not reach water table within 160 yrs.						
Lead	Did not reach water table within 160 yrs.							Did not reach water table within 160 yrs.						
Thallium	Did not reach water table within 160 yrs.							Did not reach water table within 160 yrs.						

Table 2: Concentration of Metals at Various Distances along the Centerline from Landfill 1 (Facility A: Ashgrove Cement, Chanute, KS - Upper-bound)

Metal	MMSOILS Modeling Risk Results								EPACMTP Modeling Risk Results						
	Concentration at specified distance over 160 years				Concentration at specified distance over 130 years				Concentration at specified distance over 160 years				Concentration at specified distance over 130 years		
	10 m	20 m	50 m	483 m (GWW)	10 m	20 m	50 m	483 m (GWW)	10 m	20 m	50 m	483 m (GWW)	10 m	20 m	50 m
Antimony	5.31 E-04	4.40 E-04	1.11 E-04	0.0	4.00 E-04	3.11 E-04	2.05 E-04	0.0	Did not reach water table within 160 yrs.						
Arsenic	Did not reach water table within 160 yrs.								Did not reach water table within 160 yrs.						
Barium	Did not reach water table within 160 yrs.								Did not reach water table within 160 yrs.						
Beryllium	Did not reach water table within 160 yrs.								Did not reach water table within 160 yrs.						
Cadmium	1.46 E-05	6.31 E-09	4.21 E-07	0.0	7.05 E-06	2.30 E-06	7.99 E-08	0.0	Did not reach water table within 160 yrs.						
Chromium	6.11 E-03	6.00 E-03	4.02 E-03	1.53 E-03	5.20 E-03	5.09 E-03	4.76 E-03	9.31 E-04	Did not reach water table within 160 yrs.						
Lead	Did not reach water table within 160 yrs.								Did not reach water table within 160 yrs.						
Thallium	1.17 E-08	0.0	0.0	0.0	Did not reach water table within 130 yrs.				Did not reach water table within 160 yrs.						

Table 3: Concentration of Metals at Various Distances along the Centerline from Landfill 1 (Facility O: Giant Cement, Harleyville, SC - Best Estimate)

Metal	MMSOILS Modeling Risk Results								EPACMTP Modeling Risk Results							
	Concentration at specified distance over 160 years				Concentration at specified distance over 130 years				Concentration at specified distance over 160 years				Concentration at specified distance over 130 years			
	10 m	20 m	50 m	1610 m (GWW)	10 m	20 m	50 m	1610 m (GWW)	10 m	20 m	50 m	1610 m (GWW)	10 m	20 m	50 m	1610 m (GWW)
Antimony	6.71 E-06	2.66 E-07	0.0	0.0	1.52 E-06	2.67 E-08	0.0	0.0	6.40 E-08	4.44 E-09	0.0	0.0	1.35 E-08	6.45 E-10	0.0	0.0
Arsenic	8.66 E-07	3.46 E-08	0.0	0.0	1.97 E-07	3.49 E-09	0.0	0.0	9.69 E-08	5.35 E-09	1.36 E-10	0.0	1.49 E-08	1.12 E-09	0.0	0.0
Barium	Did not reach water table within 160 yrs.								1.08 E-01	3.77 E-02	6.46 E-03	1.20 E-08	1.04 E-01	3.64 E-02	5.71 E-03	1.12 E-08
Beryllium	Did not reach water table within 160 yrs.								6.84 E-04	2.32 E-04	3.11 E-05	0.0	5.07 E-04	1.79 E-04	2.64 E-05	0.0
Cadmium	Did not reach water table within 160 yrs.								Did not reach water table within 160 yrs.							
Chromium	4.09 E-03	3.06 E-03	1.13 E-03	0.0	2.31 E-03	1.74 E-03	4.83 E-04	0.0	Did not reach water table within 160 yrs.							
Lead	Did not reach water table within 160 yrs.								Did not reach water table within 160 yrs.							
Thallium	Did not reach water table within 160 yrs.								Did not reach water table within 160 yrs.							

Table 4: Concentration of Metals at Various Distances along the Centerline from Landfill 1 (Facility O: Giant Cement, Harleyville, SC - Upper-bound)

Metal	MMSOILS Modeling Risk Results								EPACMTP Modeling Risk Results							
	Concentration at specified distance over 160 years				Concentration at specified distance over 130 years				Concentration at specified distance over 160 years				Concentration at specified distance over 130 years			
	10 m	20 m	50 m	1610 m (GWW)	10 m	20 m	50 m	1610 m (GWW)	10 m	20 m	50 m	1610 m (GWW)	10 m	20 m	50 m	1610 m (GWW)
Antimony	2.51 E-03	1.89 E-03	7.16 E-04	0.0	1.65 E-03	1.17 E-03	3.53 E-03	0.0	2.43 E-05	4.27 E-06	2.72 E-07	0.0	2.15 E-06	4.46 E-07	4.39 E-08	0.0
Arsenic	2.14 E-04	1.71 E-04	7.94 E-05	0.0	1.45 E-04	1.10 E-04	4.30 E-05	0.0	4.96 E-07	1.26 E-08	1.33 E-09	0.0	4.20 E-08	8.54 E-09	5.35 E-10	0.0
Barium	Did not reach water table within 160 yrs.								Did not reach water table within 160 yrs.							
Beryllium	Did not reach water table within 160 yrs.								Did not reach water table within 160 yrs.							
Cadmium	6.95 E-05	2.89 E-05	1.91 E-06	0.0	3.38 E-05	1.12 E-05	4.25 E-07	0.0	Did not reach water table within 160 yrs.							
Chromium	2.94 E-02	2.89 E-02	2.64 E-02	2.88 E-05	2.47 E-02	2.42 E-02	2.20 E-02	9.35 E-06	Did not reach water table within 160 yrs.							
Lead	Did not reach water table within 160 yrs.								Did not reach water table within 160 yrs.							
Thallium	5.40 E-07	2.59 E-08	0.0	0.0	7.35 E-08	1.94 E-09	0.0	0.0	Did not reach water table within 160 yrs.							

Table 5: Concentration of Metals at Various Distances along the Centerline from Landfill 1 (Facility F: Lafarge, Fredonia, KS - Best Estimate)

Metal	MMSOILS Modeling Risk Results								EPACMTP Modeling Risk Results							
	Concentration at specified distance over 160 years				Concentration at specified distance over 130 years				Concentration at specified distance over 160 years				Concentration at specified distance over 130 years			
	10 m	20 m	50 m	966 m (GWW)	10 m	20 m	50 m	966 m (GWW)	10 m	20 m	50 m	966 m (GWW)	10 m	20 m	50 m	966 m (GWW)
Antimony	3.67 E-08	5.89 E-10	0.0	0.0	2.67 E-09	0.0	0.0	0.0	Did not reach water table within 160 yrs.							
Arsenic	4.34 E-09	0.0	0.0	0.0	3.18 E-10	0.0	0.0	0.0	5.07 E-04	1.79 E-04	2.24 E-08	0.0	Did not reach water table within 130 yrs.			
Barium	Did not reach water table within 160 yrs.								9.09 E-02	1.07 E-04	2.92 E-08	0.0	8.14 E-02	6.80 E-05	1.17 E-08	0.0
Beryllium	Did not reach water table within 160 yrs.								Did not reach water table within 160 yrs.							
Cadmium	Did not reach water table within 160 yrs.								Did not reach water table within 160 yrs.							
Chromium	6.80 E-04	4.55 E-04	1.10 E-04	0.0	3.86 E-04	2.25 E-04	3.51 E-05	0.0	Did not reach water table within 160 yrs.							
Lead	Did not reach water table within 160 yrs.								Did not reach water table within 160 yrs.							
Thallium	Did not reach water table within 160 yrs.								Did not reach water table within 160 yrs.							

Table 6: Concentration of Metals at Various Distances along the Centerline from Landfill 1 (Facility F: Lafarge, Fredonia, KS - Upper-bound)

Metal	MMSOILS Modeling Risk Results								EPACMTP Modeling Risk Results							
	Concentration at specified distance over 160 years				Concentration at specified distance over 130 years				Concentration at specified distance over 160 years				Concentration at specified distance over 130 years			
	10 m	20 m	50 m	966 m (GWW)	10 m	20 m	50 m	966 m (GWW)	10 m	20 m	50 m	966 m (GWW)	10 m	20 m	50 m	966 m (GWW)
Antimony	2.89 E-05	1.94 E-05	5.15 E-06	0.0	9.88 E-06	5.39 E-06	8.03 E-07	0.0	5.02 E-07	4.06 E-08	5.35 E-10	0.0	1.42 E-07	1.11 E-08	5.35 E-10	0.0
Arsenic	6.55 E-06	4.85 E-06	1.76 E-06	0.0	2.62 E-06	1.67 E-06	3.81 E-07	0.0	2.14 E-07	1.83 E-08	5.35 E-10	0.0	Did not reach water table within 130 yrs.			
Barium	Did not reach water table within 160 yrs.								Did not reach water table within 160 yrs.							
Beryllium	Did not reach water table within 160 yrs.								Did not reach water table within 160 yrs.							
Cadmium	2.36 E-07	5.77 E-08	1.32 E-09	0.0	1.79 E-08	2.41 E-09	0.0	0.0	Did not reach water table within 160 yrs.							
Chromium	1.69 E-02	1.64 E-02	1.49 E-02	1.96 E-04	1.07 E-02	1.03 E-02	9.00 E-03	3.35 E-05	Did not reach water table within 160 yrs.							
Lead	Did not reach water table within 160 yrs.								Did not reach water table within 160 yrs.							
Thallium	Did not reach water table within 160 yrs.								Did not reach water table within 160 yrs.							

Table 7: Concentration of Metals at Various Distances along the Centerline from Landfill 1 (Facility G: Rinker, Miami, FL - Best Estimate)

Metal	MMSOILS Modeling Risk Results								EPACMTP Modeling Risk Results							
	Concentration at specified distance over 160 years				Concentration at specified distance over 130 years				Concentration at specified distance over 160 years				Concentration at specified distance over 130 years			
	10 m	20 m	50 m	1610 m (GWW)	10 m	20 m	50 m	1610 m (GWW)	10 m	20 m	50 m	1610 m (GWW)	10 m	20 m	50 m	1610 m (GWW)
Antimony	2.13 E-02	1.85 E-02	9.92 E-03	0.0	1.57 E-02	1.30 E-02	5.66 E-07	0.0	1.71 E-04	4.19 E-05	8.40 E-07	0.0	7.17 E-05	1.41 E-05	2.05 E-07	0.0
Arsenic	4.08 E-03	3.55 E-03	1.91 E-03	0.0	3.01 E-03	2.49 E-03	1.08 E-03	0.0	9.62 E-05	3.10 E-05	9.81 E-07	0.0	4.59 E-05	1.23 E-05	2.84 E-07	0.0
Barium	1.86 E-03	1.60 E-04	1.73 E-07	0.0	5.43 E-04	2.48 E-05	5.77 E-09	0.0	2.08 E-02	9.74 E-03	6.91 E-04	0.0	1.33 E-02	5.63 E-03	3.06 E-04	0.0
Beryllium	Did not reach water table within 160 yrs.								6.89 E-05	3.06 E-05	1.88 E-06	0.0	4.16 E-05	1.63 E-05	7.42 E-07	0.0
Cadmium	2.66 E-07	2.17 E-09	0.0	0.0	2.99 E-08	0.0	0.0	0.0	Did not reach water table within 160 yrs.							
Chromium	1.64 E-03	1.60 E-03	1.31 E-03	1.07 E-06	1.64 E-03	1.60 E-03	1.31 E-03	3.18 E-07	Did not reach water table within 160 yrs.							
Lead	3.36 E-05	1.79 E-07	0.0	0.0	3.17 E-06	5.03 E-09	0.0	0.0	Did not reach water table within 160 yrs.							
Thallium	1.47 E-03	1.15 E-04	1.01 E-07	0.0	4.14 E-04	1.70 E-05	3.04 E-09	0.0	6.14 E-05	7.40 E-06	5.95 E-08	0.0	1.66 E-05	1.52 E-06	9.29 E-09	0.0

Table 8: Concentration of Metals at Various Distances along the Centerline from Landfill 1 (Facility G: Rinker, Miami, FL - Upper-bound)

Metal	MMSOILS Modeling Risk Results								EPACMTP Modeling Risk Results							
	Concentration at specified distance over 160 years				Concentration at specified distance over 130 years				Concentration at specified distance over 160 years				Concentration at specified distance over 130 years			
	10 m	20 m	50 m	1610 m (GWW)	10 m	20 m	50 m	1610 m (GWW)	10 m	20 m	50 m	1610 m (GWW)	10 m	20 m	50 m	1610 m (GWW)
Antimony	1.73 E-02	1.63 E-02	1.15 E-02	0.0	1.61 E-02	1.47 E-02	9.31 E-03	0.0	1.92 E-03	9.92 E-04	9.71 E-05	0.0	9.41 E-03	4.27 E-04	3.00 E-05	0.0
Arsenic	3.31 E-03	3.14 E-03	2.32 E-03	0.0	3.23 E-03	3.00 E-03	2.03 E-03	0.0	1.25 E-04	5.28 E-05	3.16 E-07	0.0	5.38 E-05	1.96 E-05	8.43 E-07	0.0
Barium	Did not reach water table within 160 yrs.								8.97 E-03	4.07 E-03	2.64 E-04	0.0	4.42 E-03	1.69 E-03	7.22 E-05	0.0
Beryllium	Did not reach water table within 160 yrs.								3.17 E-05	1.17 E-05	4.52 E-07	0.0	9.65 E-06	2.42 E-06	4.64 E-08	0.0
Cadmium	1.38 E-03	1.17 E-03	5.59 E-04	0.0	9.82 E-04	7.86 E-04	3.01 E-04	0.0	Did not reach water table within 160 yrs.							
Chromium	2.03 E-03	1.94 E-03	1.48 E-03	9.38 E-06	2.04 E-03	1.94 E-03	1.48 E-03	5.27 E-06	Did not reach water table within 160 yrs.							
Lead	5.34 E-03	8.61 E-04	4.83 E-06	0.0	1.71 E-03	1.64 E-04	2.75 E-07	0.0	Did not reach water table within 160 yrs.							
Thallium	2.17 E-02	1.28 E-02	1.74 E-03	0.0	1.28 E-02	5.99 E-03	4.58 E-04	0.0	1.23 E-05	1.81 E-06	2.13 E-08	0.0	2.38 E-06	2.79 E-07	2.82 E-09	0.0

Table 9: Concentration of Metals at Various Distances along the Centerline from Landfill 1 (Facility J: Southdown, Lyons, CO - Best Estimate)

Metal	MMSOILS Modeling Risk Results							EPACMTP Modeling Risk Results						
	Concentration at specified distance over 160 years (mg/L)				Concentration at specified distance over 130 years (mg/L)			Concentration at specified distance over 160 years (mg/L)				Concentration at specified distance over 130 years (mg/L)		
	10 m	20 m	50 m	549 m (GWW)	10 m	20 m	50 m	10 m	20 m	50 m	549 m (GWW)	10 m	20 m	50 m
Antimony	Did not reach water table within 160 yrs.							Did not reach water table within 160 yrs.						
Arsenic	Did not reach water table within 160 yrs.							Did not reach water table within 160 yrs.						
Barium	Did not reach water table within 160 yrs.							Did not reach water table within 160 yrs.						
Beryllium	Did not reach water table within 160 yrs.							Did not reach water table within 160 yrs.						
Cadmium	Did not reach water table within 160 yrs.							Did not reach water table within 160 yrs.						
Chromium	Did not reach water table within 160 yrs.							Did not reach water table within 160 yrs.						
Lead	Did not reach water table within 160 yrs.							Did not reach water table within 160 yrs.						
Thallium	Did not reach water table within 160 yrs.							Did not reach water table within 160 yrs.						

Table 10: Concentration of Metals at Various Distances along the Centerline from Landfill 1 (Facility J: Southdown, Lyons, CO - Upper-bound)

Metal	MMSOILS Modeling Risk Results								EPACMTP Modeling Risk Results						
	Concentration at specified distance over 160 years (mg/L)				Concentration at specified distance over 130 years (mg/L)				Concentration at specified distance over 160 years (mg/L)				Concentration at specified distance over 130 years (mg/L)		
	10 m	20 m	50 m	549 m (GWW)	10 m	20 m	50 m	549 m	10 m	20 m	50 m	549 m (GWW)	10 m	20 m	50 m
Antimony	6.92 E-04	6.65 E-04	5.37 E-04	6.25 E-05	6.24 E-04	5.94 E-04	4.66 E-04	1.94 E-05	Did not reach water table within 160 yrs.						
Arsenic	4.43 E-05	4.25 E-05	3.46 E-05	5.41 E-06	4.27 E-05	4.08 E-05	3.27 E-05	2.15 E-06	Did not reach water table within 160 yrs.						
Barium	Did not reach water table within 160 yrs.								Did not reach water table within 160 yrs.						
Beryllium	Did not reach water table within 160 yrs.								Did not reach water table within 160 yrs.						
Cadmium	3.05 E-05	2.81 E-05	2.01 E-05	2.41 E-07	9.60 E-06	8.53 E-06	5.46 E-06	1.32 E-08	Did not reach water table within 160 yrs.						
Chromium	4.33 E-04	4.16 E-04	3.39 E-04	1.04 E-04	4.33 E-04	4.16 E-04	3.39 E-04	9.06 E-05	Did not reach water table within 160 yrs.						
Lead	Did not reach water table within 160 yrs.								Did not reach water table within 160 yrs.						
Thallium	7.92 E-08	5.82 E-08	2.16 E-08	0.0	4.63 E-10	4.13 E-10	1.98 E-10	0.0	Did not reach water table within 160 yrs.						

ratio for chromium is less than $1x10^{-6}$ for the best estimate and less than $1x10^{-5}$ for the upper-bound estimate. The non-linearity of the equations, specifically with respect to pH, allows for situations where the transport of a metal may be slower for high end cases than the corresponding central tendency case.

In general, the revised modeling using EPACMTP predicted lower concentrations of metals in groundwater for chromium, cadmium, and thallium and higher concentrations for barium and beryllium. For antimony and arsenic, EPACMTP generally predicted lower concentrations of each constituent, except in Facility G, where initial concentrations in groundwater were higher. At all facilities, the risk from contaminated groundwater predicted by EPACMTP were negligble (only trace amounts of barium and beryllium at Facility O were predicted to reach the receptor location). Concentrations of lead usually were negligible in both modeling exercises (only Facility G using the MMSOILS model predicted that lead would reach the water table). Concentrations of constituents in groundwater also tended to decrease more rapidly as the plume moved from the management unit to the receptor location with the EPACMTP modeling.

4.0 Limitations of the Analysis

Althought EPACMTP is a more advanced groundwater model than the MMSOILS groundwater model, there are a few important limitations to the revised analysis:

1. **Karst terrain.** EPACMTP does not improve our ability to predict leachate migration in areas of karst terrain or channelized flow. This is a significant limitation because more than 50 percent of the cement plants are in areas of fractured or channelized flow. Regardless of the accuracy of the model, results can not be extrapolated to a significant portion of the facilities.

2. **Metals speciation.** Unlike acidic municipal landfills, CKD disposal units are characterized by highly alkaline conditions. In many cases, the leachate from these units exceed pH levels of 11 standard units. The pH will affect the speciation of the metal and the subsequent movement of the metal through the vadose zone. Over time, leachate also may elevate the pH of the groundwater affecting the complexation of the metals in the groundwater, and thus, the solubility in the groundwater. The current modeling uses MINTEQA2 isotherms for several of the metals. The isotherms use a point value to represent speciation of a metal for a range of pH values. Additional study is needed to determine the representativeness of the high pH value (i.e., 7.9) for the range of pHs generally associated with leachate from CKD disposal units (i.e., 10-13).

3. **Validation.** Neither EPACMTP nor MMSOILS has undergone comprehensive field validations to evaluate their effectiveness in predicting leachate movement from waste management units. Additional steps for validation may include comparing results predicted by each model with ground water concentrations found in damage cases.

4. **Source Characteristics.** The waste form in the CKD management unit may significantly affect movement of leachate through the unit and into the vadose zone. At least one potential damage case (Alamo Cement) has suggested that water may be retained in the management unit. Other damage cases indicate that CKD may be managed beneath the natural water table. For this analysis, EPACMTP did not account for these potential differences in sources.

5. **Localized Hydrogeology.** The data describing the hydrogeology are reflective of the regional hydrogeology and may not reflect localized variations in the hydrogeology (e.g., presence of perched water tables). Thus, likelihood that releases to groundwater may occur may at a site may increase or decrease depending on site-specific hydrogeology.

ATTACHMENT A

Table 1. EPACMTP Control Parameters

Variable	Description	Value	Comments
GRPCOD	Record identifier; must be 'GP' always	GP	
MC	Monte Carlo control parameter = F(alse) for deterministic run = T(rue) for Monte Carlo run (Default).	F	
IVADOS	Control parameter for unsaturated zone simulation. = 0 if no unsaturated zone modeling is required, = 1 if unsaturated zone modeling is required (Default).	1	
ISTMOD	Control parameter for saturated zone simulation. = 0 if no saturated zone modeling is required, = 1 if saturated zone modeling is required (Default).	1	
NSPECI	Number of contaminant component species. Default = 1.	1	
KFDM	Dummy parameter, set = 1.	1	
KFS	Control parameter for selecting continuous (infinite) source or finite source modeling option = 0 if continuous source option = 1 if finite source option with prescribed leaching duration. = 2 if landfill finite source option.	1	Technical document on CKD uses constant source for prescribed finite duration. Landfill finite source option is a physically better justified assumption (KFS=2).
FULL3D	Logical control parameter for selecting fully 3D or quasi-3D saturate zone modeling option = T(rue) for fully 3D simulation = F(alse) for quasi-3D simulation Note: FULL3D = F(alse) should be used for Monte Carlo simulations	T	
METAL	Logical control parameter for metals simulation = T(rue) for metals modeling = F(alse) for non-metals modeling	T	

Variable	Description	Value	Comments
KDEVAL	Integer control parameter for selecting the scheme for determining the metals sorption isotherm (Leave blank if METAL=FALSE) = 1 Use the method of Loux for calculating k_d from pH = 2 Use linearized MINTEQA2 isotherm = 3 Use nonlinear MINTEQA2 isotherm	3	For Antimony, Arsenic, and Thallium, KDEVAL=1 is used since MINTEQA2 isotherms for these metals are unreliable and have been excluded from EPACMTP.
ISRC_TYP	Control parameter for selecting the type of waste source = 0 for landfill = 1 for surface impoundment = 2 for waste pile = 3 for land treatment	0	

Table 2. EPACMTP's Deterministic Control Parameters

Variable	Description	Value	Comments
GRPCOD	Record identifier; must be 'GP' always	GP	
ISBC	Contaminant source boundary condition = 0 if contaminant flux is given (Default), = 1 if contaminant concentration is given.	0	
IBAT	Control parameter for decaying source boundary condition, = 0 if no (continuous source or non-degrader finite source) = 1 Biochemical decay (hydrolysis) = 2 Physical decay due to leaching (source depletion) = 3 Combine 1+2 (IBAT > =1 for degrader finite sources) Note: If IBAT = 1 or 3 is selected, it is assumed that the effective hydrolysis transformation coefficients in the waste source are the same as in the unsaturated and saturated zone.	0	A value of 2 may be used if landfill finite source (KFS=2) is used.
IUSTED	Control parameter indicating whether transport is in the unsaturated zone is steady-state or transient, = 0 for transient (if KFS=1 or 2), = 1 for steady-state (if KFS=0). Leave blank if IVADOS (see record GP01) = 0.	0	
ISSTED	Control parameter indicating whether transport in the saturated zone is steady-state or transient = 0 for transient (if KFS=1 or 2) = 1 for steady-state (if KFS=0). Leave blank if ISTMOD (see record GP01) = 0.	0	
NUTOBS	Number of time values at which concentration at the exit point of the unsaturated zone is to be computed Leave blank if ISTMOD=1, and/or IUSTED=1, and/or MC=T(rue).	0	

Table 2. EPACMTP's Deterministic Control Parameters (cont.)

Variable	Description	Value	Comments
NTS	Number of time values at which receptor well concentrations in the saturated zone are to be computed Leave blank if ISTMOD=0, or ISSTED=1.	128	Exposure point concentrations are evaluated every year for the 128 y simulation period.
NWELLS	Number of receptor wells in the saturated zone. Leave blank if ISTMOD (see record GP01)=0.	17	Each simulation has 17 exposure points to evaluate concentrations.
QRMAX	Maximum groundwater vertical to horizontal flux ratio (see Eq. 2.3.34) for selecting between analytical and numerical saturated zone contaminant transport solution. Recommended value is 0.02. Leave blank if ISTMOD (see record GP01)=0.	1	Select numerical solution to avoid assumptions of analytical solution of no vertical flow.
NRATIO	Number of ratios of C_W/C_L to be used for finite source scenario (KFS=2). Default value is 8. Leave blank for continuous source analysis (KFS=0).	0	The C_W/C_L ratio for the landfill may be used if the landfill finite source option (KFS=2) is used.
ICRW	Control parameter indicating the time-dependent receptor well concentration to be computed for the finite source analysis = 0 compute peak receptor well concentration (Default) = 1 compute temporarily averaged receptor well concentration When ICRW=1 is used, the averaging period for each of the species must be specified in variable CARC, in the chemical-specific data records. The default period is 70 years.	0	

Table 3. Input Parameters for Source-Specific Group

Variable	Description	Value					Comments
		A	O	F	G	J	
AREA	Area of disposal unit (m^2) C.T. H.E.	209,032 214,500	41,836 48,200	306,330 357,500	13,000 14,500	44,825 46,000	From MMSOILS data files.
XW	Length (x-direction) of disposal unit (m) C.T. H.E.	457.2 463.14	204.5 219.55	553.5 597.91	114.0 120.42	211.7 214.48	From MMSOILS data files.
YD	Width (y-direction) of disposal unit (m)	457.2	204.5	553.5	114.0	211.7	Square area assumed in MMSOILS.
CZERO(I)	Leachate concentration emanating from the waste disposal facility (mg/L). C.T.; H.E. Lead: Antimony: Arsenic: Barium: Beryllium: Cadmium: Chromium: Thallium:	 0.53 0.022; 0.044 0.0038 0.23 0.002; 0.004 0.004; 0.008 0.053 0.011	 0.046 0.022; 0.044 0.0028 0.34 0.002; 0.004 0.004; 0.008 0.077 .026	 0.968; 0.976 0.019; 0.0167 0.0022; 0.0023 0.745; 0.869 0.0013; 0.004 0.0025; 0.008 0.346; 0.373 0.0079; 0.0108	 1.1 0.068 0.013 0.47 0.002; 0.004 0.004; 0.008 0.004; 0.008 0.43	 0.026 0.062 0.0039 0.49 0.002; 0.004 0.004; 0.008 0.038 0.053	From MMSOILS data files. A constant value of leachate concentration was used in the MMSOILS simulation, using the values used in TSOURC below, as the period of leachate generation.
RECHRG	Areal recharge rate (m/y)	0.0686	0.2609	0.2609	0.145	0.0008	Need locations and soil type, as classified by SCS.
SINFIL	Infiltration rate from disposal unit (m/y)	0.0686	0.2609	0.2609	0.145	0.0008	Need locations and soil type, as classified by SCS.
TSOURC	Duration of leaching period (y) for finite source option (KFS=1) TSOURC should be specified as a derived variable if KFS=2 (i.e. for landfills).	141	171	146	162	150	From MMSOILS data file.
DEPTH	Depth of the waste disposal facility (m) for landfill finite source option.	12	6	12	10	3.05	From Exhibit 8-2 of RTC consistent with MMSOILS data files.

Table 3. Input Parameters for Source-Specific Group (cont.)

Variable	Description	Value					Comments
		A	O	F	G	J	
FRACT	Fraction of hazardous waste in the waste disposal facility for landfill finite source option.	1	1	1	1	1	It is assumed that the waste is fully dispersed in the landfill.
CTDENS	Density of hazardous waste (g/cm^3) C.T. H.E.	1.5 1.4	1.5 1.4	1.5 1.4	1.5 1.4	1.733 1.5	From MMSOILS data files.

Table 4a. Chemical Specific Data

Variable	Description	Value								Comments
		Lead	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Thallium	
DSTAR(I)	Effective molecular diffusion coefficient (m^2/y). For a multispecies simulation, this record should be repeated for each of the components in the decay chain, i.e., NSPECI times.	1×10^{-6}	1×10^{-6}	1×10^{-6}	1×10^{-6}	1×10^{-6}	1×10^{-6}	1×10^{-6}	1×10^{-6}	From MMSOILS data files consistent with Exhibit 8-2 of RTC.
DWS(I)	Drinking water standard (mg/L), i.e., HBL or MCL value for comparison against model predicted average receptor well concentrations. For a degrader, this record should be repeated for the parent and all daughter products, i.e., NSPECI times.	0.015	0.006	0.05	2.0	0.004	0.005	0.1	0.002	Action levels of MMSOILS data files.
CARC(I)	Base exposure period (y) for calculating average receptor well concentration. Set to 70 y for carcinogens, and 35 y for non-carcinogens. Always specify this parameter as a constant. For a degrader, this record should be repeated for the parent and all daughter products, i.e., NSPECI times.	–	–	–	–	–	–	–	–	Note required for peak concentration computation at receptor well.

Table 4a. Chemical Specific Data (cont.)

Variable	Description	Value								Comments
		Lead	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Thallium	
METAL_ID	Identification number for the metal.	6	17	13	1	1 (similar sorption to Barium)	2	3	16	From EPACMTP document.

Table 4b. Chemical Specific Data

Variable	Description	Value					Comments
		A	O	F	G	J	
USPH	Soil and aquifer pH. C.T. H.E.	6.8 7.9	6.8 7.9	6.8 7.9	6.8 7.9	6.8 7.9	50 and 10% tile values in HWIR pH data base for C.T. and H.E., respectively.
FEOX	Weight percentage of iron-hydroxide in the soil and aquifer.	0.44	0.44	0.44	0.44	0.44	50% tile value in HWIR FEOX data base.
LOM	Concentration (mg/L) of dissolved organic carbon in the waste leachate.	0.004	0.004	0.004	0.004	0.004	50% tile value in HWIR data base.
USNOM	Unsaturated zone percentage organic matter.	0.105	0.105	0.105	0.105	0.105	Mean value for silt loam in HWIR data base.
ASNOM	Aquifer fraction organic carbon.	0.001	0.0001	0.001	0.001	0.0001	From MMSOILS data files.

Notes:

1) Presently the following METAL_ID codes are recognized: 1=Barium; 2=Cadmium; 3=Chromium (4+); 4=Mercury; 5=Nickel; 6=Lead; 7=Silver; 8=Zinc; 9=Copper; 10=Vanadium; 13=Arsenic; 14=Chromium (6+); 15=Selenium; 16=Thallium; 17=Antimony.

2) The unsaturated zone percentage organic matter varies with soil type and should be the same as that specified under the unsaturated zone specific group (see section 6.4.5).

3) The saturated zone fraction organic carbon should be the same as that specified under the aquifer specific group (see section 6.5.12).

4) MINTEQ nonlinear isotherms have been provided for different combinations of pH, % wt. FeOH, and organic carbon contents.

Table 5. Input Parameters for Unsaturated Zone Specific Data

Variable	Description	Value					Comments
		A	O	F	G	J	
SATK	Saturated hydraulic conductivity, K_s, (cm/hr).	0.15	0.23	0.15	21	21	From MMSOILS data files consistent with Exhibit 8-2 of RTC.
ALPHA	Moisture retention parameter, α, (cm^{-1}).	0.019	0.019	0.019	0.019	0.019	Mean value for silt loam in HWIR data base.
BETA	Moisture retention parameter, β.	1.409	1.409	1.409	1.409	1.409	Mean value for silt loam in HWIR data base.
WCR	Residual water content, θ_r.	0.068	0.068	0.068	0.068	0.068	Mean value for silt loam in HWIR data base.
WCS	Saturated water content, θ_s.	0.471	0.464	0.471	0.437	0.437	From MMSOILS data files.
DSOIL	Thickness of unsaturated zone (m).	1.83	2.13	3.05	0.305	3	From MMSOILS data files consistent with Exhibit 8-2 of RTC.
DISPR	Dispersivity, α, (m)	✓	✓	✓	✓	✓	Derived parameter from Gelhar et al. (1992) emperical relation.
POM	Percent organic matter	1	0.225	1	0.55	0.0001	From MMSOILS data files consistent with Exhibit 8-2 of RTC.
RHOB	Bulk density, ρ_b, (g/cm^3)	1.36	1.39	1.36	1.64	1.64	From MMSOILS data files consistent with Exhibit 8-2 of RTC.

Reference:

Gelhar, L.W., C. Weltry, K.R. Rehfeldt, 1992. A critical review of data on field-scale dispersion in aquifers. Water Resourc. Res; 28(7), 1955-1974.

Table 6. Input Parameters for Aquifer Specific Data

Variable	Description	Value					Comments
		A	O	F	G	J	
DIAM	Average particle diameter (cm)	0.0025	0.0025	0.0025	0.0025	0.0025	Median value from HWIR data base.
POR	Aquifer porosity	0.4	0.1	0.4	0.01	0.36	From MMSOILS data files. Note: Data file has 36 for landfill 5.
BULKD	Aquifer bulk density (g/cm^3)	1.59	1.67	1.59	2.25	1.67	From MMSOILS data files.
ZB	Aquifer Saturated thickness (m)	7.7724	45.7	7.7724	175.26	36.576	From MMSOILS data files.
XKX	Longitudinal hydraulic conductivity, K_x, (m/y) C.T. H.E.	111.252 1112.52	26.70048 267.0048	111.252 1112.52	76897.3824 153794.76	890. 8900.	From MMSOILS data files.
ANIST	Anisotropy ratio, K_x/K_z	1	1	1	1	1	Assumed.
GRADNT	Hydraulic gradient (m/m)	0.005	0.02	0.005	0.0001	0.035	From MMSOILS data files.
AL	Longitudinal dispersivity, α_L (m)	10	0.1	0.1	0.1	0.1	From MMSOILS data files.
AT	Transverse dispersivity, α_T (m)	0.02	0.02	0.02	0.02	0.02	From MMSOILS data files.
AV	Vertical dispersivity, α_V (m)	0.01	0.01	0.01	0.01	0.01	From MMSOILS data files.
PH	Ambient groundwater pH C.T. H.E.	6.8 7.9	6.8 7.9	6.8 7.9	6.8 7.9	6.8 7.9	50 and 10% tile value in HWIR data base.
FOC	Fraction organic carbon (g/g)	0.001	.0001	0.001	0.001	0.0001	From MMSOILS data files.

Table 6. Input Parameters for Aquifer Specific Data (cont.)

Variable	Description	Value					Comments
		A	O	F	G	J	
XWELL(I),	Distance in downstream direction (m) between downstream edge of the source and observation well. Repeat this record for each of the NWELLS observation wells.	305,0,0 20,0,0 483,0,0 10,0,0 50,0,0 201,0,0	805,0,0; 100,0,0 20,0,0 1610,0,0 10,0,0 50,0,0 201,0,0	305,0,0; 10,0,0 20,0,0 966,0,0 10,0,0 50,0,0 201,0,0	402,0,0; 100,0,0 20,0,0 1610,0,0 10,0,0 50,0,0 201,0,0	402,0,0; 100,0,0 20,0,0 550,0,0 10,0,0 50,0,0 201,0,0	Ag field K Ex field R Mei H (Compliance point) POC1 POC2 Private well point on Center line
YWELL(I),	Horizontal transverse distance of well from the plume centerline (m). Repeat this record for each of the NWELLS observation wells.	603,0,0 1006,0,0 1408,0,0 2011,0,0 2816,0,0	603,0,0 1006,0,0 1408,0,0 2011,0,0 2816,0,0	603,0,0 1006,0,0 1408,0,0 2011,0,0 2816,0,0	603,0,0 1006,0,0 1408,0,0 2011,0,0 2816,0,0	603,0,0 1006,0,0 1408,0,0 2011,0,0 2816,0,0	Private well point on Center line Private well point on Center line Private well point on Center line Private well point on Center line Private well point on Center line
ZWELL(I)	Depth of well below water table (m). Repeat this record for each of the NWELLS observation wells. Note ZWELL should be given as a fraction of the saturated zone thickness, unless distribution type 12 (Section 6.5.13), i.e. constant well depth, is being used.	167,265,0 502,488,0 836,712,0 1171,936,0 1672,1271,0 2341,1718,0	167,175,0 502,398,0 836,622,0 1171,846,0 1672,1181,0 2341,1628,0	167,143,0 502,367,0 836,590,0 1171,814,0 1672,1149,0 2341,1596,0	167,144,0 502,367,0 836,591,0 1171,815,0 1672,1150,0 2341,1597,0	167,156,0 502,380,0 836,604,0 1171,827,0 1672,1162,0 2341,1609,0	Private well point on 2nd sector Private well point on 2nd sector Private well point on 2nd sector Private well point on 2nd sector Private well point on 2nd sector Private well point on 2nd sector

Table 7. Infiltration Rates Dependent on Location, from HWIR Data Base

Facility ID	Facility Name	City	State	Infiltration (m/y)			Nearest Climatic Center	Climatic Center # (from EPACMTP data base)
				Silt Loam	Sandy Loam	Silty Clay Loan		
*A	Ashgrove	Chanute	KS	0.0686	0.1006	0.0456	Tulsa, OK	34
O	Giant	Haryville	SC	0.2609	0.3287	0.2123	Charleston, SC	93
*F	LA FARGE	Fredonia	KS	0.2609	0.3287	0.2123	Tulsa, OK	93
G	RINCEE	Miami	FL	0.1450	0.2201	0.1019	Miami, FL	97
J	Southdown	Lyons	CO	0.0008	0.0008	0.0036	Denver, CO	03

*Facilities where nearest climatic center is not located in the same state.