ECF-Hanford-12-0004
Revision 1

STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for 100 Area F and IU Source Areas

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

P.O. Box 1600
Richland, Washington 99352

Approved for Public Release;
Further Dissemination Unlimited

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Draft D	Revised calculation to use updated EPA IRIS (Integrated Risk Information System) basis.	05/03/2013	All ☒
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Environmental Calculation File

STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for 100 Area F and IU Source Areas

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Terms

ARARs	applicable regulations and requirements
CHPRC	CH2M HILL Plateau Remediation Company
COPC	contaminant of potential concern
CPK	peak groundwater concentration
DOE	U.S. Department of Energy
ECF	environmental calculation file
EPA	U.S. Environmental Protection Agency
EQL	estimated quantitation limit
FEPs	features, events, and processes
HEIS	Hanford Environmental Information System (environmental database)
HISI	Hanford Information System Inventory (software database)
MCL	maximum contaminant level
PNNL	Pacific Northwest National Laboratory
POCal	point of calculation
PRG	preliminary remediation goal
OU	Operable Unit
RAG	remedial action goal
RESRAD	RESidual RADiation (screening software)
RI/FS	Remedial Investigation/Feasibility Study
RUM	Ringold upper mud
SSL	soil screening level
STOMP	Subsurface Transport Over Multiple Phases (modeling software)
TINs	triangulated irregular networks
WQS	water quality standard

1 Purpose

The purpose of this environmental calculation file (ECF) is to provide soil screening levels (SSLs) and preliminary remediation goals (PRGs) for protection of surface water and of groundwater in the 100-FR-1, 100-FR-2, 100-IU-2, and 100-IU-6 source Operable Units (OUs). This calculation is performed with models implemented in the STOMP (Subsurface Transport Over Multiple Phases) fate and transport simulation software (PNNL-11216, *STOMP Subsurface Transport Over Multiple Phases: Application Guide*; PNNL-12030, *STOMP Subsurface Transport Over Multiple Phases: Theory Guide*; PNNL-15782, *STOMP Subsurface Transport Over Multiple Phases: Version 4.0: User's Guide*). This calculation follows the approach set forth in DOE/RL-2011-50, *Regulatory Basis and Implementation of a Graded Approach to Evaluation of Groundwater Protection.* Detailed information on the development and basis of the models implemented in STOMP for this calculation is provided in SGW-50776, *Model Package Report: Vadose Zone Model for the River Corridor*.

SSLs are used to identify areas needing further investigation. PRGs represent soil concentration or radionuclide activity that can remain in the vadose zone at a site without causing an exceedance of groundwater, or surface water, quality standards. Based on numerical flow and solute transport simulations developed using a number of bounding assumptions, SSLs and PRGs specific to the 100-F, 100-IU-2, and 100-IU-6 source areas were calculated for 192 non-radionuclides and 29 radionuclides in groundwater and 192 non-radionuclides in surface water (specifically, the Columbia River). The approach used here is to calculate SSLs in the same manner as PRGs, with the difference being that SSLs are calculated using higher recharge rates based on an irrigated farming scenario (recognizing this is not the planned land use for these OUs), while PRGs are based on planned land use of conservation with native vegetation. This approach honors the primary importance of recharge as parameter influencing breakthrough rates for vadose zone contamination into groundwater, and uses irrigation recharge rates to provide an upper bound on this parameter for screening purposes. The SSL and PRG values produced in this calculation are only applicable to the specified OU for those waste sites where the assumptions and conditions described in this ECF are representative.

Conceptual and numerical models of flow and solute transport under variably saturated conditions were developed for conditions that are representative of the lithology and hydrology observed at various waste sites within the 100-F, 100-IU-2 and 100-IU-6 source areas. Conditions specific to the 100 Area, or the 100-F, 100-IU-2, or 100-IU-6 OUs, include time-varying recharge rates specific to the 100 Area, OU-specific vadose zone thickness and lithology, area-specific hydraulic properties, and OU-specific aquifer fluxes. The numerical model implementing the conceptual model is developed assuming that aqueous-phase flow under variably saturated conditions follows the Richards equation and the transport of dilute solutes follows the advection-dispersion equation with radioactive decay and linear sorption and no volatilization or hydrodynamic dispersion.

Contaminant migration from waste sites in the 100-F, 100-IU-2, and 100-IU-6 source areas through the vadose zone to the underlying aquifer is controlled by the driving forces, interactions between water and sediments, and interactions between the contaminants and the sediments. The hydraulic driving forces include gravity; matric potential gradients; recharge, which is the end result of competition between precipitation, evaporation, transpiration, infiltration, run-off, and run-on; and man-made discharges, such as those from septic tank leach fields, ponds, lagoons, pipe and tank leaks, and irrigation. The types, thicknesses, and properties of the sediments can all affect the rate and direction of solute and water movement to the aquifer. A concentration of a contaminant in the groundwater (and in the downgradient Columbia River) are dependent on the solute flux from the vadose zone; aquifer thickness, properties, and flux rates; travel distance; groundwater and river water mixing; and the location sampled. Each

contaminant's propensity to sorb to vadose zone or aquifer materials can also be important controlling factors on the groundwater concentration determination.

The STOMP-W (water) operational mode of the STOMP code was used to implement the model for this calculation. The STOMP-W (water) operational mode solves the Richards equation (termed the water mass conservation equation in STOMP, which for water phase only reduces to the Richards equation) and the advection-dispersion equation (termed the solute mass conservation equation in STOMP) for dilute solute transport in the aqueous phase under variably saturated conditions in porous media. The governing equations solved by the STOMP software are presented in PNNL-12030. The STOMP numerical simulations provided predictions of groundwater concentration and time to reach the breakthrough of the maximum concentrations for a list of contaminants based on a range of recharge rate scenarios, sediment types, vadose zone thicknesses, and properties appropriate to the 100-F, 100-IU-2, and 100-IU-6 Areas. The peak concentration within 1000 years was used in calculating SSLs and PRGs. The 1000-year limit was based on regulatory agreement.

2 Methodology

One-dimensional fate and transport simulations were used to calculate unit-length SSL and PRG values for the 100 Area 100-F, 100-IU-2, and 100-IU-6 source areas. The STOMP code was selected to perform these simulations on the basis of its ability to adequately simulate the vadose zone features, events, and processes (FEPs) relevant to calculating unit-length SSLs and PRGs in the 100-Area and to satisfy the other code criteria and attributes identified in DOE/RL-2011-50. DOE/RL-2011-50 describes the approach and provides the regulatory basis for using STOMP in this type of evaluation. Detailed information on the development and basis of the models used in this calculation are provided in SGW-50776.

Many of the methodologies, model inputs, and assumptions for computing PRGs were developed to determine remedial action goals (RAGs) as part of DOE/RL-96-17, *Remedial Design Report/Remedial Action Work Plan for the 100 Area*. Although the calculation methods are similar, the RAGs were calculated with the RESRAD (RESidual RADiation) software (ANL/EAD-4, *User's Manual for RESRAD Version 6*), whereas the SSLs and PRGs in this calculation were calculated using the STOMP software.

2.1 Definition of Soil Screening Levels and Preliminary Remediation Goals

SSLs are risk-based concentrations derived from standardized equations combining exposure information assumptions with US Environmental Protection Agency (EPA) toxicity data (EPA/540/F095/041, *Soil Screening Guidance: Fact Sheet*). EPA provides a methodology for calculation of risk-based, site-specific SSLs for contaminants in soil that may be used to identify areas needing further investigation at National Priorities List sites. The approach used here is to derive SSLs in the same manner as PRGs (see below), with the only difference in the calculation being the recharge rates used to represent future conditions: PRGs are calculated based on native vegetation recharge rates, whereas SSLs are calculated based on an irrigated farming scenario. This approach recognizes the primary importance of recharge as parameter influencing breakthrough rates for vadose zone contamination into groundwater, and uses the irrigation based recharge rates as an upper bound on this parameter for screening purposes.

PRGs represent the maximum quantity, whether soil concentration or radionuclide activity, of a contaminant of potential concern (COPC) that can remain in the vadose zone without causing an exceedance of applicable regulatory standards. SSLs and PRGs can be defined for protection of groundwater or protection of surface water simply by the choice of the applicable standard used in the

calculation. The PRG calculation in this ECF is evaluated based on the peak release of a given COPC under a native vegetation recharge scenario (Section 3.2.1.1). In contrast, the SSL calculation is based on a conservative (bounding) irrigation recharge scenario (Section 3.2.1.2). The value of a SSL or of a PRG for a particular COPC depends on a number of key factors, including:

- waste site characteristics, specifically, source mass distribution and distance to the water table
- land cover condition and the associated net recharge rate
- interactions between the vadose zone geology and water movement
- interactions between the vadose zone geology and contaminant chemistry

Model simulations were carried out for the non-radionuclide COPCs identified in ECF-Hanford-10-0442, *Calculation of Nonradiological Soil Concentrations Protective of Groundwater Using the Fixed Parameter 3-Phase Equilibrium Partitioning Equation for the 100 Areas and 300 Area*, and for the radionuclide COPCs identified in ECF-Hanford-10-0429, *Documentation of Preliminary Remediation Goals (PRGs) for Radionuclides Using the IAROD Exposure Scenario for the 100 and 300 Area Remedial Investigation/Feasibility Study (RI/FS) Report*.

2.2 Identification of Representative Stratigraphic Columns

Borehole data were used to identify representative stratigraphic columns for each source area. Only two lithologic units are present in the vadose zone at 100-F, 100-IU-2, and 100-IU-6 Areas: the gravel-dominated Hanford formation and the Ringold Formation Unit E, which contains a slightly smaller percentage of coarse-grained sediments and a higher percentage of finer-grained sediments than the Hanford formation (SGW-40781, *100-HR-3 Remedial Process Optimization Modeling Data Package;* SGW-46279, *Conceptual Framework and Numerical Implementation of 100 Areas Groundwater Flow and Transport Model*).

The water table elevations of June 2008 were selected to provide representative (not extreme) high water table conditions; the month of June is typically when the highest river stages occur in this reach of the Columbia River. Use of water table elevations from the high water stage period (represented by the June 2008 data) result in a conservative (smaller) thickness of the vadose zone for each well and borehole to develop the representative stratigraphic profiles. These well and borehole data were used to estimate the thicknesses of each lithologic unit in each source within the vadose zone aquifer sediments. The wells and boreholes were grouped based on the proportion of each lithologic unit present and total vadose zone thickness. A representative stratigraphic column was selected for each well and borehole group within each source area. This process resulted in four stratigraphic columns to support model construction (see Section 3.1 below).

The peak groundwater concentrations within 1000 years was identified from the time series of solute concentrations in the water flux across the downgradient aquifer boundary (representing the 5 m monitoring well) reported by the STOMP code for each flow and transport simulation. The 1000-year timeframe for this calculation was based on regulatory agreement. The average concentration for the topmost 5 m was assumed representative of the groundwater concentration that would be measured within a 5-m long monitoring well screen that straddles the water table.

2.3 STOMP Flow and Transport Simulation

Peak groundwater concentrations in the aquifer at the downgradient edge of the modeled representative stratigraphic columns were calculated using STOMP to solve the governing equations for flow and solute transport under variably saturated conditions. Peak concentrations of selected contaminants (Section 3.3) were calculated for two different contaminant source distributions (Section 3.2.4) with two recharge scenarios and three different soil types controlling infiltration (Section 3.2.1) for each representative stratigraphic column (Section 3.1).

2.4 Point of Calculation, Point of Compliance, and Protectiveness Criteria

In accordance with risk assessment guidelines, the determination of soil contamination impacts to groundwater and surface water also requires the definition and rationale for (1) the Point of Calculation (POCal) i.e., the place/point in the groundwater domain where modeled groundwater concentrations are to be assessed for potential impacts and protectiveness (at the point of compliance), and (2) the protectiveness metric, i.e., the groundwater and surface water metric(s) to be used in the assessment of protectiveness at the POCal (DOE/RL-2011-50).

The POCal for the protection of groundwater and surface water is related to the "Exposure Point" in the context of conventional human health risk assessments (EPA/540/1-89/002, *Risk Assessment Guidance for Superfund Volume 1, Human Health Evaluation Manual [Part A]*) and to "Point of Compliance" in federal and state regulations and guidelines (DOE/RL-2011-50).

The "point of compliance" under the WAC is the soil throughout the vadose zone (WAC-173-340-740(6)(b)). The POCal is the point where the peak groundwater concentration resulting from the uniform initial soil concentration is calculated in the forward calculation. This peak groundwater concentration is then used to back-calculate the maximum allowable soil concentration at the point of compliance (all soil in the vadose zone) to determine the maximum soil contamination level that will not result in exceedance of groundwater or surface water protection levels.

For this calculation, the POCal is the outflow (downgradient) edge of the 1-D column for the grid blocks that are located in the topmost 5 m of the aquifer representing the screened portion of a monitoring well. The peak value of concentration within the topmost 5 m of the aquifer was scaled by the appropriate regulatory compliance criteria in a back-calculation step to determine unit-length SSL and PRG values for the point of compliance (vadose zone soil). The protectiveness criteria is the applicable water quality standards for groundwater and surface water (e.g., applicable regulations and requirements [ARARs], maximum contaminant levels [MCLs], or applicable water quality standards) values for each contaminant. The applicable water quality standard for each contaminant for protectiveness of groundwater and surface water in the 100F, 100-IU-2 and 100-IU-6 Areas are included in the Attachments A and B to this ECF.

2.5 Calculation of Soil Screening Levels and Preliminary Remediation Goals

The calculation of peak values of groundwater concentration with STOMP provides the first, forward calculation step to deriving unit-length SSL and PRG values. Because STOMP was used in the forward calculation to compute peak groundwater concentrations that result from a unit initial source concentration (1.0 mg/kg soil concentration, uniformly applied over the assumed contaminated thickness of the vadose zone), the result can then be used in a second, back-calculation step to determine unit-length SSL and PRG values. The second, or back-calculation, step involves scaling the peak groundwater concentration against the appropriate regulatory compliance criteria to back-calculate the maximum initial soil concentration that would not result in an exceedance. The maximum value obtained from this back-

calculation step is assigned as the unit-length SSL or PRG value (depending on the recharge scenario used). As a measure of maximum allowable contaminant concentration in the soil, unit-length SSLs and PRGs are expressed as contaminant mass times the unit distance in the direction of groundwater flow per mass of soil for non-radionuclides (e.g., mg·m/kg) and as contaminant activity times the unit distance in the direction of groundwater flow per mass of soil for radionuclides (e.g., pCi·m/g).

The unit-length SSL for each COPC is computed (in the back-calculation step) as:

$$SSL_{unit-length} = C_I \frac{WQS}{CPK} \qquad \text{Equation 1}$$

where,

$SSL_{unit\text{-}length}$ = unit-length soil screening level, expressed in units of contaminant mass or activity for each meter in the general direction of groundwater flow per unit mass of soil $\left[\frac{\text{mg}}{\text{kg}}\cdot\text{m or } \frac{\text{pCi}}{\text{g}}\cdot\text{m}\right]$

C_I = initial soil concentration, expressed as contaminant mass or activity per unit mass of soil (note this an arbitrary initial concentration used in STOMP in the forward calculation, applied uniformly over the appropriate soil depth range – see Section 3.2.4) $\left[\frac{\text{mg}}{\text{kg}} \text{or } \frac{\text{pCi}}{\text{g}}\right]$

WQS = water quality standard, expressed as contaminant mass or activity per unit volume of water $\left[\frac{\text{mg}}{\text{L}} \text{or } \frac{\text{pCi}}{\text{L}}\right]$

CPK = peak groundwater concentration, expressed as contaminant mass or activity per unit volume of water (note this is the resulting peak groundwater concentration obtained as a result from STOMP in the forward calculation for a unit-width (1-m) soil column model oriented in the direction of groundwater flow, with initial soil concentration C_I) $\left[\frac{\text{mg}}{\text{L}} \text{or } \frac{\text{pCi}}{\text{L}}\right]$

For unit-length SSL calculations with Equation 1, the *CPK* value is obtained from simulations using the conservative irrigation recharge scenario (see Section 3.2.1.2).

Similarly, the unit-length PRG for each COPC is computed (in the back-calculation step) as:

$$PRG_{unit-length} = C_I \frac{WQS}{CPK} \qquad \text{Equation 2}$$

For unit-length PRG calculations with Equation 2, the *CPK* value is obtained from simulations using the native vegetation recharge scenario (see Section 3.2.1.1).

The surface water quality standards are used as WQS values to compute unit-length SSLs and PRGs protective of surface water, whereas the groundwater quality standards as WQS values to compute unit-length SSLs and PRGs protective of groundwater. As seen from Equation 1 and Equation 2, the calculation of unit-length SSL and PRG values is the same: the difference between these is only that the results of the bounding irrigation recharge scenario are applied to the SSL calculation while the results of the native vegetation recharge scenario are applied to the unit-length PRG calculation. If a WQS was not available for a COPC, then the corresponding unit-length SSL or PRG values were encoded “NA” to signify that there was no applicable water quality standard available.

Unit-length SSL and PRG values calculated using Equation 1 and Equation 2 are compared to a set of upper and lower thresholds described in the subsections that follow, and values that exceeded these thresholds were handled as described.

The unit-length SSL and PRG values calculated using Equation 1 and Equation 2, respectively, are derived from model simulations representative of a soil column that extends a distance of one meter along the general direction of groundwater flow. To determine waste-site values for evaluation of exposure point concentrations (EPCs), the unit-length values are divided by the representative length of the waste site in the general direction of groundwater flow. To illustrate this concept, assume that the calculated unit-length SSL for some COPC is $10\,\frac{mg}{kg}\cdot m$ (Figure 1a). That means that a concentration of 10 mg/kg of the COPC in the vadose zone of a one-meter wide soil column results an outflow from that column of groundwater with a concentration equal to the MCL. Suppose, however, that the waste site under consideration has a representative length of 5 m – i.e., extends 5 m in the general direction of groundwater flow. This situation can be represented as five one-meter wide soil columns assembled in series along the direction of groundwater flow (Figure 1b). In this case, the contamination from each individual column contributes to the outflow concentration in groundwater, so the five-meter effective SSL for evaluation of this specific waste site ($SSL_{evaluation}$) would be

$$SSL_{evalaution} = \frac{SSL_{unit-length}}{L_{\parallel GW}} = \frac{10\,\frac{\mathrm{mg}}{\mathrm{kg}}\cdot \cancel{\mathrm{m}}}{5\,\cancel{\mathrm{m}}} = 2\,\frac{\mathrm{mg}}{\mathrm{kg}}$$

Where $SSL_{evaluation}$, used for evaluation of EPC values,is calculated by scaling the unit-length value ($SSL_{unit\text{-}length}$) by $L_{\parallel GW}$, the representative lineal dimension of the waste site decision unit in the general direction of groundwater flow.

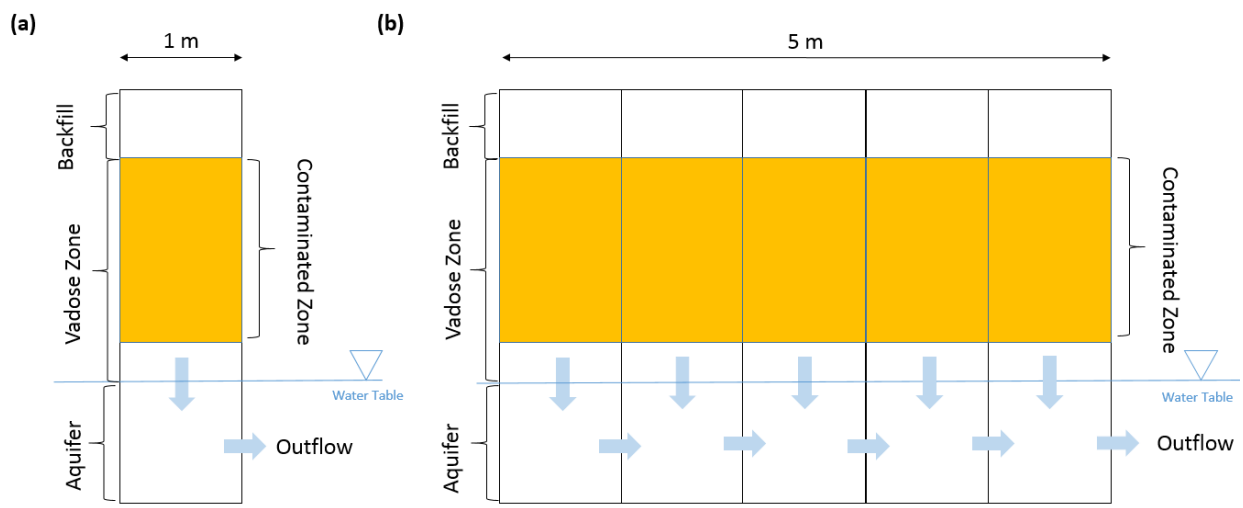


Figure 1. Example of Application of Unit-Length SSL or PRG to a Waste Site Decision Unit

When scaling the unit-length SSL or PRG values for use in comparison to EPC values, two additional checks are required;

1. It is possible that scaling by the representative waste site decision unit dimension could result in evaluation SSL or PRG values that are less than the background level for a given COPC; in these cases, the EPC will not be considered to exceed the evaluation (scaled) SSL or PRG values; and

2. It is possible that scaling by the representative waste site decision unit dimension could result in evaluation SSL or PRG values that are less than the estimated quantification limit (EQL); in these cases, the EPC will not be considered to exceed the evaluation (scaled) SSL or PRG values.

2.5.1 Lower Threshold of Numerical Significance for Peak Groundwater Concentrations

Breakthrough is assumed not to occur in cases where the simulated peak groundwater concentration within the 1000-year limit does not exceed 0.0001 µg/L for non-radionuclide COPCs, or 0.0001 pCi/L for radionuclide COPCs in at least two representative stratigraphic columns. This breakthrough threshold is used to set a minimum level of numerical significance for groundwater peak concentrations reported by the numerical model. Use values less than this breakthrough threshold would result in extremely high unit-length SSL or PRG values that would not constitute a meaningful limit on residual soil contamination. Consequently, where breakthrough does not occur under this assumption, the unit-length SSL or PRG value is encoded "NR" to signify a non-representative result.

2.5.2 Lower Threshold of Estimated Quantitation Limit for Soil Screening Levels and Preliminary Remediation Goals

If the unit-length SSL or PRG calculated for a given COPC is below the EQL for the soil concentration of that COPC, then the EQL is substituted for the unit-length SSL or PRG value as a lower bound. The soil EQL represents the lowest concentration that can be reliably measured within specified limits of precision and accuracy during routine laboratory operating conditions. EQLs are normally arbitrarily set rather than explicitly determined; for this calculation, EQLs are those specified in Appendix A of DOE/RL-2009-43 Rev. 0, *Sampling and Analysis Plan for the 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units Remedial Investigation/Feasibility Study*.

2.5.3 Upper Threshold of Pore Space Maximum Contaminant Mass Capacity for Non-radionuclide Soil Screening Level and Preliminary Remediation Goal Values

Unit-length SSL and PRG values were calculated from the peak groundwater concentrations using Equation 1 and Equation 2, respectively, and the applicable surface water and groundwater regulatory standards. Where simulated peak groundwater concentrations were very small, application of Equation 1 and Equation 2 would yield physically unrealistic soil concentrations, e.g., 10 kg of aluminum per 1 kg of soil. Listing such unphysical protection levels is not meaningful, so an upper physical bound for unit-length SSL and PRG values is specified here that is derived based on considering the extreme of total contaminant mass that can occupy the soil pore space within a unit mass (1.0 kg) of bulk soil. The bulk density (ρ_b) of 100 Area soils is 1930 kg/m^3, so the total volume (V_T) of this soil (sum of soil and pore space) is calculated as

$$V_T = \frac{m_{soil}}{\rho_b} = \frac{1\ \text{kg}}{1930\,\frac{\text{kg}}{\text{m}^3}} = \ 5.18 \times 10^{-4}\ \text{m}^3$$

At maximum, COPC mass is assumed to occupy the total porosity fully. Therefore, the maximum mass of COPC in the soil is calculated as

$$m_{max,p} = \ n_T \times V_T \times \rho_p \qquad \text{Equation 3}$$

where n_T is the total porosity and ρ_p is the particle density of the COPC. In the 100 Area, the highest total porosity of Hanford or Ringold is 0.28. The particle density of the COPC is assumed equal the highest

particle density of the Hanford or Ringold, 2650 kg/m^3 for the Hanford formation (PNNL-18564). Substituting into Equation 3, the maximum mass of COPC in 1.0 kg soil is calculated as:

$$m_{max,p} = (0.28) \times \left(5.18 \times 10^{-4}\ \mathrm{m}^3\right) \times \left(2650\ \frac{\mathrm{kg}}{\mathrm{m}^3}\right)$$
$$= 0.384\ \mathrm{kg} \times \left(\frac{1{,}000{,}000\ \mathrm{mg}}{1\ \mathrm{kg}}\right) = 384{,}000\ \mathrm{mg}$$

Thus, the maximum unit-length SSL or PRG value for non-radionuclides is 384,000 mg·m per kg of soil. Therefore, unit-length SSL or PRG values that exceed this physical upper bound are truncated at physical upper bound value 384,000 mg·m/kg. Note that this physical upper bound is not applied to radionuclide unit-length SSL or PRG values because these are expressed in terms of activity rather than mass.

A similar threshold was presented for maximum radioactivity in soil in SGW-50776. However, it was redundant to apply that limit here because a value for that would exceed that limit would also exceed the lower threshold of numerical significance for peak groundwater concentrations (Section 2.5.1).

2.5.4 Cleanup Levels for Hexavalent Chromium based on Limitation of Sorption Data

ECF-Hanford-11-0165, *Evaluation of Hexavalent Chromium Leach Test Data Conducted on Vadose Zone Sediment Samples from the 100 Area*, provides quantitative evaluations of leach test results and the derivation of a conservative-basis K_d for hexavalent chromium for evaluation of future fate and transport of residual vadose zone contamination after interim remedial actions have been implemented for source waste sites in the vadose zone. These evaluations were based on the results of leaching studies conducted on soil samples from a large number (about 200) of leach studies for vadose zone soils across the River Corridor, including both high concentration/low volume waste sites, low concentration effluent waste sites, and boreholes not associated with a waste site. The soil concentration data for which the K_d value was derived had a maximum value of 6.0 mg/kg, and hence there is no basis to infer greater soil cleanup levels for hexavalent chromium based on the limited range of these data. These leach test data also indicate that for hexavalent chromium at concentrations below 6.0 mg/kg are highly non-leachable. Therefore, the SSL and PRG values for hexavalent chromium using the K_d recommended in ECF-Hanford-11-0165 (0.8 mg/L) are set to a soil concentration value of 6.0 mg/kg, consistent with the data range and leaching test results. This value is not scaled by the representative dimension in the general direction of groundwater flow because the basis for the K_d value are bounding results for intentionally aggressive leaching methods that showed Cr(VI) concentrations below 6 mg/kg in the vadose zone are highly non-leachable – a result that is not dependent on the dimensionality of the model. Additionally, note that the soil PRG values for protection of groundwater and surface water for hexavalent chromium is not based on the results of fate and transport modeling, but rather on interim cleanup actions (originally based on the “100 times rule) which assigns the more restrictive value of 2.0 mg/kg.

3 Assumptions and Inputs

A pair of sequential STOMP simulations was used to determine peak groundwater concentrations. The first simulation, called the historic (pre-2010) simulation, simulated water flow in the representative stratigraphic columns for a 2010-year period ending in the calendar year 2010. The purpose of this first long simulation period was first to achieve equilibrium in the flow conditions and moisture content in the model domain at long-term native vegetation conditions (by simulating for an arbitrarily long time) and then simulate subsequent flow conditions and moisture content resulting from changes in surface conditions up to calendar year 2010. Review of the matric potential and volumetric water content values at the end of the arbitrarily long period simulated with native vegetation recharge rates were checked to

confirm that equilibrium (steady state) conditions had been attained, confirming that the arbitrary period chosen was sufficiently long. Results from the historic (pre-2010) simulations provided the initial aqueous pressure conditions (and hence moisture content distribution) for the second simulation, called the predictive (post-2010) simulation. This second simulation solved for water flow and for contaminant transport for 1000 years, using the initial moisture conditions from the first simulation and a bounding assumption for the initial distribution of COPC contaminant mass or activity in the soil profile. The predictive (post-2010) simulation was repeated for each COPC, using the appropriate distribution coefficient (K_d) and half-life (where applicable, for radionuclides) to predict the peak groundwater concentrations of each COPC resulting from its assumed bounding initial contamination levels, and to determine the year of occurrence of that peak groundwater concentration.

STOMP estimates of contaminant concentration depend on the model inputs and assumptions. Inputs to the models and their underlying assumptions are divided into the following categories for discussion:

- Model domain
- Boundary and initial conditions
- Hydraulic parameters
- Contaminant transport parameters
- Simulation duration
- Uncertainties, assumptions, and conservatism

Each of these input categories are discussed in the sub-sections that follow.

3.1 Model Domain

Conceptually, the model represents a column of sediments that comprise a vadose zone underlain by an aquifer. Recharge-driven flow moves downward through the vadose zone, where it encounters contamination that is eventually transported to an underlying aquifer, across which a pressure gradient drives horizontal flow. At the start of each predictive (post-2010) simulation, the vadose zone comprises a cover of clean fill with constant thickness as well as contaminated and uncontaminated sediments of varying thickness. The aquifer constitutes the base of the column with a minimum thickness of 5 m so that a 5-m-long monitoring well screen could be simulated. Depending on source-area-specific geology, the vadose zone comprises either Hanford formation alone or a combination of Hanford and Ringold Unit E, whereas the saturated zone can comprise only Hanford, a combination of Hanford and Ringold Unit E, or only Ringold Unit E. If present, the contact between the Ringold Unit E and the Ringold upper mud (RUM) forms the bottom of the aquifer.

The model represents the vadose zone as a vertical one-dimensional column of evenly spaced grid blocks, each containing a node at the centroid. In STOMP, boundary conditions are specified at the faces of the grid blocks, so each grid block is assigned an arbitrary but constant length to avoid large grid Courant numbers in the aquifer grid blocks during transport simulations. Each grid block is 0.25 m in height and 10 m in length. A length of 10 m was chosen to reduce the Courant number below 1.0 to control numerical dispersion. The Courant number represents a simple guideline for selecting grid element and time step size to limit numerical dispersion in advection dominated problems (Huyakorn and Pinder, 1983). In practice, the time step is easier to control in a simulation because the grid is fixed in advance. STOMP includes an automatic Courant limitation scheme that automatically subdivides transport time

steps within flow-solution time steps to ensure the Courant limit is maintained throughout the computational mesh; this feature of STOMP was used in this calculation. Following the simulation, the contaminant aqueous concentration output was scaled back to 1.0 m length by taking the aqueous concentrations and dividing by 10. The accuracy of this methodology was verified through simulation with varying grid dimensions (not presented here).

Grid block Courant numbers for the aquifer grid blocks, in which flow is horizontal under fully saturated conditions, was all less 1.0. Grid block Courant numbers for the vadose zone grid blocks, in which flow is vertical under variably saturated conditions, were all less 1.0 for all recharge scenarios.

Total column thickness and the thickness of the vadose zone vary according to the geology of each source area. Only the thickness of the clean backfill was held constant at 4.5 m. Thickness of the vadose zone, thickness of the aquifer (saturated zone), and the percentages of the different lithologic units in each were determined using borehole data from the Hanford Environmental Information System (HEIS) borehole database (Table 1 and Table 2). A conservative (thinner) estimate of vadose zone thickness was calculated by taking the difference between ground surface elevation and the June 2008 water table elevation, which is representative of the seasonal high water table elevation.

Because of natural variability in the thickness of various hydrostratigraphic units, it is not practical to calculate unit-length SSL or PRG values for all possible variations in thicknesses observed in the various boreholes. Instead, representative stratigraphic columns were identified. Representative columns were identified by collecting and reviewing geologic data from boreholes nearest to the waste sites in each source area. All borehole data were taken from the HEIS borehole database. The columns include the vadose zone and the unconfined aquifer. Using water table elevations to represent the annually occurring highest water table, a conservative (smaller) thickness of the vadose zone was computed for each borehole. The borehole data also provided estimates of the thicknesses of each lithologic unit within the vadose zone and within the aquifer. The boreholes were divided into groups based on the proportion of each lithologic unit and total vadose zone thickness for each source area. This process yielded four representative vadose zone thicknesses of 12, 10, 8, and 12 m for 100-F and four vadose zone thicknesses of 40, 22, 10, and 8 m of 100-IU-2/100-IU-6. Examination of all wells within the 100-F 12-m-thickness group reveals a range of compositions for the vadose zone, but the 10 boreholes in this group can easily be divided into two sub-groups (Table 1):

Table 1. Determination of Vadose Zone and Saturated Zone Thickness and Geology for the 100-FR-1 and 100-FR-2 Source Areas

Representative Column Index	Representative VZ Thickness (m)	Representative VZ Composition	Thickness of Hanford in VZ (m)	Thickness of Ringold E in VZ (m)	Corresponding Wells	Actual VZ Composition	Actual VZ Thickness (m)	Actual Aquifer Thickness (m)	Average SZ Thickness (m)	SZ Composition
100-F Column 1	12	100% Hanford	12	0	199-F5-46	100% Hanford	12.40	4.82	6.14	100% Hanford
					199-F5-45		11.81	3.89		
					199-F5-52		12.22	7.90		
					199-F5-2		11.38	11.79		
					199-F5-54		11.53	9.74		
					199-F5-47		13.42	5.63		
					199-F5-4		12.10	3.14		
					199-F8-4		11.31	2.86		
					199-F8-2		11.00	5.46		
100-F Column 2	10	100% Hanford	10	0	199-F5-5	100% Hanford	10.77	11.18	10.39	100% Hanford
					199-F5-6		10.95	10.08		
					199-F5-3		9.90	9.91		
100-F Column 3	8	100% Hanford	8	0	199-F5-1	100% Hanford	9.00	9.90	4.94	100% Hanford
					199-F8-3		7.45	1.70		
					199-F6-1		8.28	6.96		
					199-F8-7		8.53	1.22		
100-F Column 4	12	40% Hanford 60% Ringold E	4.8	7.2	199-F5-48	43% Hanford 57% Ringold E	12.76	3.09	3.09	100% Ringold E

VZ = vadose zone; SZ = saturated zone

Table 2. Determination of Vadose Zone and Saturated Zone Thickness and Geology for 100-IU-2 and 100-IU-6 Source Areas

Representative Column Index	Representative VZ thickness (m)	Representative VZ Composition	Thickness of Hanford in VZ (m)	Thickness of Ringold E in VZ (m)	Corresponding Wells	Actual VZ Composition	Actual VZ thickness (m)	Actual Aquifer thickness (m)	Average Aquifer thickness (m)	SZ Composition
100-IU Column 1	40	100% Hanford	40	0	699-67-51	100% Hanford	40.02	23.99	23.99	17% Hanford 83% Ringold E
100-IU Column 2	22		22	0	699-65-50		22.54	12.51	12.51	100% Hanford
100-IU Column 3	10		10	0	699-77-36		10.19	5.05	6.49	
					699-80-43P		9.11	4.61		
					699-63-25A		9.10	9.80		
100-IU Column 4	8		8	0	699-80-39B		7.42	5.69	5.11	
					699-80-43Q		8.84	4.88		
					699-80-43R		8.94	4.78		

VZ = vadose zone; SZ = saturated zone

- 100% Hanford formation
- 40% Hanford formation / 60% Ringold Unit E

A 5-m thickness of the saturated zone (aquifer) was used in STOMP simulations in accordance with WAC 173-340-747(5)(f)(i) and equation 747-4 for A, aquifer mixing zone. Figure 2 depicts the representative stratigraphic columns for the 100-FR-1 and 100-FR-2 OUs, and Figure 3 depicts the representative stratigraphic columns for the 100-IU-2 and 100-IU-6 OUs. Each column was assumed to contain clean backfill in the uppermost 4.5 m of the column, representing conditions following interim remediation.

STOMP's inactive nodes feature was not used in this model.

3.2 Boundary Conditions and Initial Conditions

Solving the governing equations for variably saturated flow and transport requires specification of boundary conditions and initial conditions. A complete set of boundary and initial conditions must be specified for each governing equation for input to STOMP.

For the water mass conservation equation, flow boundary conditions were specified to represent one-dimensional vertical flow in vadose zone resulting from recharge through the top boundary, and lateral flow in the saturated zone in response to the hydraulic gradient. A Neumann-type (specified flux) boundary condition was applied at the top surface to simulate effective recharge; the flux rate was varied, stepwise constant, to represent different recharge rates over time. Neumann-type boundary conditions with no flow (zero flux) were assigned to all the vertical boundaries (east, west, south, and north) of the vadose zone to maintain one-dimensional, vertical flow. The bottom boundary of the model domain was assigned a Neumann-type boundary condition with no-flow (zero flux) to constrain the aquifer to a 5-m thickness (Figure 4a). The east and west boundaries of the saturated zone portion of the domain was assigned a hydraulic gradient boundary condition to maintain the specified lateral flow rate in the aquifer, while the north and south boundaries were assigned Neumann-type boundary conditions with no flow (zero flux) to constrain the aquifer flow to a one horizontal direction. Note here that in discussing lateral boundaries, the directions east, west, north, and south are conventions used in the STOMP code. For this model, these direction references do not (necessarily) align to cardinal directions for any given actual waste site. Rather, the east-west dimension in this STOMP representation is intended to represent (align to) the direction of groundwater flow for any waste site.

For the solute mass conservation equation, specified zero-flux boundaries were applied at the top of the model domain, along both edges of the vadose zone, along the upgradient edges of the aquifer grid blocks, and the bottom of the aquifer (Figure 4b). The downgradient edges of the aquifer grid blocks were assigned STOMP's outflow solute type boundary condition (see page 6.21 of PNNL-12030, and page 4.4 of PNNL-15782), which transports solute mass out of the domain according to the advective flux term in the solute mass conservation governing equation but does not allow solute to enter back into the domain.

3.2.1 Upper Boundary Conditions

For water flow, a time-varying Neumann type (specified water flux) boundary condition was applied at the top surface (Figure 4a) to represent net infiltration (destined to become recharge). The net infiltration into the vadose zone, which is used in the model to represent the recharge into the aquifer, is driven by the competition between precipitation, potential evaporation, transpiration, run-off and run-on. In an arid or semi-arid climate, downward fluxes resulting from this competition are episodic and usually infrequent, but this effect is typically damped towards a nearly constant rate with depth as soil moisture variability with depth measured at Hanford Site lysimeters shows (PNNL-17841, *Compendium of Data for the*

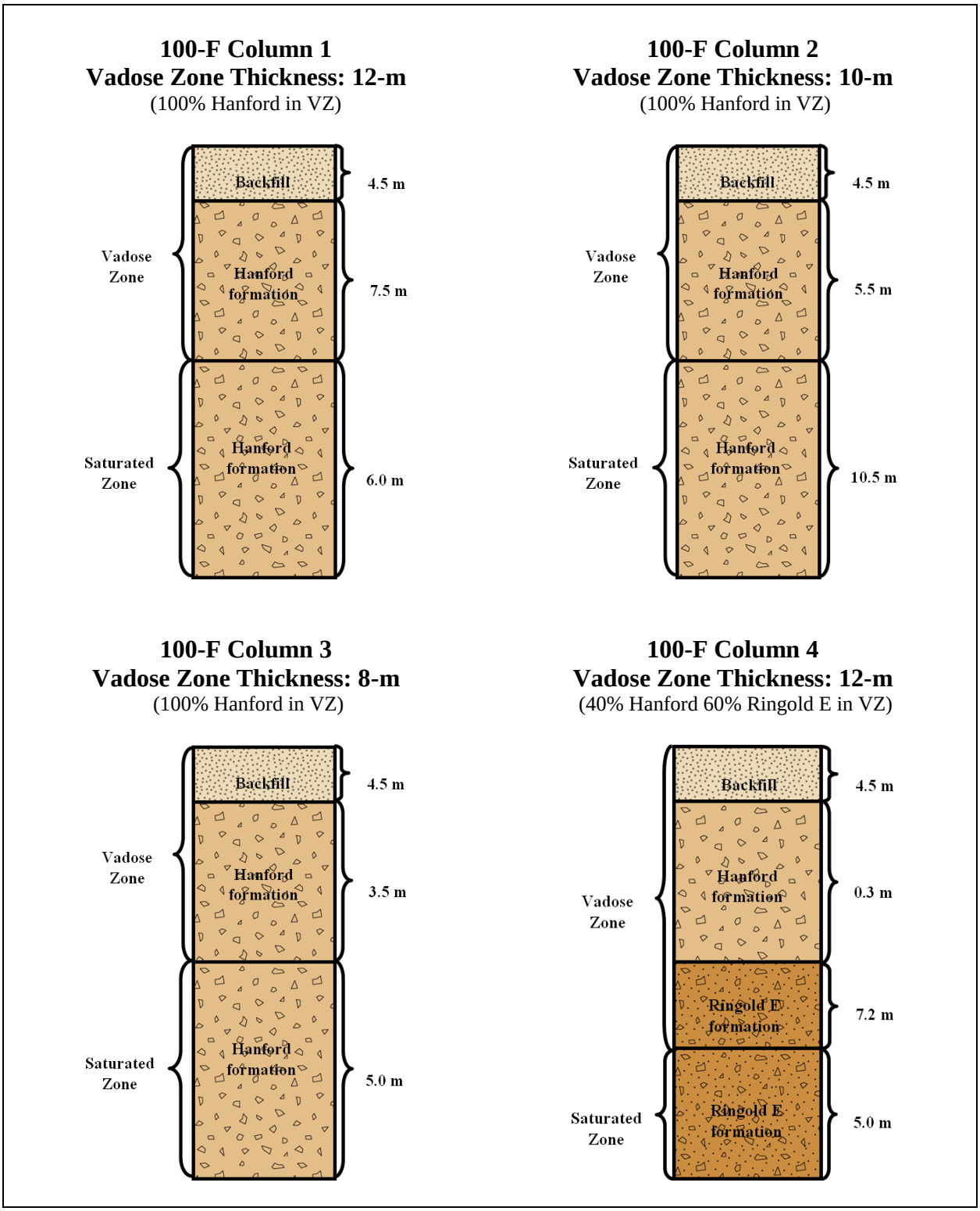


Figure 2. Representative Stratigraphic Columns for 100-FR-1 and 100-FR-2 Operable Units

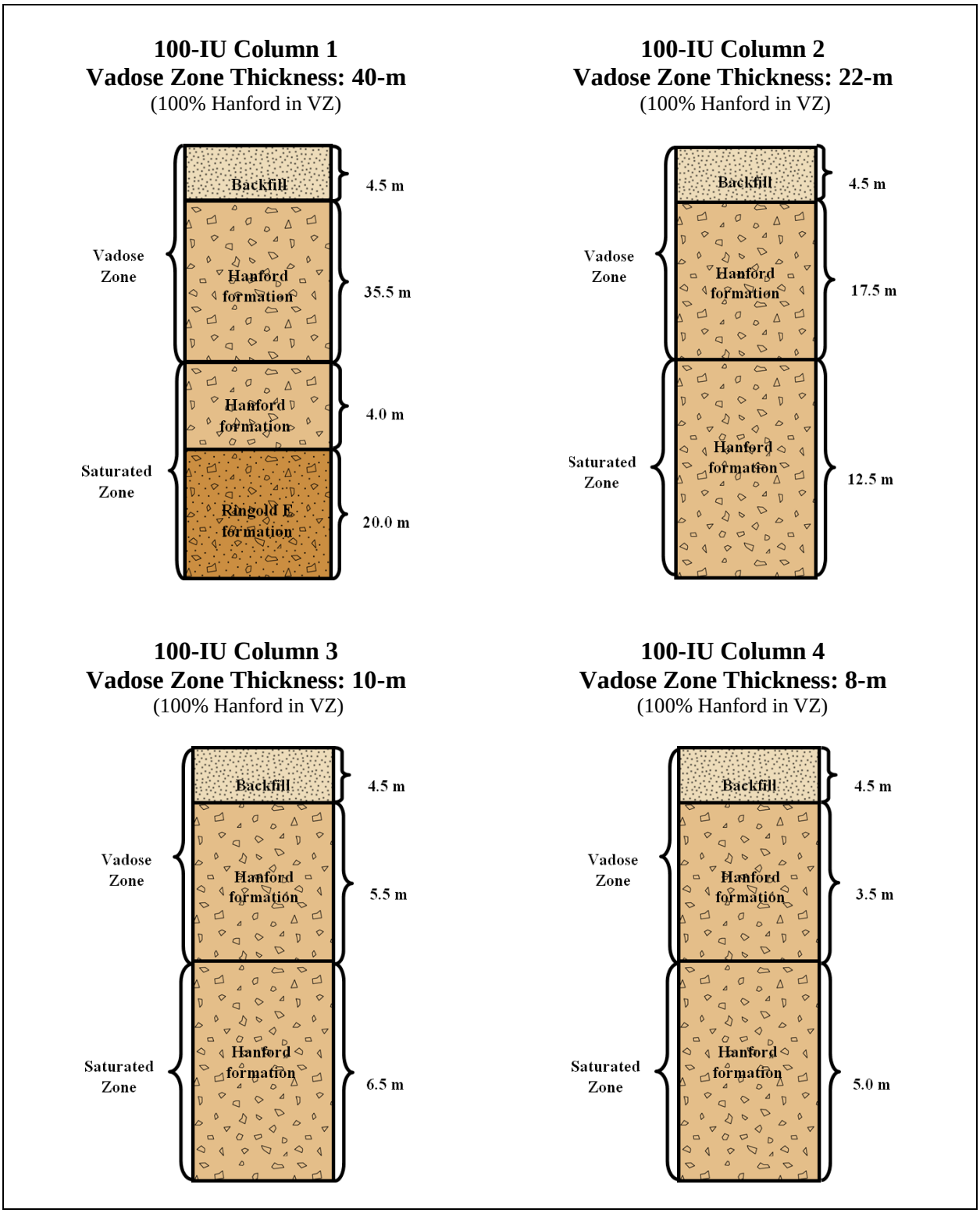


Figure 3. Representative Stratigraphic Columns for 100-IU-2 and 100-IU-6 Operable Units

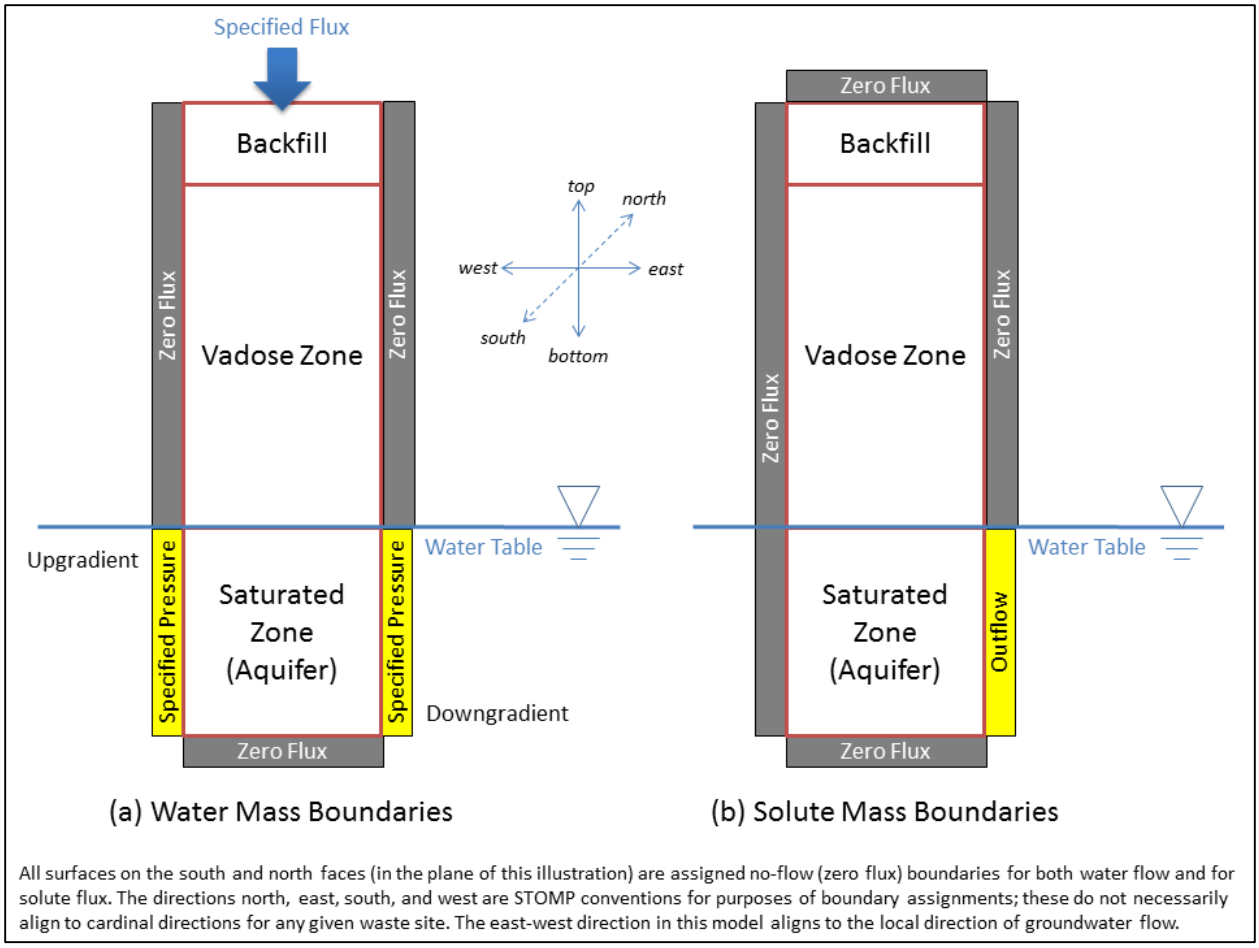


Figure 4. Boundary Conditions for (a) Water Mass and (b) Solute Mass Conservation Equations

Hanford Site (Fiscal Years 2004 to 2008) Applicable to Estimation of Recharge Rates). This is the basis for representing recharge in the vadose zone model using a constant rate applicable to a given soil type and vegetation cover (DOE/RL-2011-50). A number of studies have been carried out at the Hanford Site to ascertain representative long-term averages of the episodic fluxes, i.e., recharge rates, such as those compiled by Pacific Northwest National Laboratory (PNNL) in PNNL-14702 Rev. 1, *Vadose Zone Hydrology Data Package for Hanford Assessments*) for the 100 Areas. The 100-Area-specific recharge rates reported in PNNL-14702 Rev. 1 vary with surface soil type, providing an estimate of the range of possible recharge rates for various land uses. The three surface soil types were the Ephrata sandy loam or stony loam, Burbank sandy loam and Rupert sand.

Each calculation of a unit-length SSL or PRG with STOMP requires a pair of simulations; the first is a simulation of water flow only for historic recharge conditions, needed to obtain the soil moisture conditions throughout the model domain at the start time for the second simulation. The second is a coupled simulation of water flow and contaminant transport, starting from the assumed initial contaminant distribution (100:0 or 70:30 models) and the initial moisture distribution provided by the first simulation. Calendar year 2010 was set as the time when the first, historic (pre-2010) simulation ends and the second, predictive (post-2010) simulation begins. Recharge rates were conservatively simulated in STOMP as a specified flux boundary condition applied to the top boundary of the model (Figure 4a) for each recharge scenario and each soil type. Rates were assumed to change over time in step function-fashion for each recharge scenario.

For the historic (pre-2010) simulations, land use and recharge rates were assumed to transition from native vegetation (mature shrub-steppe) during pre-Hanford conditions to a Hanford Site operational period with bare soil from 1944 to 2010. The pre-Hanford phase was assumed to begin in calendar year 0, an arbitrary date that was selected merely to ensure steady-state moisture conditions are achieved in the solution for the applicable recharge rate by the 1944 year of transition to Hanford operations. The Hanford Site operational period is conservatively assumed to consist of bare soil conditions, maintained vegetation free, for all waste sites. The recharge rates for each historic phase (pre-Hanford and Hanford operations) are applied to the top boundary as a constant rate within each phase.

For the predictive simulations (post-2010), two different recharge scenarios were evaluated, representing different future land uses. The native vegetation recharge scenario represents U.S. Department of Energy (DOE) planned land use with restoration and maintenance of a native shrub-steppe plant community. The irrigation recharge scenario represents a bounding condition of irrigated agriculture.

For solute transport, specified zero flux boundaries were applied at the top of the model domain, along both edges of the vadose zone, along the upgradient edges of the aquifer grid blocks, and the bottom of the aquifer (Figure 4b). The downgradient edges of the aquifer grid blocks were assigned STOMP's outflow solute boundary condition (see page 6.21 of PNNL-12030, and also page 4.4 of PNNL-15782), which transports solute out of the domain according to the advective flux term in the governing equation and does not allow solute to enter back into the domain (Figure 4b).

3.2.1.1 Native Vegetation Recharge Scenario

The native vegetation recharge scenario (Table 3 and Figure 5) is used for calculation of unit-length PRG values. This recharge scenario is representative of DOE planned land use with restoration and maintenance of a native shrub-steppe plant community. The scenario is comprised of two historic phases discussed previously and three future phases that represent recharge rates changes corresponding to postulated future land use/cover transitions. The first future phase (2010 to 2015) represents a period of continued bare soil cover. The second future phase (2015 to 2020) represents grasses and shrubs as the vegetation matures over a transition period of 30 years (transition period duration from DOE/RL-2011-50), followed by establishment of a mature shrub steppe in the last future phase that lasts for the remainder of the simulation. Recharge rates diminish in each successive phase for this scenario.

Revegetation of waste sites following remediation is assumed in this scenario, consistent with revegetation that is occurring in the 100 Areas accordance with the *Hanford Biological Resources Management Plan* (DOE/RL-96-32 Rev. 1). Revegetation has been successfully conducted in the 100 Area following other remediation activities (for examples, refer to these annual issues of the *River Corridor Closure Contractor Revegetation and Mitigation Monitoring Report*: WCH-299 (2008), WCH-362 (2009), WCH-428 (2010), WCH-512 (2011), and WCH-554 (2012).

3.2.1.2 Irrigation Recharge Scenario

The irrigation recharge scenario (Table 4 and Figure 6) is used for calculation of unit-length SSL values. This recharge scenario represents an upper bound value on recharge rates from irrigated agriculture land use. This recharge scenario is comprised of future phases with transition from bare soil conditions to long-term irrigated farming. Although this recharge scenario is inconsistent with DOE land use plans, it is used here to represent an upper bound on recharge rates for screening purposes. The bounding nature of this recharge scenario is reinforced further by the assumption that irrigated agriculture commences five years in the future, much sooner than is reasonable given that Hanford Site remediation activities are expected to continue for decades to come and constrain land use accordingly.

Table 3. Native Vegetation Recharge Scenario Phases and Recharge Rates (mm/yr)

Surface Soil Type	Historic Simulation (pre-2010) (calculation of initial hydraulic conditions)		Predictive Simulation (post-2010) (calculation of peak groundwater concentration)		
	Pre-Hanford (<1944)	Hanford Operations (1944-2010)	Bare Soil (2010-2015)	Transitional Shrub Steppe (2015-2045)	Mature Shrub Steppe (2045>)
Ephrata sandy loam or stony loam [(a)]	1.5	17.0	17.0	3.0	1.5
Burbank sandy loam [(b)]	3.0	52.0	52.0	6.0	3.0
Rupert sand [(c)]	4.0	44.0	44.0	8.0	4.0

a. Source: PNNL-14702 Rev. 1, Table 4-15, Ephrata sandy loam and Ephrata stony loam for reactor along river areas; no vegetation, young shrub-steppe, and shrub-steppe

b. Source: PNNL-14702 Rev. 1, Table 4-15, Burbank loamy sand, for reactor along river areas; no vegetation, young shrub-steppe, and shrub-steppe

c. Source: PNNL-14702 Rev. 1, Table 4-15, Rupert sand for reactor along river areas; no vegetation, young shrub-steppe, and shrub-steppe

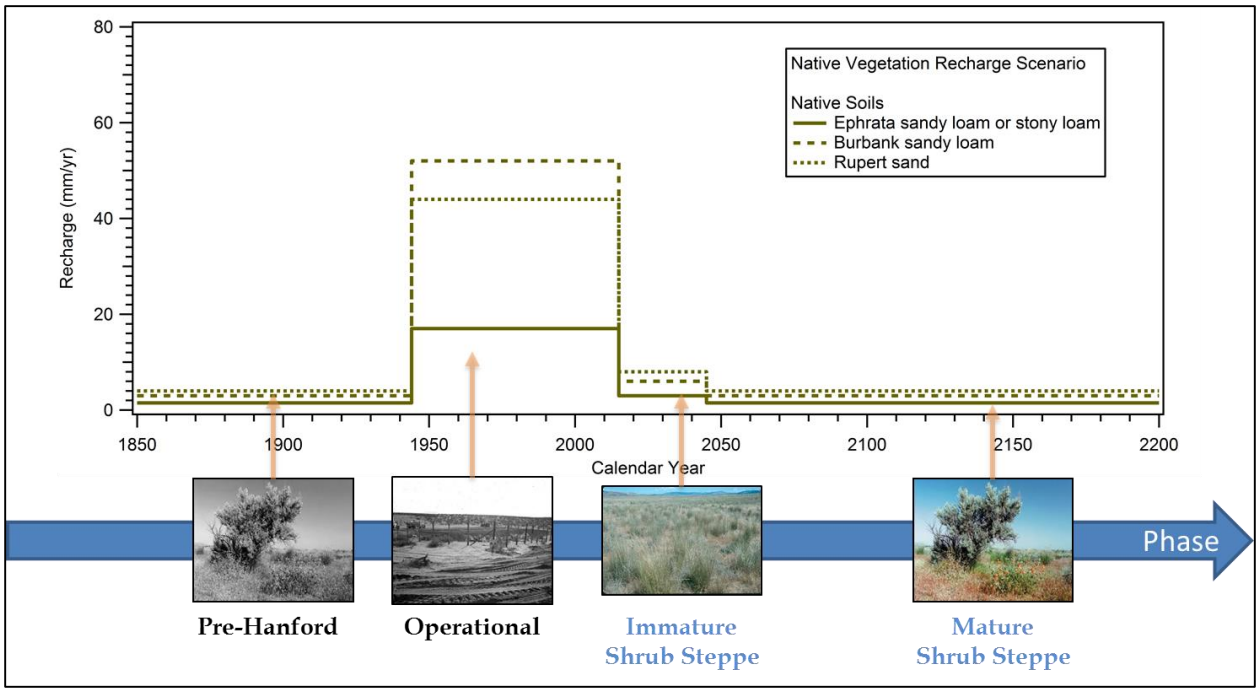


Figure 5. Native Vegetation Recharge Scenario

Table 4. Irrigation Recharge Scenario Phases and Recharge Rates (mm/yr)

Surface Soil Type	Historic Simulation (pre-2010) (calculation of initial hydraulic conditions)		Predictive Simulation (post-2010) (calculation of peak groundwater concentration)		
	Pre-Hanford (<1944)	Hanford Operations (1944-2010)	Bare Soil (2010-2015)	Irrigation I (2015-2045)	Irrigation II (2045>)
Ephrata sandy loam or stony loam	1.5 [a]	17.0 [a]	17.0 [a]	71.4 [d]	69.9 [d]
Burbank sandy loam	3.0 [b]	52.0 [b]	52.0 [b]	74.4 [d]	71.4 [d]
Rupert sand	4.0 [c]	44.0 [c]	44.0 [c]	76.4 [d]	72.4 [d]

a. Source: PNNL-14702 Rev. 1, Table 4-15, Ephrata sandy loam and Ephrata stony loam for reactor along river areas; no vegetation, young shrub-steppe, and shrub-steppe

b. Source: PNNL-14702 Rev. 1, Table 4-15, Burbank loamy sand, for reactor along river areas; no vegetation, young shrub-steppe, and shrub-steppe

c. Source: PNNL-14702 Rev. 1, Table 4-15, Rupert sand for reactor along river areas; no vegetation, young shrub-steppe, and shrub-steppe

d. Recharge rates for future irrigation phases represent incremental increases over corresponding undisturbed native vegetation recharge rates, based on WDOH guidance (WDOH/320-015, *Hanford Guidance for Radiological Cleanup*). The recharge increment attributable to irrigation alone is 68.4 mm/yr. This increment is added to the corresponding rate for immature shrub steppe (8.0 mm/yr) and mature shrub steppe (4.0 mm/yr) phases of the native vegetation recharge scenario (Table 3) to obtain the total recharge rate.

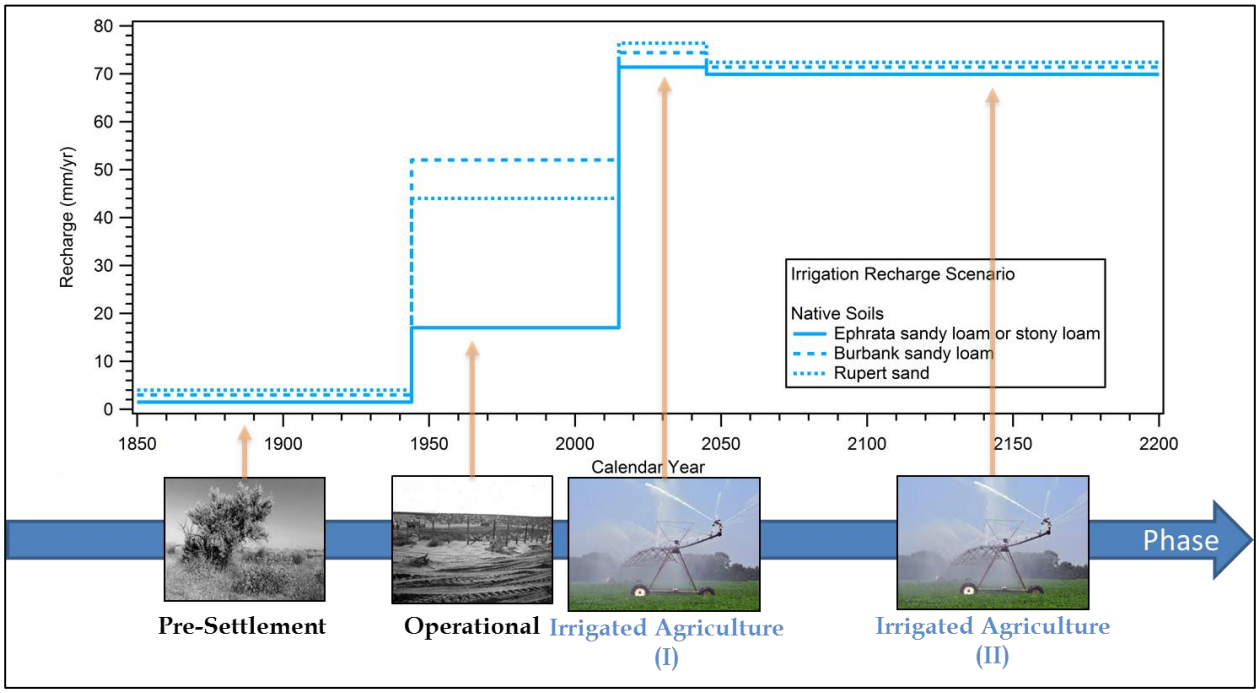


Figure 6. Irrigation Recharge Scenario

Recharge rates for the irrigation phases of this recharge scenario were estimated using the same approach used to assess interim remediation at other 100 Area waste sites (DOE/RL-96-17) following Washington Department of Health guidance (WDOH/320-015, *Hanford Guidance for Radiological Cleanup*). These previous site assessments used Remedial Action Goals (RAGs) calculated from RESRAD simulations that assumed total recharge was a combination of irrigation and native vegetation (base case) recharge rates. As the base case rates used in the RESRAD simulations differ from those adopted for the native vegetation recharge scenario (from PNNL-14702 Rev. 1), the RESRAD equation for total recharge was solved to determine the rate attributable to irrigation alone.

According to the RESRAD manual, total recharge is a function of precipitation, evapotranspiration, run-off, and applied irrigation and is defined as:

$$I = (1 - C_e)[(1 - C_r)P_r + I_{rr}] \qquad \text{Equation 4}$$

where I = annual recharge rate (LT^{-1}), C_e = evapotranspiration coefficient (dimensionless), C_r = runoff coefficient (dimensionless), P_r = annual precipitation rate (LT^{-1}), and I_{rr} = annual irrigation rate (LT^{-1}). Using Equation 4 and the DOE/RL-96-17 RESRAD values for these parameters, C_e = 0.91, C_r = 0.2, P_r = 0.16 m/yr, and I_{rr} = 0.76 m/yr, yielded a total recharge rate of 80 mm/yr. Solving Equation 4 with I_{rr} = 0 yielded the base case (native vegetation recharge) rate of 11.6 mm/yr and therefore the recharge attributable to irrigation alone is 68.4 mm/yr. This rate was then added to the native vegetation recharge scenario rates for the corresponding future phase to determine a recharge rate for the irrigation recharge scenario for each soil type in each future phase (Table 4). For example, the irrigation recharge scenario for the Ephrata sandy loam and stony loam soils sets the recharge rate to 17 mm/yr from 2010 to 2015, 71.4 mm/yr from 2015 to 2045, and 69.9 mm/yr from 2045 to 3010 (Table 4).

3.2.2 Lower Boundary Conditions

The base of the model domain in all cases is assigned a constant zero-flux boundary condition for both water transport and solute transport (Figure 4). This boundary condition limits the aquifer representation in this model to the appropriate thickness.

3.2.3 Lateral Boundary Conditions

For the portion of the model domain in the vadose zone (Figure 4a) a constant zero-flux boundary condition for both water transport and solute transport is assigned to restrict (with respect to arrival time of peak solute concentration and peak magnitude) the representation in the vadose zone to one-dimensional vertical flow. This is a conservative representation with respect to the arrival time and the magnitude of the peak concentration.

For the portion of the model domain in the saturated zone (aquifer; refer to Figure 4a), a constant Dirichlet type (specified head) boundary condition is specified for water transport at opposite edges aligned to the hydraulic gradient to represent the water table at the desired elevation and impose the desired hydraulic gradient. The hydraulic gradients values assigned to the edges of the saturated aquifer model cells were based on head data for March 2008 because the greatest number of wells was measured in that month, yielding the greatest number of measurements for all 100 Area source areas. Triangulated Irregular Networks (TINs) were fitted to the wells using ArcGIS and hydraulic gradients were computed for each TIN (Table 5). The gradient magnitudes typically varied across two or more orders of magnitude, so the median, a measure of the central tendency of the computed gradients, was selected as a representative value, yielding hydraulic gradients of 0.0010 m/m at 100-FR-1 and 100-FR-2, 0.0014 m/m at 100-IU-2, and 0.0025 at 100-IU-6.

Table 5. Hydraulic Gradient for March 2008

Source Operable Units	Number of TINS	Hydraulic Gradient (m/m)				
		Minimum	Maximum	Median	Arithmetic average	Geometric average
100-FR-1 100-FR-2	14	0.0002	0.0025	0.0010	0.0011	0.0009
100-IU-2	8	0.0006	0.0024	0.0014	0.0014	0.0013
100-IU-6	14	0.0001	0.0071	0.0025	0.0028	0.0013

For solute transport, the upgradient edge of the portion of the model domain in the aquifer and all edges of the model domain in the vadose zone portion of the model domain are assigned zero-flux boundary conditions (Figure 4b). The downgradient edges (Figure 4b) of the aquifer grid blocks were assigned STOMP's outflow solute boundary condition (see page 6.21 of PNNL-12030, and also page 4.4 of PNNL-15782); this conditions provides for transport of solute out of the domain according to the advective flux term in the governing equation but does not allow solute to enter back into the domain.

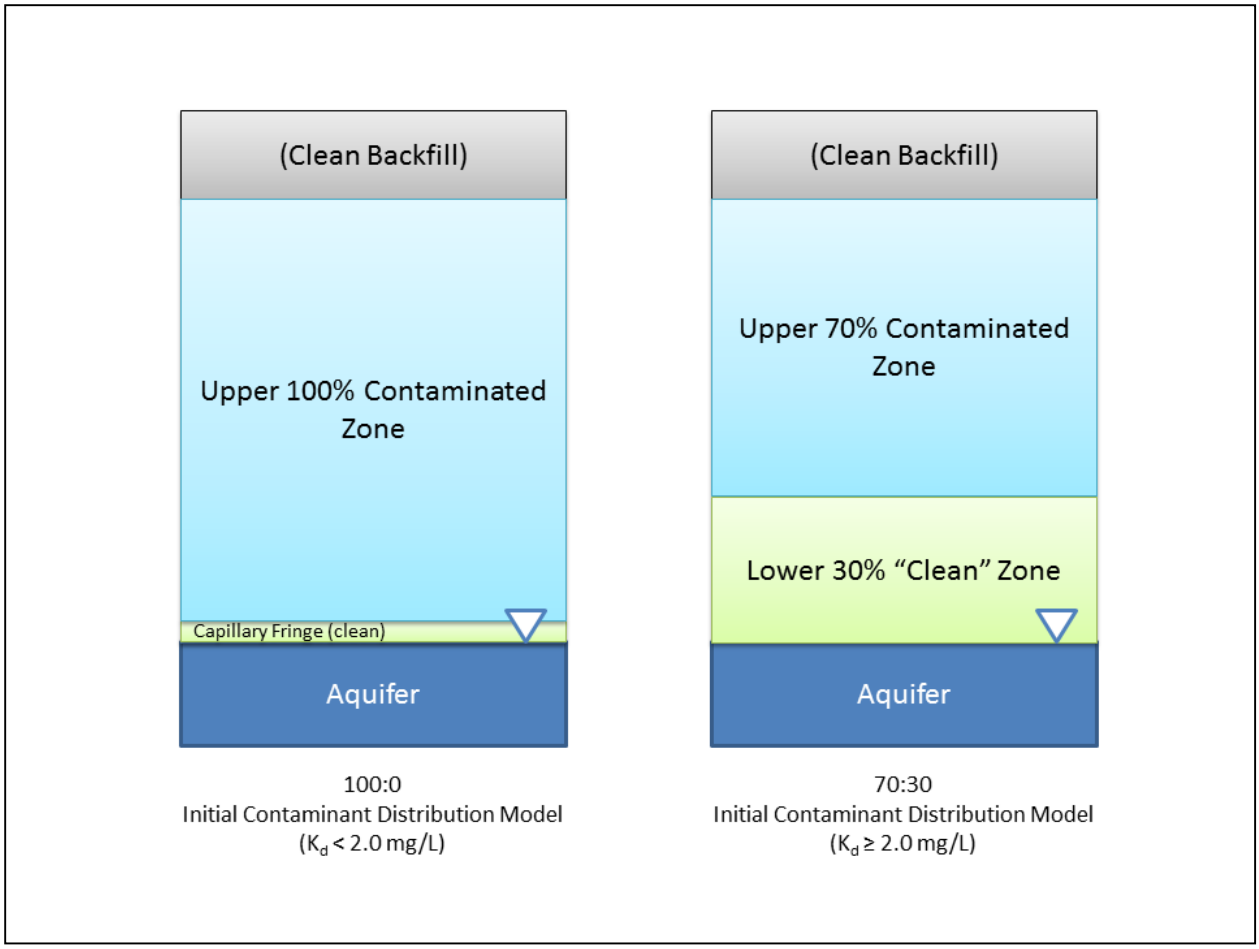
3.2.4 Initial Conditions

An arbitrary value was assigned as the initial pressure for the historic (pre-2010) flow simulations. A value of 86,656.7 Pa, approximately equivalent to –1.5 m matric potential, was assigned to the nodes in the vadose zone whereas the aquifer grid blocks were assigned values that matched the boundary condition pressures. Final pressures from the historic (pre-2010) simulations were used as the initial pressures for the predictive (post-2010) flow and transport simulations.

Based on SGW-50776, *Model Package Report: Vadose Zone Model for the River Corridor* and in SGW-51818, *Conceptual Basis for Distribution of Highly Sorbed Contaminants in 100 Areas Vadose Zone*, and the analysis reported below in Section 3.5, all contaminants were grouped into two groups, one with lower distribution coefficients in the range $K_d < 2$ mL/g, and other with the higher distribution coefficients in the range ≥ 2 mL/g.

For the lower K_d contaminants ($K_d < 2$ mL/g), a uniform concentration of 1.0 mg/kg was applied in the entire vadose zone, from below the clean backfill down to 0.5 m (two simulation grid blocks) above the water table. This is termed the 100:0 initial source distribution (Figure 7). Initial concentration in the 0.5-m-zone above the water table was not applied due to the presence of capillary fringe and water table movement in the periodically rewetted zone that would result from river stage fluctuations. Placing the initial mass at the water table can also result in unrepresentative large peak releases in the simulation start because of the extreme concentration gradients created by the application of this initial condition.

For the higher K_d contaminants ($K_d \geq 2$ mL/g), based on information presented in SGW-51818, the conservative assumption of contamination throughout the full thickness of the vadose zone is modified. For these contaminants, the upper 70% of the vadose zone below the clean backfill was assumed to be contaminated while the lower 30% is treated as uncontaminated; this is termed the 70:30 initial source distribution (Figure 7). The 70:30 initial source distribution assumption is deemed conservative for the high K_d contaminants, with respect to peak concentration, based on observed limited vertical extent of such contaminants.



Note: Strontium-90 (K_d = 25 mL/g) is an exception, simulated with 100:0 model; see text for explanation.

Figure 7. 100:0 and 70:30 Initial Contaminant Distribution Models

A notable exception to the K_d based assignment of an initial source distribution was made for the COPC strontium-90. Because field data revealed that this COPC was found throughout the vadose zone at several sites, use of a 70:30 initial source distribution for this COPC would clearly be non-conservative. Accordingly, unit-length SSL and PRG values were calculated for strontium-90 using the 100:0 initial source distribution at all sites. Strontium-90 is distributed throughout the vadose zone despite its relatively high K_d value for reasons having to do with historic discharge practices that no longer dominate the subsurface. A complete discussion of this is provided in the nature and extent of contamination discussion found in Chapter 4 of the Remedial Investigation/Feasibility Study (RI/FS) report for this OU. This exception might be considered as a site-specific treatment, but was applied to all sites for this COPC only in the first-level modeling under the graded approach (DOE/RL-2011-50).

The use of a unit initial concentration is an arbitrary convenience to support calculation of unit-length SSLs and PRGs in a back-calculation step (Section 2.5) using Equation 1 and Equation 2, respectively. The unit concentration (1.0 mg/kg or 1.0 pCi/kg) therefore should not be confused as constituting actual observed waste site residual soil concentrations.

3.3 Hydraulic Parameters

To the extent possible, source-area-specific hydraulic and transport parameter values were used in the STOMP simulations. Based on previous Hanford studies and on the fact that all available measurements of hydraulic properties made the same assumption, the sediments were assumed to follow the van Genuchten (1980) moisture retention constitutive relation and the Mualem –van Genuchten relative permeability constitutive relation (Mualem, 1976), thus requiring values to be specified in STOMP for each lithologic unit for

- K_s, saturated hydraulic conductivity, (LT^{-1})
- n_T, total porosity (L^3L^{-3})
- θ_s, saturated volumetric water content, called diffusive porosity n_D in STOMP (L^3L^{-3})
- s_r, residual saturation (dimensionless), equal to the residual volumetric water content divided by the saturated volumetric water content
- α, van Genuchten fitting parameter (L^{-1}), proportional to inverse of the air entry matric potential
- n, van Genuchten exponential fitting parameter (dimensionless)

The van Genuchten m parameter was assumed to be fixed and equal to $(n - 1)/n$ and the Mualem β exponent was assumed to be fixed at 0.5 (Mualem, 1976; RPP-20621, *Far-Field Hydrology Data Package for the Integrated Disposal Facility Performance Assessment*). These Mualem-van Genuchten hydraulic parameters were obtained for the Hanford formation from PNNL-15125, *Flow and Transport in the Hanford 300 Area Vadose Zone-Aquifer-River System*. A summary of the hydraulic parameters are listed in Table 6.

Hydraulic parameters were also required for the backfill portion of the model domain. The simulated peak groundwater concentrations will be insensitive to the backfill hydraulic parameters because contaminated vadose zone sediments are located beneath clean backfill in all source distribution models for all simulations. The backfill parameter values used for the 100-FR-1, 100-FR-2, 100-IU-2, and 100-IU-6 OU simulations (Table 6) are identical to those used in the 200 Area PRG calculation simulations (Table 8 in ECF-200MW1-10-0080, *200-MW-1 Contaminant Fate and Transport Model to Evaluate Impacts to Groundwater in Support of DOE/RL-2008-38 Decision Draft*; Table 11 in ECF-200PW1/3/6-10-0326, *Screening Process and Contaminant Fate and Transport Model to Evaluate Impacts to Groundwater in Support of DOE/RL-2007-27 Draft B*).

The Hanford formation and the Ringold Unit E are comprised of well-to-poorly sorted sandy gravels or sandy silty gravels. In contrast, the backfill is comprised of poorly sorted sand and gravel with varying fractions of eolian loess and silt (RPP-20621; SGW-40781; SGW-41213, *100-KR-4 Remedial Process Optimization Modeling Data Package*; and SGW-46279; PNNL-18564, *Selection and Traceability of Parameters to Support Hanford-Specific RESRAD Analyses*). Within the 100-FR-1, 100-FR-2, 100-IU-2, and 100-IU-6 OUs, the Hanford formation tends to be coarser grained than the Ringold Unit E. The former tends to contain larger gravel clasts than the latter, but the Ringold Unit E can locally contain significant amounts of gravel (SGW-40781; SGW-41213; and SGW-46279). Where present, the Ringold upper mud (RUM) was assumed to function as a lower boundary with a zero-flux boundary condition (i.e., as an aquitard) to the aquifer (SGW-46279) and so was not incorporated in the model domain interior.

OU-specific values for several Mualem-van Genuchten hydraulic parameters were obtained for the Hanford formation from data package SGW-46279 (for entire 100 Area). The data package cites RPP-20621 as the source of the unsaturated hydraulic properties of 15 samples of sandy gravels from the 100 Area areas (Table 6). These 100 Area sediments are dominated by the gravel fraction (> 2-mm size), with gravel clasts accounting for 43 to 75% of the total sample mass (Table 6; RPP-20621). Moisture retention data were measured on the non-gravel sediment fraction (< 2mm size) and corrected for gravel fraction. The gravel correction was done using Equation 5 (WHC-EP-0883, *Variability and Scaling of Hydraulic Properties for 200 Area soils, Hanford Site*, Equation 4):

$$\theta_{(b,s)} = F_f \theta_{(f,s)} = (1 - F_g)\theta_{(f,s)} \qquad \text{Equation 5}$$

where $\theta_{(b,s)}$ is the volumetric moisture content of the bulk soil which includes gravel, $\theta_{(f,s)}$ is the volumetric moisture content of the fines (the fraction tested in the laboratory), F_f is the volumetric fraction of the bulk soil sample passing through the No. 10 sieve (< 2mm), and F_g is the volumetric gravel fraction (the complement of F_f). This is well-established procedure for soils with substantial aggregate such as the Hanford Site. In other cases, hydraulic conductivities were measured on the bulk samples that included the gravel fraction using the constant-head permeameter method for saturated hydraulic conductivity (K_s) and the unit gradient method for unsaturated hydraulic conductivity (Table 6; RPP-20621). The K_s measurements were assumed to represent vertical hydraulic conductivity.

Aquifer properties for Hanford formation and Ringold Unit E are presented in SGW-47040, *Geohydrologic Data Package in Support of 100-FR-3 Modeling, Rev. 1*. Additional information is presented in SGW-40781 and SGW-46279. The horizontal K_s (saturated zone hydraulic conductivity) for Hanford formation for 100-F geographic area is determined to be about 48.3 m/day based on geometric mean of the calibrated range of hydraulic conductivity reported from a draft version of 100 Area groundwater flow and transport model. The vertical K_s value for Hanford formation in the aquifer is assumed ten times smaller than horizontal K_s (4.8 m/day). The horizontal K_s estimate for Hanford formation has progressed with updates to the 100 Area model from inclusion of additional geologic information and/or refinements to the boundary conditions. The average horizontal K_s was estimated to be 63 m/day in SGW-46279, Rev. 0. It was estimated to be 100 m/day in SGW-46279, Rev. 2, for the 100-F geographic area. In the most current update (ECF-100FR3-11-0116, *Modeling of RI/FS Design Alternatives for 100-FR-3*), the average horizontal K_s is estimated to be 30 m/day, with values ranging from 10 to 221 m/day within the 100-F geographic area. Several slug test measurements in the 100-F area suggest horizontal K_s value for the Hanford formation varies from about 11 m/day to 225 m/day (SGW-47040, Rev. 1). Due to considerable variability observed in horizontal K_s for 100-F geographic area, the value of 48.3 m/day, originally derived from geometric mean calculation, is deemed reasonable and representative for the unit-length SSL/PRG calculations.

For the 100-IU-2 and 100-IU-6 geographic areas, due to paucity of site-specific information, the horizontal and vertical K_s values for Hanford formation are taken to be the same as that for the 100-H geographic area (ECF-Hanford-11-0063), which are based on pumping test and slug test data. Saturated horizontal hydraulic conductivity estimates for Hanford formation, based on pumping test and slug tests in the 100-H area, typically range from 15 m/day to 1811 m/day (SGW-46279). A geometric mean of about 98 m/day is calculated for saturated horizontal K_s of Hanford formation.

Table 6. Mualem-van Genuchten Hydraulic Parameters for Sandy Gravels in the 100 Area Vadose Zone

Sample	HSU [a]	Operable Unit	Well Number	Depth (m)	Percent Gravel	θ_s Saturated Volumetric Moisture Content (cm^3/cm^3)	θ_r Residual Volumetric Moisture Content (cm^3/cm^3)	α van Genuchten Inverse Air Entry Head Fitting Parameter (1/cm)	n van Genuchten Exponential Fitting Parameter (-)	K_s Fitted Saturated Hydraulic Conduc-tivity (cm/s)
2-1307	Ringold	100-HR-3	199-D5-14	18.90	43	0.236	0.0089	0.0130	1.447	1.29E-04
2-1308	Ringold	100-HR-3	199-D5-14	30.64	58	0.120	0.0208	0.0126	1.628	6.97E-05
2-1318	Hanford	100-HR-3	199-D8-54A	15.54	60	0.124	0.0108	0.0081	1.496	1.67E-04
2-2663	Hanford	100-BC-5	199-B2-12	8.20	61	0.135	0.0179	0.0067	1.527	6.73E-05
2-2664	Ringold	100-BC-5	199-B2-12	24.84	73	0.125	0.0136	0.0152	1.516	1.12E-04
2-2666	Hanford	100-BC-5	199-B4-9	21.49	71	0.138	0.00	0.0087	1.284	1.02E-04
2-2667	Hanford	100-BC-5	199-B4-9	23.93	75	0.094	0.00	0.0104	1.296	1.40E-04
3-0570	Hanford	100-KR-1	116-KE-4A	3.50	60	0.141	0.00	0.0869	1.195	2.06E-02
3-0577	Hanford	100-FR-3	199-F5-43B	7.16	66	0.107	0.00	0.0166	1.359	2.49E-04
3-0686	Hanford	100-FR-1	116-F-14	6.49	55	0.184	0.00	0.0123	1.600	5.93E-04
3-1702	Hanford	100-DR-2	199-D5-30	9.78	68	0.103	0.00	0.0491	1.260	1.30E-03
4-1086	Ringold	100-K	199-K-110A	12.77	65	0.137	0.00	0.1513	1.189	5.83E-02
4-1090	Hanford	100-K	199-K-111A	8.20	50	0.152	0.0159	0.0159	1.619	4.05E-04
4-1118	Hanford	100-K	199-K-109A	10.30	66	0.163	0.00	0.2481	1.183	3.89E-02
4-1120	Ringold	100-K	199-K-109A	18.90	63	0.131	0.0070	0.0138	1.501	2.85E-04

a. HSU = hydrostratigraphic unit

Saturated zone horizontal and vertical hydraulic conductivity used for 100-D area for Ringold Formation (ECF-Hanford-11-0063) is used to represent the horizontal and vertical K_s values for the saturated Ringold Formation at 100-FR-1, 100-FR-2, 100-IU-2, and 100-IU-6 OUs. An estimate of approximately 22 m/day is used for horizontal K_s and an order less for the vertical K_s. Value from 100-D was chosen because of the availability of more representative pumping test dataset (23 pumping test data measures were available for Ringold Formation in 100-D compared to only 3 pumping test data measures for 100-H). The slug test based estimates of horizontal K_s for 100-F area show a range from 9 m/day to 69 m/day indicating that 22 m/day is a reasonably representative value for the unit-length SSL/PRG calculations. Table 7 summarizes all the hydraulic parameters used in the STOMP simulations at 100-FR-1, 100-FR-2, 100-IU-2, and 100-IU-6 for the vadose zone, saturated zone, and the backfill.

The Mualem-van Genuchten hydraulic properties for the Hanford formation were estimated for each source area by averaging the individual parameter values for all samples collected from that area (Table 6). For example, samples from boreholes 199-F5-43B and 199-F5-51 were selected to provide mean properties for 100-F Area. Vertical saturated hydraulic conductivity of Hanford formation was averaged using the geometric mean of the four measurements whereas the other parameters were averaged using the arithmetic mean. An exception is the saturated volumetric water content, called θ_s in the van Genuchten moisture retention relation and diffusive porosity in STOMP. The θ_s values in Table 6 were determined by applying a gravel correction factor to the values determined in the laboratory on the < 2 mm fraction. The absence of the gravels may have resulted in underestimation of the void volume available for flow because of the difficulty in reconciling the high K_s values with very low porosity values. Therefore, the Hanford-wide estimate of 0.25 was used. Because there are no measurements specific to the 100-IU-2 and 100-IU-6 OUs (Table 6), the parameters for Hanford formation in the vadose zone at 100-FR-1 and 100-FR-2 are adopted as representative of those at nearby 100-IU-2 and 100-IU-6.

The document and database review for this ECF did not yield OU-specific or even 100-Area-specific Mualem-van Genuchten property values for the Ringold Unit E or the backfill. In the absence of more site-specific data, Hanford-wide mean parameter values for the backfill and the Ringold Unit E were taken from Table A.12 in PNNL-18564. Mean hydraulic parameters for six samples of backfill and 18 samples of Ringold Unit E gravels that were collected within the Hanford Site (PNNL-18564) were selected to represent these units within the 100 Area. Thus, the Ringold Unit E intervals located in the vadose zone had the same Mualem-van Genuchten properties in all source areas, as did the backfill. The backfill parameters used for the 100 Area simulations were also used in flow and transport simulations under variably-saturated conditions at other waste sites. An example are the PW-1/3/6 waste sites in the 200 Area (Table E5-8 in Appendix E of DOE/RL-2007-27, *Feasibility Study for the Plutonium/Organic-Rich Process Waste Group Operable Unit: Includes the 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units*). Groundwater peak concentrations were insensitive to backfill parameters because contaminated vadose zone sediments are located beneath the backfill in all source distribution models for all simulations.

3.4 Contaminant Transport Parameters

The contaminant transport parameters required by STOMP are the particle density (ρ_p) of each unit, dispersion coefficients, half-lives ($t_{1/2}$) for radiological COPCs, and distribution coefficients (K_d) for COPCs.

The particle density (ρ_p) values of the backfill, Hanford, and Ringold units can be calculated using the bulk density (ρ_B) and porosity. Bulk density is necessary for retardation scaling factor calculations. Estimates of bulk density for Hanford and Ringold units were obtained from PNNL-14702 Rev. 1, which

Table 7. Hydraulic Parameters used for 100-F, 100-IU-2, and 100-IU-6 Source Areas

Source Operable Units	Zone [a]	Formation	n_T Total Porosity (cm³/cm³)	n_D Diffusive Porosity (cm³/cm³)	α van Genuchten Inverse Air Entry Head Fitting Parameter (1/cm)	n van Genuchten Exponential Fitting Parameter (-)	s_r Residual Saturation (-)	K_s Saturated Hydraulic Conductivities Horizontal (cm/s)	K_s Saturated Hydraulic Conductivities Vertical (cm/s)
100-FR-1 100-FR-2 100-FR-3	BF	Hanford	0.276	0.262	0.019	1.40	0.162	5.98E-04	5.98E-04
	VZ	Hanford	0.280	0.250	0.0145	1.48	0	3.83E-03	3.84E-04
	VZ	Ringold E	0.280	0.280	0.008	1.66	0.093	4.13E-03	4.14E-04
	SZ	Hanford	0.280	0.250	0.0145	1.48	0	5.59E-02	5.59E-03
	SZ	Ringold E	0.280	0.280	0.008	1.66	0.093	2.59E-02	2.59E-03
100-IU-2 100-IU-6	BF	Hanford	0.276	0.262	0.019	1.40	0.162	5.98E-04	5.98E-04
	VZ	Hanford	0.280	0.250	0.0145	1.48	0	3.83E-03	3.84E-04
	SZ	Hanford	0.280	0.250	0.0145	1.48	0	1.13E-01	1.13E-02
	SZ	Ringold	0.280	0.280	0.0080	1.66	0.093	2.59E-02	2.59E-03

a. BF = backfill; VZ = vadose zone; SZ = saturated zone.

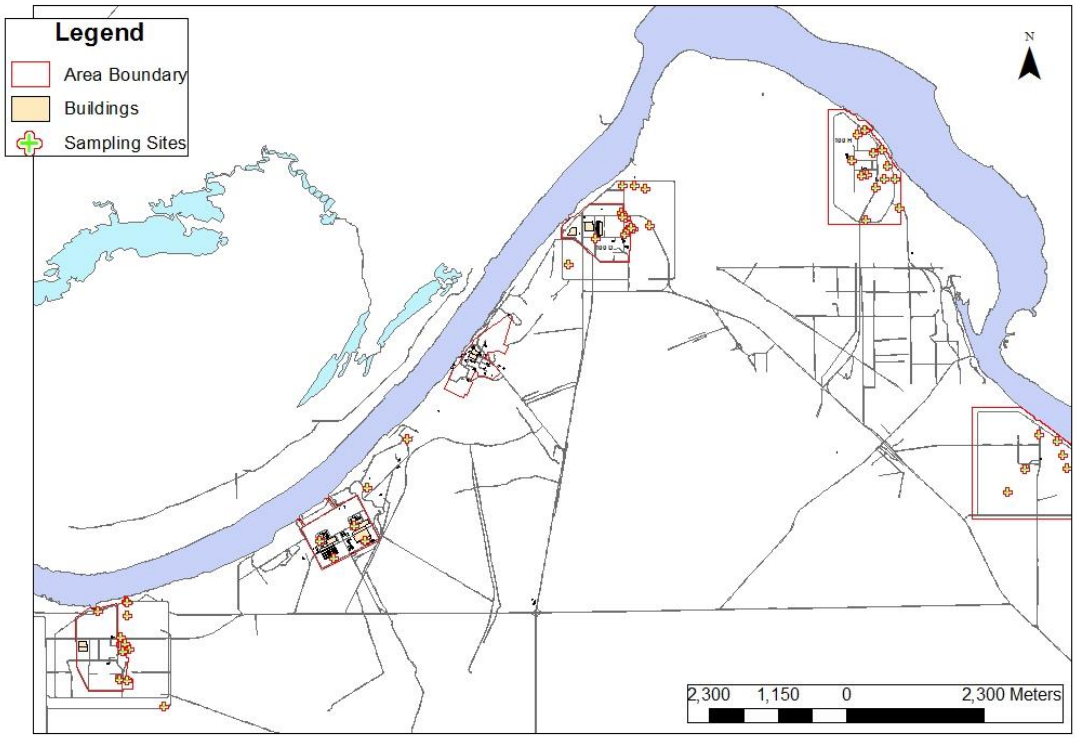
gave 1.91 g/cm^3 for the Hanford and 1.90 g/cm^3 for the Ringold. The bulk density estimate used for backfill was 1.94 g/cm^3 (PNNL-18564).

Hydrodynamic dispersion was conservatively assumed negligible, so dispersivity values were all set to zero. Setting dispersivity values to zero yields higher peak concentrations than setting non-zero values. This, therefore, is a conservative assumption with respect to unit-length SSL and PRG values. (Numerical dispersion is a separate consideration; steps taken to minimize numerical dispersion in the STOMP code calculations are discussed in Section 3.1).

Distribution coefficient (K_d) values for all nonradionuclide COPCs were selected in ECF-Hanford-10-0442, and for radionuclide COPCs in ECF-Hanford-10-0429. These values are listed for each COPC in the tables of unit-length SSL values listed in Attachment A, and of unit-length PRG values listed in Attachment B, of this ECF. One COPC's K_d value requires elaboration here, that for hexavalent chromium. The site-specific, conservative basis value selected for this COPC was derived from the site-specific analysis for the 100 Area presented in ECF-Hanford-11-0165 Rev. 1, *Evaluation of Hexavalent Chromium Leach Test Data Conducted on Vadose Zone Sediment Samples from the 100-Area)*. The leach test data analyzed in ECF-Hanford-11-0165 included F/IU area samples (Figure 8). The K_d value is considered bounding because it was selected on the basis that 90% of the K_d values in that analysis had higher sorption values. Thus, this value would not be appropriate to represent hexavalent chromium migration in a predictive model, but is appropriate for use in this bounding calculation of unit-length SSL and PRG values. Further, this value for K_d of hexavalent chromium is applicable only to the residual fraction of hexavalent chromium remaining in the vadose zone; it is inapplicable to the mobile fraction that migrated out of the vadose zone in the past. Simulations were run for 1000 years to produce peak groundwater concentrations for a subset of the entire range of distribution coefficients required for all non-radionuclide COPCs. The subset is comprised of 26 distribution coefficients (listed in Table 8) between zero and 16 mL/g. Peak concentrations were calculated for the specific COPC distribution coefficients using the regression methods described in Section 5.1.3. Radionuclide COPCs were directly simulated (no regression) to account for radioactive delay during transport as well as retardation.

STOMP accounts for contaminant first-order decay in the solute mass conservation equation (PNNL-12030). Half-life values ($t_{1/2}$) for radionuclide COPCs were obtained from ECF-Hanford-10-0429, *Documentation of Preliminary Remediation Goals (PRGs) for Radionuclides Using the IAROD Exposure Scenario for the 100 and 300 Area Remedial Investigation/Feasibility Study (RI/FS) Report*. These values are listed in those tables pertaining to radionuclides in Attachments A and B of this ECF for each radionuclide COPC. Chain decay is not accounted for in this calculation. No radionuclide COPC is simulated that has significant daughter products (no significant daughter/decay products associated with the alpha, beta, and gamma emitters that are present at 100-FR-1, 100-FR-2, 100-IU-2, or 100-IU-6; the gamma emitters do not have any decay products).

Biodegradation is neglected in this calculation, which is generally a conservative assumption because the result it to overstate the persistence of a COPC by neglecting its biodegradation. However, in some circumstances this may be nonconservative where biodegradation products are also COPCs. For example, COPCs such as chloroform can degrade to methylene chloride and chloromethane, which have higher cancer slope factors. Dichloroethylene can eventually degrade to vinyl chloride, which has a higher cancer slope factor than dichloroethylene. Predictive (post-2010) simulations of water flow and contaminant transport were run for 1000 years to produce peak groundwater concentrations for each COPC based on its K_d values, and accounting for radioactive decay for radionuclide COPCs, using the K_d values and half-lives listed in the tables in Attachments A and B of this ECF.



100 Areas Hexavalent Chromium Batch Leaching Testing Sampling Sites

Figure 8. Location of Leach Test Data Samples Evaluated for Derivation of a Bounding, Site-specific K_d Value for Residual Hexavalent Chromium

Table 8. Distribution Coefficients (K_d) Simulated in STOMP for Non-radionuclide COPCs to Support Regression of Peak Groundwater Concentration on K_d

K_d (mL/g)						
0	0.01	0.08	0.40	0.80	4.0	14.0
0.00001	0.02	0.10	0.50	0.90	8.0	16.0
0.0001	0.04	0.20	0.60	1.0	10.0	
0.001	0.06	0.30	0.70	2.0	12.0	

3.5 Simulation Duration

A 1000-year limit was established for purposes of unit-length SSL and PRG calculation by agreement with regulatory agencies. Accordingly, the peak concentration within the 1000-year predictive (post-2010) simulation was used to calculate the unit-length SSL and PRG values.

The time of occurrence for peak groundwater concentration may be after the 1000-year limit for contaminants subject to high sorption. Because of the 1000-yr limit, however, only the peak groundwater concentration within 1000 years is used as the basis for unit-length SSL or PRG values. Typically, breakthrough at numerically significant levels is not simulated within 1000 years for contaminants with high sorption values, although the threshold for breakthrough will depend on the recharge scenario used. These cases commonly result in an "NR" (non-representative) coding assigned for the unit-length SSL or PRG (Section 2.5.1).

A set of test case simulations were run to demonstrate the adequacy of K_d of 2 mL/g as the point for distinguishing between low K_d and high K_d contaminants. For this test, Column 1 from 100-FR-1 and 100-FR-2 OUs was chosen for the test case. The native vegetation recharge scenario rates for Burbank sandy loam was applied and 100:0 initial contaminant distribution was used for the initial solute condition. The breakthrough curves for different distribution coefficients are shown in Figure 9. The simulations were run for 1000 years (calendar years 2010 to 3010); the end of the simulations is denoted by the vertical dashed line at year 3010 in these figures. Observation of the breakthrough curves in Figure 9 reveals that for the distribution coefficients < 2 mL/g the peak concentration occurs within 1000 years and for the distribution coefficients > 2 mL/g the peak concentration occurs after 1000 years. These results indicate that the initial assumption of grouping the contaminants into two broad groups, one with low distribution coefficients < 2 mL/g and another one with the high distribution coefficients ≥ 2 mL/g for both unit-length SSL and PRG calculations is sound.

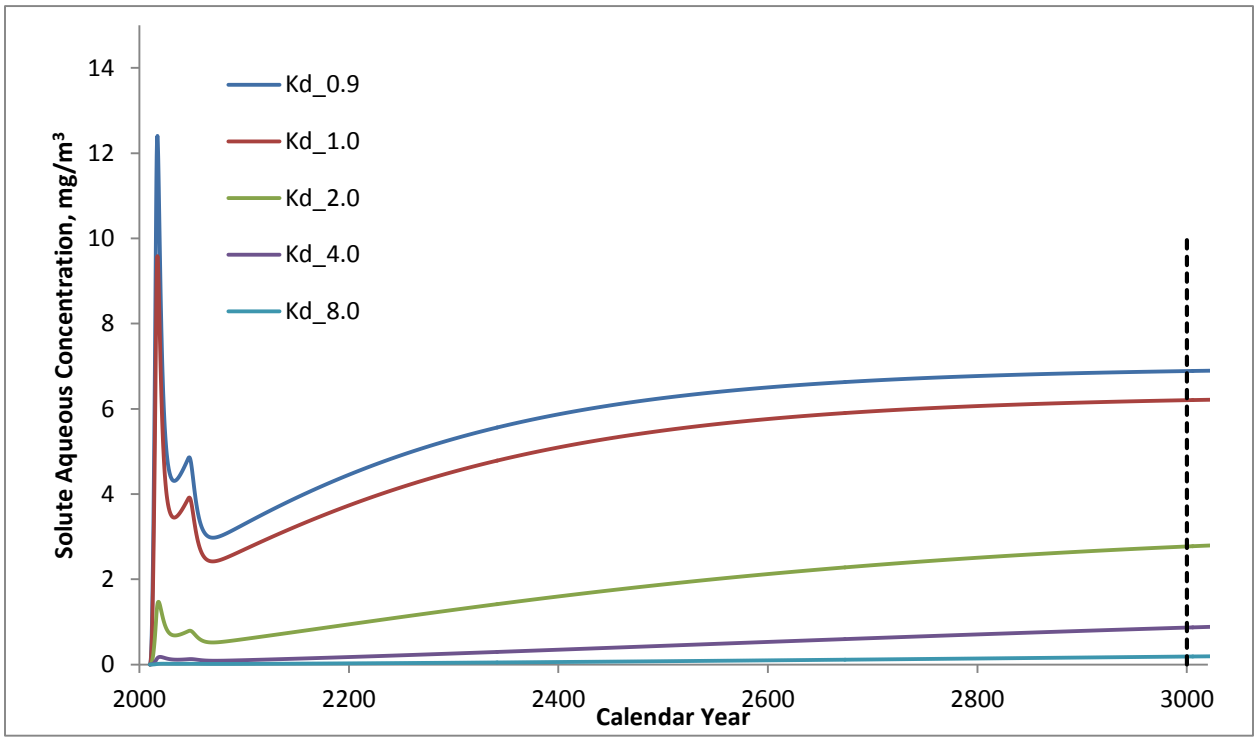


Figure 9. Peak Groundwater Concentration as a Function of K_d for Native Vegetation Recharge Scenario

3.6 Uncertainties, Assumptions, and Conservatism

Potential sources of uncertainty in risk assessments are primarily in the categories of (1) model uncertainties, (2) scenario uncertainties, and (3) parameter uncertainties. Model uncertainty pertaining to the equations used as numerical representations of the natural processes is expected to be relatively small (DOE/RL-2011-50).

DOE/RL-2011-50 provides a summary evaluation of the comparisons of field data and field test results to corresponding model results obtained using the STOMP code, and the evaluation indicates that the equations used in STOMP adequately simulate the natural processes. The technical basis regarding scenario and parameter selection and the evaluation of uncertainty and variability is also documented in DOE/RL-2011-50. Documentation is provided in DOE/RL-2011-50 on (1) dominant model factors, (2) model parameter values and plausible ranges of parameter values, (3) model assumptions and effects on model results, and (4) model limitations.

Application of the unit-length SSL and PRG values calculated herein requires an understanding of which assumptions and modeling choices were conservative and which were not. Conservative assumptions and modeling choices include:

- Recharge is represented in the numerical model by uniform, but time-varying, flux rates specified over particular periods so that vadose zone flow is always downward. In contrast, recharge in an arid vadose zone occurs only as often as the combination of precipitation and antecedent moisture conditions allow, i.e., sporadically or infrequently, so that there can be long periods when shallow vadose-zone pore water movement is controlled more by evaporation and transpiration near the surface than gravity, resulting in upward movement or reduced downward seepage velocity.
- The one-dimensional simulations force all contamination through the vadose zone down to the aquifer, whereas infiltrating water and solutes tend to migrate laterally as the wetting front redistributes following an infiltration event.
- The recharge rates for the native vegetation scenario used to calculate unit-length PRGs uses bounding native vegetation rates based on numerous lysimeter and tracer recharge studies (PNNL-17841).
- The unit-length SSL values to be used for screening calculated for bounding recharge rates postulated in the irrigation recharge scenario. This is not the expected land use, and the irrigation is assumed to commence much sooner than is reasonable.
- The initial condition (either the 100:0 or 70:30 model) represents a bounding initial condition that effectively assumes the maximum residual soil contamination level is uniformly present over the entire applicable vadose zone thickness (a peak concentration would not be expected to occur over the entire depth range).
- The vadose zone thicknesses for the representative stratigraphic columns were minimized by using water tables from a typical high-water month when developing the stratigraphic columns for use in an average annual model; this minimizes contaminant transport time, thereby resulting in higher and earlier groundwater peak concentrations.
- Dilution upon mixing of groundwater with Columbia River water is assumed negligible.
- Dispersion is assumed negligible, which leads to larger peak concentrations than if dispersion had been included.

- Volatile organic compounds are assumed to have negligible volatilization so that the resulting peak concentrations are larger than if volatilization had been included.
- Geometric means of measured aquifer horizontal hydraulic conductivity values are lower, and thus more conservative, than arithmetic means because the values typically span several orders of magnitude.

Assumptions that may or may not be conservative include:

- The median hydraulic gradient value for each source area may be too large by several-fold for waste sites near the Columbia River and may be several times too large for waste sites that are farther inland from the river.
- The assumption of a five-meter-thick aquifer may or may not be conservative for those 100 Area locations with aquifer thicknesses less than 5 m.

4 Software Applications

STOMP was the primary software used for this calculation; as approved software, the information required is provided in this section.

Microsoft Excel®[1] spreadsheets were used to calculate contaminant inventory values and approximate contaminant solute concentrations, back-calculate unit-length SSL and PRG values, and evaluate the results produced by STOMP. These calculations were performed on a desktop with ID INTERA-00295. The hardware is a Dell®[2] Precision E7200 with a 2.53-GHz Intel® Core™2 Duo CPU processor and 3.25 GB of RAM loaded with the Windows® XP Professional 64-bit operating system.

4.1 Approved Software

The vadose zone fate and transport calculations are performed using CHPRC Build 2 of the STOMP software, registered in the Hanford Information System Inventory (HISI) under identification number 2471. STOMP use by CHPRC is managed under the following software lifecycle documents: CHPRC-00222, STOMP *Functional Requirements Documen*t; CHPRC-00176, *STOMP Software Management Plan*; CHPRC-00211, *STOMP Software Test Plan*; CHPRC-00515, *STOMP Acceptance Test Report*; and CHPRC-00269, *STOMP Requirements Traceability Matrix*.

4.1.1 Description

The following required information for the STOMP software package used for this calculation is provided here:

- Software Title: STOMP
- Software Version: CHPRC Build 2
- HISI Identification Number: 2471

[1] Excel® and Windows® are registered trademarks of Microsoft Corporation in the United States and other countries.

[2] Dell® and PowerEdge® are registered trademarks of Dell Products, Inc.

- Workstation type and property number (from which software is run): STOMP was executed on the GREEN Linux®[3] above Cluster that is owned and managed by INTERA, Inc., a preselected subcontractor to CHPRC. The computer property tag for the frontend node is INTERA-00469 and this cluster is located at INTERA's Richland, Washington office. This node is a Dell® PowerEdge® R510 with two 6-core Intel®[4] Xeon® X5660 processors @ 2.80GHz and 48 GB of RAM. As given by the command "uname –a", the operating system details are

```
Linux green 2.6.32-32-server #62-Ubuntu SMP Wed Apr 20 22:07:43 UTC 2011 x86_64
GNU/Linux (gcc version Ubuntu 4.4.3-4ubuntu5 4.4.3)
```

4.1.2 Software Installation and Checkout

A copy of the *Software Installation and Checkout Form* for the STOMP installation used for this calculation is provided in Attachment C to this ECF.

4.1.3 Statement of Valid Software Application

DOE/RL-2011-50 contains a summary of the main model attributes and code selection criteria that serve as the basis for the demonstration of the adequacy of the STOMP code for use in vadose zone modeling at Hanford. The results of the evaluation in DOE/RL-2011-50 show that the STOMP code is capable of meeting or exceeding the identified attributes and criteria. The comparison of the code selection criteria to the STOMP code capabilities indicates the STOMP code is capable of simulating all of the necessary FEPs, and that STOMP meets all of the other required code selection criteria. Section 6.4.1 of DOE/RL-2011-50 addresses code selection criteria, including quality assurance documentation of verification studies for specific model attributes (e.g., unsaturated flow, solute transport, infiltration, and drainage), and includes a discussion of other code related criteria (i.e., inter-code comparisons, hardware requirements, solution methodology, dimensionality, and output capability).

The results of CHPRC acceptance testing (CHPRC-00515) demonstrate that the STOMP software is acceptable for its intended use by the CHPRC. Installations of the software are operating correctly, as demonstrated by the INTERA Linux Cluster system producing the same results as those presented for selected problems from the STOMP application guide (PNNL-11216) in accordance with the software test plan (CHPRC-00211).

5 Calculation

STOMP simulations were created and run using the representative stratigraphic columns, boundary conditions, initial conditions, and parameter values described in Section 3. The details of calculation of general unit-length SSL and PRG values are described in Section 5.1. Site-specific modeling is described in Section 5.2.

5.1 Calculation of Soil Screening Levels and Preliminary Remediation Goals

The source-area-specific unit-length SSL values for 100-F, 100-IU-2, and 100-IU-6 OUs are presented in Attachment A of this ECF. The source-area-specific unit-length PRG values are presented for 100-F, 100-IU-2, and 100-IU-6 OUs in Attachment B of this ECF. Details of this calculation are provided below.

[3] Linux® is the registered trademark of Linus Torvalds in the U.S. and other countries.

[4] Intel® and Xeon® are registered trademarks of Intel Corporation.

5.1.1 Time Step and Solution Control

The STOMP simulator solves a wide variety of nonlinear, single- or multiphase flow and transport problems for variably saturated geologic media. Partial differential conservations equations for component mass, energy, and solute mass comprise the fundamental equations for the simulator. STOMP solves flow and transport problems in the subsurface environment in one, two, or three dimensions. STOMP solves the fundamental equations for flow using an integral volume finite difference approach with the nonlinearities in the discretized equations resolved through Newton-Raphson iteration. The fundamental equation for solute transport are discretized to algebraic form following the integrated finite difference method of Patankar (1980) that is implicit using backward Euler time differencing, or by other techniques available in STOMP (e.g., TVD). STOMP solves the linear systems of equations that result from the Newton-Raphson linearization or the solute transport solution using either a direct, banded matrix solver or an indirect conjugate gradient-based solver.

For this calculation, the STOMP-W operational mode (solving for water mass and solute mass conservation) with the direct, banded matric solver was used for all simulations. The Patankar (1980) technique was used for solute transport simulation. Details of the software quality assurance requirements met for use of STOMP are in Section 4.

For solution control, the maximum time step permitted was 0.01 years. The grid dimension of 10.0 m in the horizontal direction by 0.25 m in the vertical direction was deliberately specified to maintain grid Courant numbers below the threshold of 1.0 to minimize numerical dispersion in the saturated zone. STOMP's automatic Courant limitation feature was used to control numerical dispersion in the unsaturated nodes.

The aqueous concentrations calculated using STOMP was scaled down unit horizontal grid length (1.0 m) by dividing the aqueous concentrations by 10. The accuracy of this methodology was verified through simulation of varying grid dimensions (details not presented in this ECF).

5.1.2 Peak Groundwater Concentration Calculation

STOMP was used to simulate groundwater concentration for each model time step along a portion of the domain's downgradient boundary corresponding to the top 5 m of the aquifer for the following set of simulations:

→ Two recharge scenarios (native vegetation and irrigation), each for

  → Twelve stratigraphic columns (Figure 2 and Figure 3; four columns for 100-F with one hydraulic gradient, plus four columns for 100-IU run with two hydraulic gradients), each for

    → Three surface soil types, each for

      - All radionuclides COPCs with their respective K_d values and decay half-lives (Attachments A and B of this ECF), up to the K_d threshold for which no breakthrough occurs within 1000 years, and
      - 26 K_d values for non-radionuclide COPCs listed in Table 8 to support a regression analysis to calculate peak groundwater concentration based on K_d value.

For non-radionuclide COPCs, peak groundwater concentrations obtained by running STOMP simulations for the discrete set of K_d values listed in Table 8 for the irrigation recharge scenario in the case of unit-length SSLs, and for the native vegetation recharge scenario in the case of unit-length PRGs. These peak

concentrations were then used in a regression analysis to provide the means to estimate peak groundwater concentration within 1000 years from the K_d value of each nonradionuclide COPC as follows:

1. For COPCs in the range $K_d \leq 1.0$, the 'FORECAST' function in Excel® that uses a best fit (least squares) linear regression is used to estimate peak concentration.
2. For COPCs in the range $1.0 < K_d < 2.0$ mL/g, a fitted regression equation created by performing a linear (or non-linear) regression of STOMP simulated peak concentrations against K_d values in the range 0.5 to 1 mL/g. This range is estimated separately from higher K_d values because a different initial solute condition (100:0 initial distribution) is used for $K_d < 2.0$ than for higher values.
3. For the COPCs in the range $2.0 \leq K_d \leq 8.0$ mL/g, the 'FORECAST' function in Excel® that uses a best fit (least squares) linear regression is used to perform a linear regression of STOMP simulated peak concentrations against K_d values over the same range. This range is estimated separately from lower K_d values because a 70:30 distribution is used (in contrast to the 100:0 initial solute distribution applied for lower K_d values).
4. For COPCs in the range $K_d > 8.0$ mL/g, a fitted regression equation created by performing regression of STOMP simulated peak concentrations against K_d values in the range of 8 to 16 mL/g is used. An example is shown in Figure 10 using 100-FR-1 and 100-FR-2 representative stratigraphic column 1 (Figure 2) under the irrigation recharge scenario for the Ephrata sandy loam surface soil.

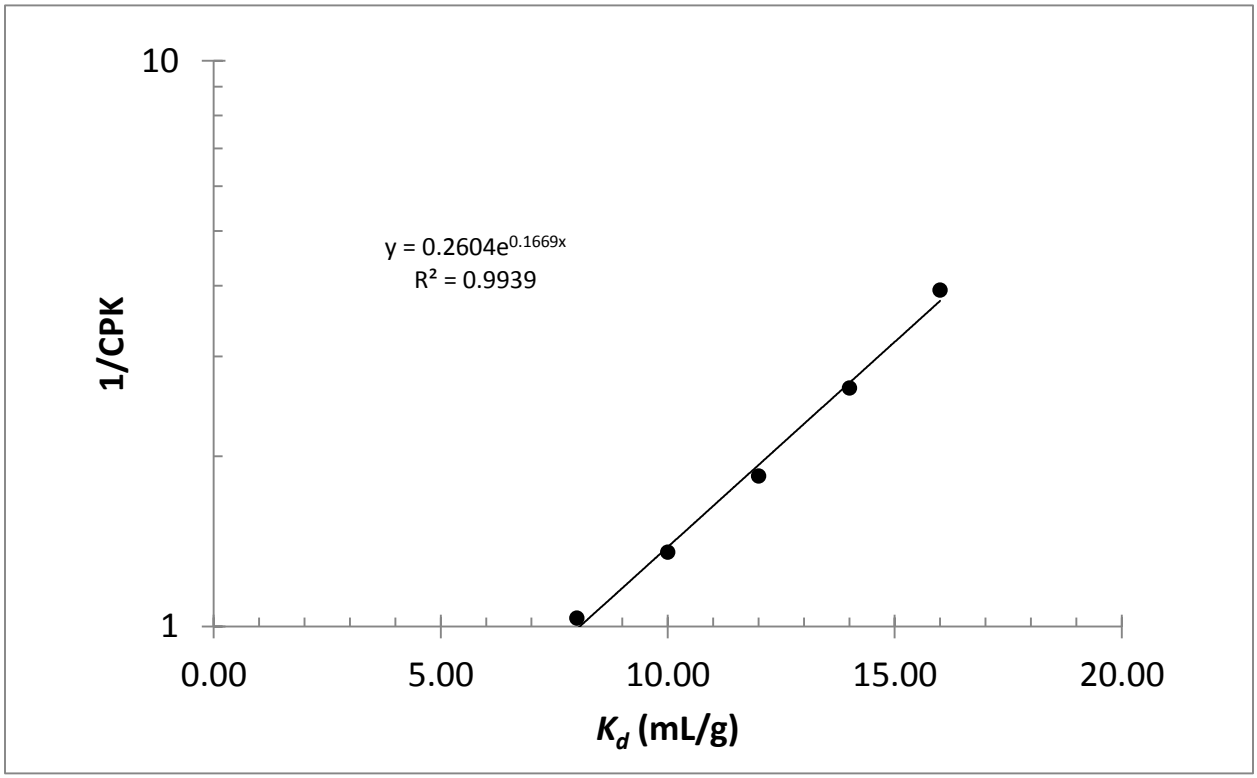


Figure 10. Regression Equation for Higher K_d Contaminants Under Irrigated Recharge Scenario for 100-F Column 1

Radionuclide COPCs were directly simulated (no regression) to account for radioactive delay during transport as well as retardation. Fluxes through the downgradient boundary were written to a surface flux file, one of STOMP's standard output options. For each time step, STOMP writes the water mass and solute mass flux rates passing through the surface as well as the cumulative water and solute mass that have passed through the surface. Groundwater concentration within the 5-m-long surface was conservatively estimated by calculating it at the aquifer edge beneath the downgradient edge of the waste site footprint. The solute mass flux per unit time was divided by the water volume flux per unit time to yield a groundwater concentration at each time step.

The upper and lower bounds for unit length PRGs and SSLs were then applied:

- Lower threshold of numerical significance for peak groundwater concentration (Section 2.5.1)
- Lower threshold of EQL (Section 2.5.2)
- Upper threshold of pore space maximum concentration for non-radionuclide COPCs (Section 2.5.3)

For scaling unit-length PRG and SSL values for evaluation of EPC values, the following truncations apply:

- Lower threshold of 90th percentile background concentration, where available, for evaluation (scaled) PRG and SSL values
- Lower threshold of EQL for evaluation (scaled) PRG and SSL values

Finally, note that the SSL or PRG values for Cr(VI) are set based on limitations of the data supporting K_d value use; these values are not scaled by a representative dimension Refer to Section 2.5.4 for further explanation.

5.1.3 Effective Dilution Factor

Dilution of vadose zone contaminant release in the aquifer is directly accounted for within the STOMP simulation because the aquifer is directly represented in the model domain as a function of the aquifer thickness and the hydraulic gradient. Consequently, an aquifer dilution factor is not applied to scale the concentrations reported by STOMP, but rather it is implicit in the concentrations reported by STOMP in this formulation. For comparison purposes, the effective dilution factor in this model can be calculated. The dilution factor is as the ratio of the combined aquifer and vadose zone water fluxes to the vadose zone water flux (WAC 173-340-747):

$$DF = \frac{Q_{VZ} + Q_A}{Q_{VZ}} \qquad \text{Equation 6}$$

where DF = the dimensionless dilution factor, Q_{VZ} equals the volumetric flux from the vadose zone into the aquifer (L^3T^{-1}) and Q_A represents the volumetric flux through the topmost 5 m of the aquifer (L^3T^{-1}).

Equation 6 is applied using the recharge rates for each scenario and phase (Table 3; Table 4), median hydraulic gradients (Table 5), and aquifer saturated hydraulic conductivities (Table 7), along with dimensions of the STOMP model domain (Section 3.1). The resulting dilution factors are substantially higher where the aquifer is comprised of Hanford formation than where the aquifer is comprised of Ringold Formation because the higher hydraulic conductivity in the Hanford formation results in greater fluxes for a similar gradient. The dilution factors presented in Table 9 and Table 10 provide an indication of the magnitude of dilution calculated by STOMP.

Table 9. Effective Dilution Factors[a] for Native Vegetation Recharge Scenario Phases

Source Area	Aquifer Formation	Effective Dilution Factor by Surface Soil Type		
Bare Soil Phase (2010-2015)		Ephrata sandy loam and stony loam	Burbank sandy loam	Rupert sand
100-FR-1 100-FR-2	Hanford	520	171	201
	Ringold	241	79.6	93.9
100-IU-2	Hanford	1,470	481	568
	Ringold	338	111	131
100-IU-6	Hanford	2,940	961	1,140
	Ringold	674	221	261
Transitional Shrub-Steppe Phase (2015-2045)		Ephrata sandy loam and stony loam	Burbank sandy loam	Rupert sand
100-FR-1 100-FR-2	Hanford	2,940	1,470	1,100
	Ringold	1,360	682	512
100-IU-2	Hanford	8,320	4,160	3,120
	Ringold	1,910	955	716
100-IU-6	Hanford	16,600	8,320	6,240
	Ringold	3,820	1,910	1,430
Mature Shrub-Steppe Phase (2045 >)		Ephrata sandy loam and stony loam	Burbank sandy loam	Rupert sand
100-FR-1 100-FR-2	Hanford	5,880	2,940	2,210
	Ringold	2,730	1,360	1,020
100-IU-2	Hanford	16,600	8,320	6,240
	Ringold	3,820	1,910	1,430
100-IU-6	Hanford	33,300	16,600	12,500
	Ringold	7,630	3,820	2,860

a. Dilution factors calculated per Washington Administrative Code (WAC 173-340-747); calculation of dilution is for the steady-state recharge rate in each respective recharge phase. Instantaneous dilution in STOMP varies as a function of the instantaneous water flux from the vadose zone entering the aquifer at the water table, which changes in response to time-varying recharge rates.

Table 10. Effective Dilution Factors[a] for Irrigation Recharge Scenario Phases

Source Area	Aquifer Formation	Effective Dilution Factor by Surface Soil Type		
Bare Soil Phase (2010-2015)		Ephrata sandy loam and stony loam	Burbank sandy loam	Rupert sand
100-F	Hanford	520	171	201
	Ringold	241	79.6	93.9
100-IU-2	Hanford	1,470	481	568
	Ringold	338	111	131
100-IU-6	Hanford	2,940	961	1,140
	Ringold	674	221	261
Irrigation I Phase (2015-2045)		Ephrata sandy loam and stony loam	Burbank sandy loam	Rupert sand
100-F	Hanford	125	120	116
	Ringold	58.2	55.9	54.5
100-IU-2	Hanford	351	337	328
	Ringold	81.1	77.9	75.9
100-IU-6	Hanford	700	672	654
	Ringold	161	155	151
Irrigation II Phase (2045 >)		Ephrata sandy loam and stony loam	Burbank sandy loam	Rupert sand
100-F	Hanford	127	125	123
	Ringold	59.5	58.2	57.4
100-IU-2	Hanford	358	351	346
	Ringold	82.9	81.1	80.0
100-IU-6	Hanford	715	700	691
	Ringold	165	161	159

a. Dilution factors calculated per Washington Administrative Code (WAC 173-340-747); calculation of dilution is for the steady-state recharge rate in each respective recharge phase. Instantaneous dilution in STOMP varies as a function of the instantaneous water flux from the vadose zone entering the aquifer at the water table, which changes in response to time-varying recharge rates.

It is emphasized here that the dilution factors reported in Table 9 and Table 10 were not explicitly applied to dilute STOMP results. Rather, dilution is actually calculated within the STOMP solution using the calculated instantaneous water fluxes in the model domain, time step by time step. Thus, dilution is implicitly accounted for within the model results, rather than explicitly applied as a post-calculation step to model results.

For context, if the default fixed parameter three-phase partition model (WAC 173-340-747(3)(a)) were used to establish soil concentrations for groundwater protection, the default groundwater dilution factor is 20 for unsaturated zone soil. However, this default is not applicable to this calculation, because it uses alternative fate and transport models (WAC 173-340-747(8)) and not the default parameter three-phase partition model. Where alternative fate and transport models are used, the WAC requires that dilution "be based on site-specific measurements or estimated using a model incorporating site-specific characteristics". This requirement is met in this calculation by using STOMP to model the aquifer with the appropriate aquifer thickness and a median hydraulic gradient based on site-specific measurements.

5.1.4 Calculation of Soil Screening Levels and Preliminary Remediation Goals

In post-processing of the STOMP surface flux files, the peak groundwater concentration within 1000 years for the predictive simulations (Section 5.1.2) was identified for each simulation. For each COPC, and for each source area (100-FR-1, 100FR-2, 100-IU-2, or 100-IU-6), the maximum of the peak concentrations simulated for the representative stratigraphic columns for that source area (Figure 2 and Figure 3) was selected as the basis for calculation of the unit-length SSL (if the irrigation recharge scenario) or unit-length PRG (if the native vegetation recharge scenario). This process of using the maximum groundwater concentration result provided an additional bounding aspect to this calculation, because unit-length SSL and PRG values for all waste sites in a given source area are based on results for the stratigraphic column that is least protective for the range of stratigraphic columns representative of that source area.

Evaluation of unit-length SSL and PRG calculations for the full set of representative stratigraphic columns developed for all 100 Area source OUs indicates that the K_d threshold value (the K_d value at which the peak groundwater concentration does not exceed the breakthrough concentration threshold) is strongly influenced by the vadose zone thickness. Generally, for 70:30 initial source distributions, thicker vadose zone columns result in smaller K_d threshold values. Because the vadose zone thickness is highly variable across the 100-Area, a statistically significant K_d threshold value that is generally applicable throughout the 100-Area is useful for efficient determination of unit-length SSL and PRG values. Results from all representative columns that have been identified across the 100-Area are compared to calculate the required threshold K_d value. Separate comparisons were conducted for the unit-length SSL and PRG calculations resulting from the respective recharge scenarios associated with these calculations. In total, 35 representative columns that were developed for the various geographic areas within the 100-Area were included in this comparison. For each of these 35 representative stratigraphic columns, three different recharge rate time histories were applied (based on the three surface soil types; refer to Table 3 and Table 4) resulting in 105 representative stratigraphic column/recharge rate history combinations, all simulated under two recharge scenarios (irrigation for unit-length SSL values and native vegetation for unit-length PRG values).

The vadose zone thickness varied from 3.5 m to 35.5 m and the K_d threshold for unit-length SSLs (that are based on the irrigation recharge scenario) varied from 6 to 130 mL/g. The median K_d threshold value for unit-length SSL calculations was found to be 25 mL/g, which provides the most representative K_d threshold across the 100 Area. This value is similar to K_d threshold of 22 mL/g for unit-length SSL selected for the 100-D/H source areas (ECF-Hanford-11-0063). Based on results of this comparison, and in recognition of maintaining consistency with the 100-D/H calculations that yielded nearly the same K_d

threshold value, a 22 mL/g K_d threshold is selected for unit-length SSL calculations throughout the 100 Area. Further, it is noted that the thickness of vadose zone in the representative stratigraphic columns was conservatively biased with respect to vadose thickness because these were developed for maximum water table conditions (conservative with respect to vadose zone thickness). Using, for example, average water table conditions would have resulted in thicker vadose zone columns, and thereby reduce the K_d threshold value calculated in this process. Recognizing this conservative bias, a K_d threshold of 22 mL/g is considered reasonable for the purpose of determining unit-length SSL values. Furthermore, contaminants with K_d in the range of 20 mL/g or more have not been observed in the 100 Area groundwater (in dissolved state), reinforcing confidence that the K_d threshold value of 22 mL/g is reasonable.

A similar approach is used to determine the K_d threshold for unit-length PRGs (that are based on the native vegetation recharge scenario). The breakthrough groundwater concentrations calculated for most of the representative stratigraphic columns for 100-D/H source area remained below the threshold breakthrough concentration between K_d of 1 and 2 mL/g (ECF-Hanford-11-0063); therefore a K_d threshold of 1 mL/g is chosen. The results for other representative columns across the 100-Area are very similar and overwhelmingly indicate K_d threshold between 1 and 2 mL/g. Therefore, a K_d threshold of 1 mL/g is chosen for the unit-length PRG calculations for use throughout the 100 Area.

In summary, based on this evaluation, COPCs with K_d values exceeding the K_d threshold value of 22 mL/g for unit-length SSLs and 1 mL/g for unit-length PRGs are assigned the “NR” code.

5.2 Site-Specific Modeling

DOE-RL/2011-50 provides a graded approach for calculation of unit-length SSL and PRG values. Under this graded approach, for which the first-level, generalized model is non-representative, or in cases where the bounding assumptions merit reconsideration for specific site conditions, may be evaluated further using a site-specific modeling approach (second-stage model). This approach combines the efficiency of a generalized modeling approach (first level) with the judicious use of site-specific modeling (second level) only where the additional modeling is merited. Here, second-level modeling is used to evaluate if more realistic (that is, less bounding) evaluation using more site-specific information can remove a site (Retention Basin 116-F-14) from the list of exceedances.

5.2.1 Site 116-F-14

The EPC exceeded the SSL for Cr(VI) at this site in the first level of the Graded Approach. The small exceedance was not large, so the representativeness of the generalized conceptual site model, assumptions, and inputs parameter are evaluated here. The results demonstrated the need for a site-specific model to refine the SSL and PRG values to be more representative.

5.2.1.1 Background

The following information is available in the Waste Information and Disposal System (WIDS) for this site:

> **Site Description:** Site 116-F-14 was a rectangular, concrete-lined, open-top reservoir designed to retain reactor cooling water from the 105-F single-pass reactor prior to being discharged to the Columbia River. The basin had an estimated capacity of 5.67E+08 L (1.5E+08 gal). It was divided into two equal sections by weir walls running lengthwise from inlet to outlet end. Each section was subdivided by a series of wooden baffles. The site was surrounded by sprinklers (Hanford Drawing H-1-14321) installed on the top of the wall to keep the sludge from drying out during those times when effluent was not being discharged to the basin. This site was located about 530 m east-northeast of the 105-F Reactor Building.

Site Comment: Shortly after the reactor was shut down in 1965, water inside the basin was pumped to the 116-F-2 overflow trench. One and a half meters (5 ft.) of clean fill material was placed over the sludge in the bottom of the basin and the basin walls were spray coated with asphalt. The steel aboveground effluent pipeline that ran from the reactor building to the basin was cut into 6.1-m (20-ft.) sections. The pipeline was 460 m (1,500 ft.) long and 152-cm (60-in.) in diameter. The cut sections of effluent pipe were laid on top of the fill in the east section of the basin. Additional decommissioning was done in 1978-1979. The upper 3.1 m (10 ft.) of the basin's vertical walls were knocked down. At this time, the effluent pipe sections were moved to the west basin section. Sampling of the retention basin and vicinity was performed in 1975 with test pits and soil borings in and around the retention basin and nearby structures (Dorian and Richards, 1978). Material sampled during this effort included the soil fill within the basin, residual sludge on the basin floor, concrete samples obtained from the basin floor and walls, soil from beneath the basin floor, and subsurface soils outside the basin. The sample locations and results can also be found in DOE/RL-90-33. Seven backhoe pits and three soil borings were dug inside the 116-F-14 basin. The test pits (identified as AN, BN, CN, DN, AS, CS, and DS) only extended to a depth equal to the bottom of the basin to collect samples of basin backfill material and sludge. The three boreholes (identified as S, T, and U) provided samples of the basin fill and sludge, but also extended through the bottom of the basin for the collection of soil samples from beneath the basin. Analytical results are recorded in UNI-946 and in DOE/RL-90-33. Based upon the reported sample depths, the thickness of the fill material ranged from 1.1 m (3.5 ft.) to 1.8 meters (6 ft.). The Dorian and Richards report (UNI-946) states that the sludge thickness averaged approximately 7 cm (3 in.). The highest concentrations of radionuclides were found in the sludge samples, with concentrations of europium-154 as high as 9,800 pCi/g, europium-152 as high as 14,000 pCi/g, and nickel-63 as high as 34,000 pCi/g. Extensive sampling (Dorian and Richards, 1978) was performed on other soil borings and surface samples taken from locations adjacent to the outside of the basin. The sample locations and results can be found in DOE/RL-90-33. The highest radionuclide concentrations were observed in borehole "L", located approximately 50 m (160 ft.) southeast of the basin, and borehole "W", located near the northwest corner of the basin. Concentrations of europium-152 and europium-154 were as high as 6,200 pCi/g and concentrations of cobalt-60 were as high as 560 pCi/g in these boreholes. Elevated concentrations of these constituents were also observed in boreholes E, F, and X. The basin was decommissioned in stages over time from 1965 through 1999. Some areas of the basin that had been posted as a Surface Contamination Area (SCA) were radiologically surveyed and downposted to Underground Radioactive Material (URM) in 1994. The trench containing the cut pieces of effluent pipe remained posted as a Surface Contamination Area (SCA) until they were removed in 1999. The piping was transported to the Environmental Restoration Disposal Facility (ERDF). The area was covered with 30 cm (1 ft.) of clean backfill material. The remaining posted contamination areas were downposted to URM in 1999. In a July 1, 2003 letter from BHI a reference was made about a steel surface pipeline that had been identified in early aerial photographs. The pipeline was used to pump liquid wastes from the north end of the 116-F-14 Retention Basin to the north end of the 116-F-2 Liquid Waste Disposal Trench. However, since the pipeline was not found during excavation of the 116-F-14 and the 116-F-2 sites, it was concluded that the steel surface pipeline had been removed prior to reactor shutdown. Since the pipeline was not found during remediation activities and whereas the soil at each end of the pipeline was sampled, it was discussed with and agreed by the regulators that no additional sampling was required.

Release Description: Numerous instances of retention basin and pipeline leakage occurred during the operation of the basin resulting in areas of soil contamination. The basin leaked at

many locations along its walls and bottom. Hanford Drawing H-1-70247 (Retention Basin Leak Repair) shows some of the many types of repairs performed on the basin, including repairs of vertical cracks in the basin walls, removal of spilled concrete, rebuilding of expansion joint and repairs of cracks in the floor of the basin. The largest recorded leak extended roughly 7.6 m (25 ft.) from the foot of the unit wall. The leak, discovered in the summer of 1952, occurred in the effluent lines leading from the basin to the 148-F Pumphouse. Another release of contamination occurred at a large manhole located north of the 107-F basin (identified as P-22F on Hanford Drawing H-1-13850). Effluent overflowed intermittently for an extended period during the early 1950's before it was stopped. In 1955, water overflowed from the basin and contaminated the soils adjacent to the basin and a narrow path between the basin and the Columbia River. This release was identified as UPR-100-F-2. Contamination levels were 20,000 to 60,000 counts per minute with a maximum of 350 millirads/hour. HW-54636 contains information regarding the ground contamination size and shape. At least once during reactor operations, an unknown quantity of sludge was removed from the bottom of the basin and buried approximately 30.5 m (100 ft.) southeast of the southeastern corner of the basin. An estimated 1.8E+06 kg (2,000 tons) of sludge remained in the retention basin (Dorian and Richards 1978). In 1952, a hole was dug adjacent to the basin inlet pipe to drain the pipe. The hole and associated soil contamination were stabilized by covering it with clean soil, gravel, and cobbles. In 1964, high winds spread contamination when the basin was emptied and dry for maintenance. Known leakage from the 116-F-14 basin appears to have occurred primarily along the south and west sides. Estimates of leakage rates are not well documented, but the presence of a groundwater mound beneath the basin extended as high as 3 m (10 ft.) above the pre-existing water table elevation, suggests that significant leakage had occurred (Dorian and Richards 1978).

5.2.1.2 Basis for Site-Specific Evaluation

LFI borehole 199-F5-51 (A5682) was drilled at location shown in Figure 11 before interim remediation at this site (DOE/RL-93-82, *Limited Field Investigation Report for the 100-FR-1 Operable Unit*), and yielded only nondetects for Cr(VI) under this site. The cleanup verification package (CVP) for this site (CVP-2001-00009 Rev. 0, *Cleanup Verification Package for the 116-F-14 Retention Basin*) reported measurements of remaining contamination after remediation. The CVP data for Cr(VI) included shallow and deep zone results, although the applicable depth ranges to these respective zones were not defined. The shallow samples were collected from the sidewalls of the excavation, and the deep samples from the floor of the excavation. For the shallow zone, there were six nondetects and four detects (values 1.2, 0.76, 1.2, and 2.1 mg/kg). For the deep zone, 12 detects (ranging from 0.4 to 11 mg/kg) and 3 nondetects were reported.

The RI borehole 199-F5-55 (C7970) was drilled to provide vertical information on the distribution of contaminants below this site (Figure 7); the location of this borehole is also shown in Figure 11. Note that this RI borehole was not located within the original extent of the waste site, but approximately 20 m (66 ft.) west of the boundary; however, this is still within the extent excavated during the interim remedial action (see Figure 11) it represents an area where contamination from this basin could occur owing to redistribution during remedial activities. The excavation was roughly 6.1 m (20 ft.) below ground surface, which is where the RI borehole indicated Cr(VI) was present above detection levels, but not at deeper sampled locations.

Based on the above information and data, it is apparent that the initial distribution assumptions used in the first level of the Graded Approach for calculating SSLs and PRGs is excessively conservative with respect to Cr(VI) contamination at site 116-F-14. Hexavalent chromium contamination is mostly limited in spatial distribution to depths near the excavated depth, based on the RI borehole data (Figure 12) and

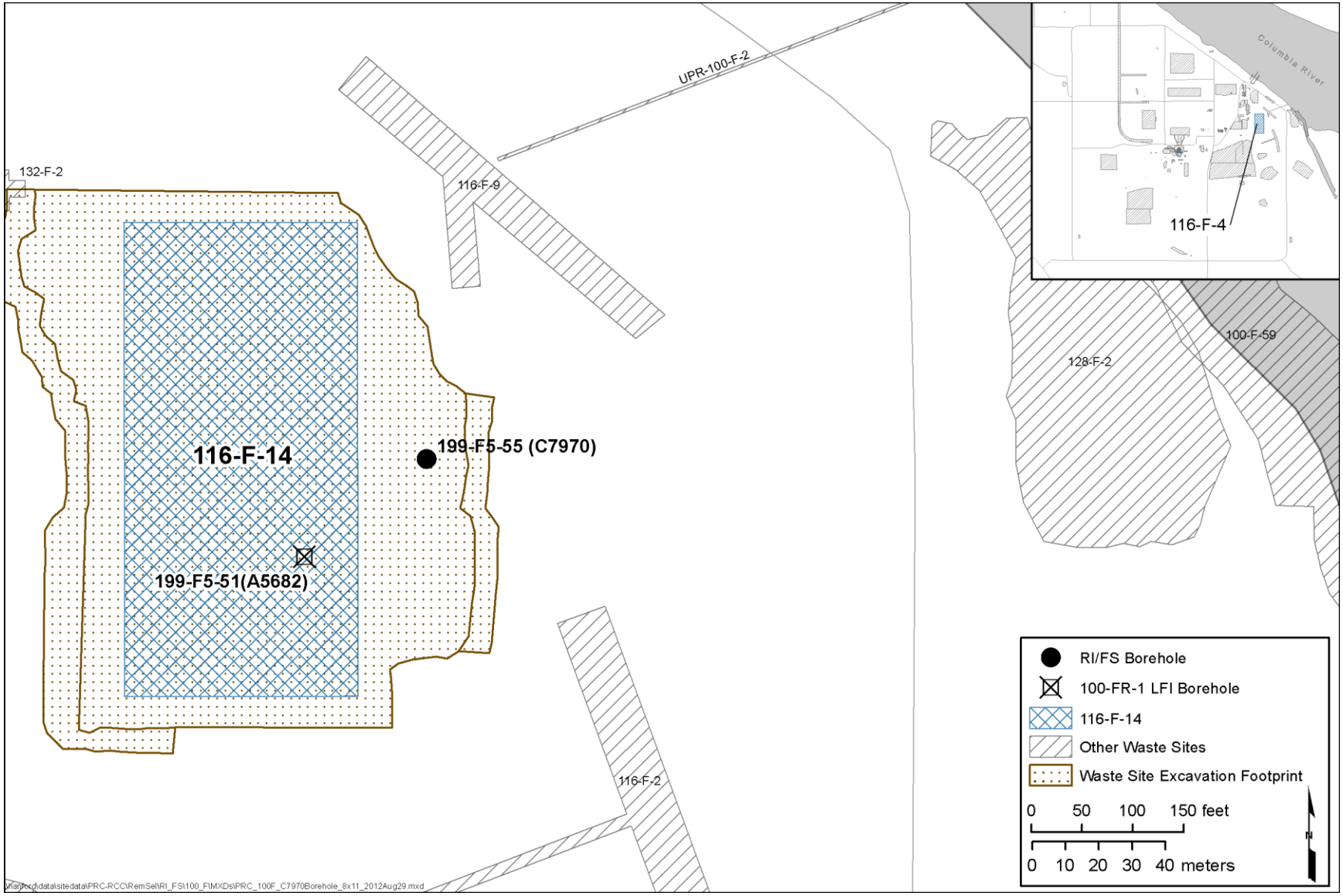


Figure 11. Site 116-F-14 Location, Interim Remedial Action Excavation Extent, and Location of Limited Field Investigation and Remedial Investigation Boreholes

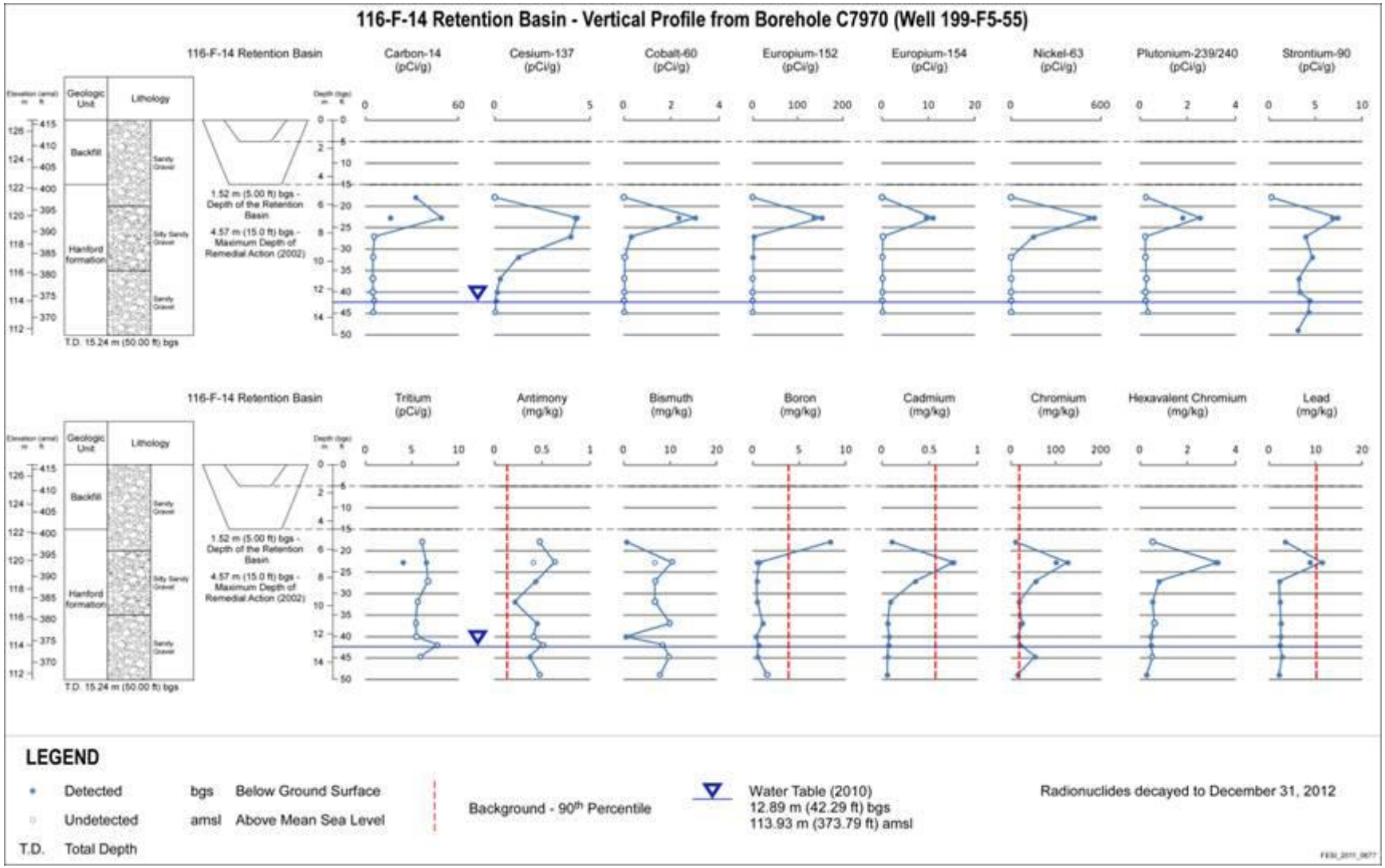


Figure 12. Vertical Profile from RI Well (199-F5-55)

absence of Cr(VI) detections above background in the LFI well. Moreover, the distribution of this contaminant at this site is highly variable spatially, based inference from LFI borehole data and CVP data. This is consistent with the fact that this site was a concrete lined facility, wherein contamination was strongly correlated to structural breaks in the concrete liner would have resulted in a highly variable pattern of contamination compared to facilities designed for infiltration (e.g., infiltration trenches or cribs).

5.2.1.3 Site-Specific Model Development

Based on the spatial variability of the contaminant distribution observed above, a modeling approach is adopted that evaluates this site with variability directly incorporated as follows:

1. The vertical distribution of Cr(VI) contamination is represented by the soil contamination profile obtained from the RI borehole (C7590) (Figure 7); that is, the extent of the soil profile contaminated above background is used to represent the depth interval contaminated at any given location within this waste site.
2. Each individual CVP reported concentration of Cr(VI) is assumed to represent of a fraction of the waste site area, providing a measure of spatial variability of the contamination over this site.
3. Any CVP value represents the peak vertical concentration (consistent with RI vertical data) and will be distributed vertically in the same proportion as the RI well vertical profile.
4. A single one-dimensional representative column from 100-FR-1 and 100-FR-2 OUs, selected from the suite used for first-level modeling under the Graded Approach, will be selected as most representative of site 116-F-14. The column most representative is 100-F representative stratigraphic column 1 (refer to Figure 2).
5. The site dimension parallel to the direction of groundwater flow was set 10m based on site description.
6. The surface soil actually prevalent at site 116-F-14 is Rupert sand; only those recharge rates associated with this surface soil will be used for recharge scenarios in site-specific modeling of this site.
7. Multiple one-dimensional simulations will be performed, one per reported concentration (#2, above), distributed vertically consistent with the initial vertical distribution of Cr(VI) over the depth range of the RI borehole (#1, above).
8. A cumulative distribution function of the resulting peak concentrations for both native vegetation recharge and Irrigation recharge will be developed to illustrate the spatial variability.
9. Other model aspects remained as in the first-step model; A K_d value of 0.8 mL/g was used for Cr(VI).

5.2.1.4 Site-Specific Model Results

Simulations were performed using the site-specific information detailed above to predict peak Cr(VI) groundwater concentrations in this second-step site-specific model. The resulting concentrations for the spatially distributed representation of this site results in a distribution of predicted groundwater peak Cr(VI) concentrations. These are shown as a cumulative distribution plot in Figure 13.

From Figure 13 it is evident that for, the native vegetation recharge scenario, 100 % of the peak concentrations fall below the groundwater (48 µg/L) and surface water (10 µg/L) standard. This is strongly indicative that residual Cr(VI) contamination at this site will not cause exceedances of either the

groundwater or surface water standards. For the irrigation recharge scenario, while the distribution of concentrations that does not exceed the groundwater standard in 95% of the area represented, it does exceed the surface water standard over more than 60% of the area represented in this distributed model.

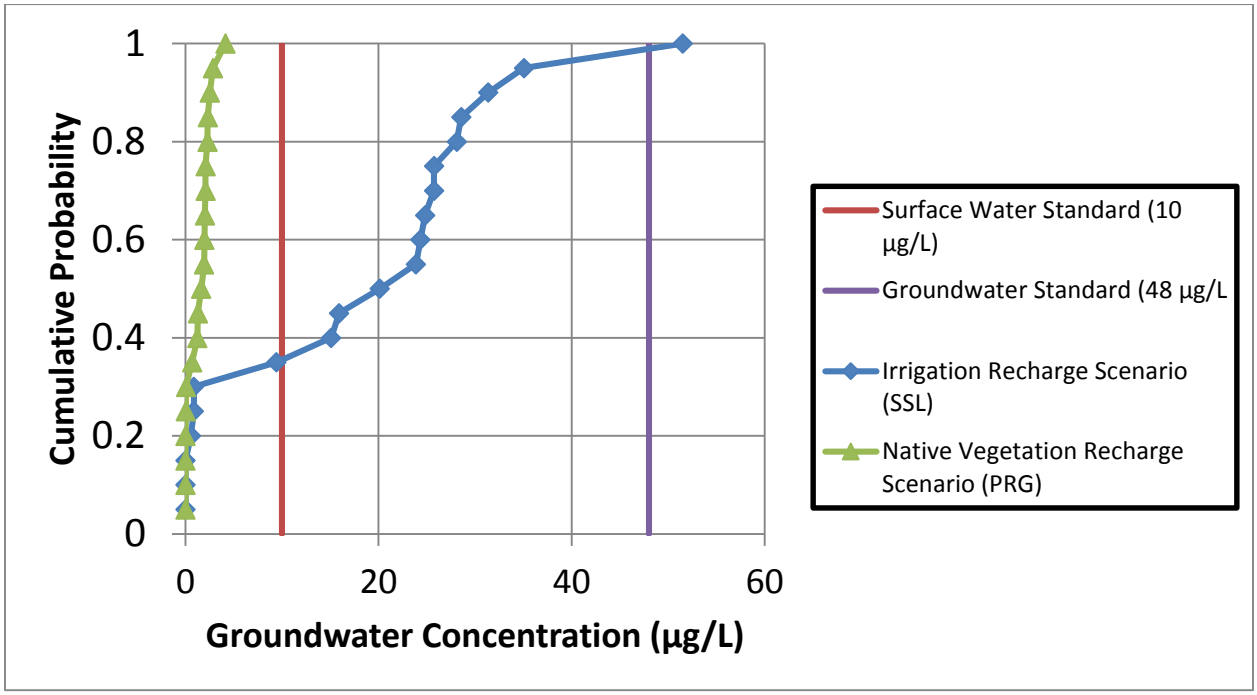


Figure 13. Cumulative Distribution of Predicted Peak Groundwater Concentration of Hexavalent Chromium for Site-Specific Spatially Distributed Model of Site 116-F-14

6 Results/Conclusions

The results of this calculation include tabulated unit-length SSL and PRG values (described in Section 6.1) and a sensitivity analysis on model results (described in 6.2).

6.1 Unit-Length Soil Screening Value and Preliminary Remediation Goal Results

As described in Section 5.1, for each COPC, the maximum of the peak groundwater concentrations calculated with STOMP for the range or stratigraphic columns for each source area (100-F, 100-IU-2 and 100-IU-6) using the irrigation recharge scenario was used in Equation 1 to compute the unit-length SSL value for each COPC. The resulting unit-length SSL values protective of surface water and of groundwater are reported for each COPC in Attachment A to this ECF.

Similarly, for each COPC, the maximum of the peak groundwater concentrations from the range of stratigraphic columns simulated for each source area (100-FR-1 & 100-FR-2, 100-IU-2, and 100-IU-6) using the native vegetation recharge scenario was used in Equation 2 to compute the unit-length PRG value. The resulting unit-length PRG values protective of surface water and groundwater are reported for each COPC in Attachment B to this ECF.

Note the following provisions apply with regard to unit-length SSLs and PRGs reported in Attachments A and B to this ECF, respectively:

- For evaluation of EPC values, the unit-length SSL and PRG values are to be scaled by the representative waste site dimension in the general direction of groundwater flow; this is accomplished by dividing the unit-length value by the representative dimension, checking that the scaled value is not less than the background level or the EQL or 90th percentile background level (where applicable) of the COPC, and then comparing to the EPC value.

- For COPCs for which an applicable water quality standard was not available, the "NA" symbol was applied to the unit-length SSL and PRG values (Section 2.5).

- Breakthrough was assumed not to occur if the simulated peak concentrations in groundwater within the 1000-year limit did not exceed 0.0001 µg/L for non-radionuclide COPCs, or 0.0001 pCi/L for radionuclide COPCs, in more than one representative stratigraphic column (Section 2.5.1). Based on evaluation of breakthrough above this threshold simulated for all representative stratigraphic columns developed throughout the 100 Area, K_d threshold values were identified to be 1 mL/g for unit-length PRG values and 22 mL/g for unit-length SSL values. For any COPC with a K_d value exceeding these thresholds, the “NR” symbol was applied for these COPCs to designate a non-representative result, signifying that these results were below a level of numerical significance.

- If the calculated value for any unit-length SSL or PRG was less than the EQL for soil concentration for a given COPC, then the unit-length SSL or PRG value was set equal to the EQL for that COPC (Section 2.5.2).

- If the calculated unit-length SSL or PRG value for any non-radionuclide COPC exceeded an upper bound of 384,000 mg/kg, then that unit-length SSL or PRG value was truncated at 384,000 mg/kg (Section 2.5.3).

- The cleanup level for hexavalent chromium is set to 6.0 mg/kg based on the evaluation in ECF-Hanford-11-0165; this value is not dependent on waste site size. (see Section 2.5.4).

The unit-length SSL and PRG values resulting from the simulations and estimation are intended only for application to sites for which the conditions and assumptions underpinning these calculations are representative. Some waste sites may require a more rigorous investigation of site-specific conditions than those underlying the unit-length SSL and PRG values found in Attachments A and B, respectively, of this ECF. This was done in the case of the 116-F-14 Retention Basins, where site-specific modeling was used to demonstrate this site would not cause exceedances of the groundwater standard, but has a significant expectation of exceeding the surface water standard at the POCal.

6.2 Sensitivity Analyses

Sensitivity analyses on model results are reported in this section.

6.2.1 Sensitivity Analysis: Evaluation of K_d Influence on Contaminant Breakthrough

Representative stratigraphic column 1 for the 100-F Area (Figure 2) was simulated with irrigation recharge scenario for Ephrata sandy loam or stony loam using an effective 100:0 source distribution. Figure 14 shows the resulting breakthrough curves for K_d values ranging from 0.9 – 8.0 mL/g. Observation of the breakthrough curves in Figure 14 shows that all the peak concentrations all occur within the 1000 year simulation time limit. Because the irrigation recharge rate is high in this scenario, it results in flushing the contaminants through the vadose zone quickly even for high K_d values. Again, it is emphasized that the irrigation recharge scenario applied here does not represent the actual site conditions or DOE’s land use plans. Rather, it is used here only as a limiting conservative condition for the limited

purpose of calculating unit-length SSLs only. Any waste site decision unit that does not pass the screening levels represented by scaled SSLs will be further evaluated against appropriate scaled PRG values for determination of site remediation actions.

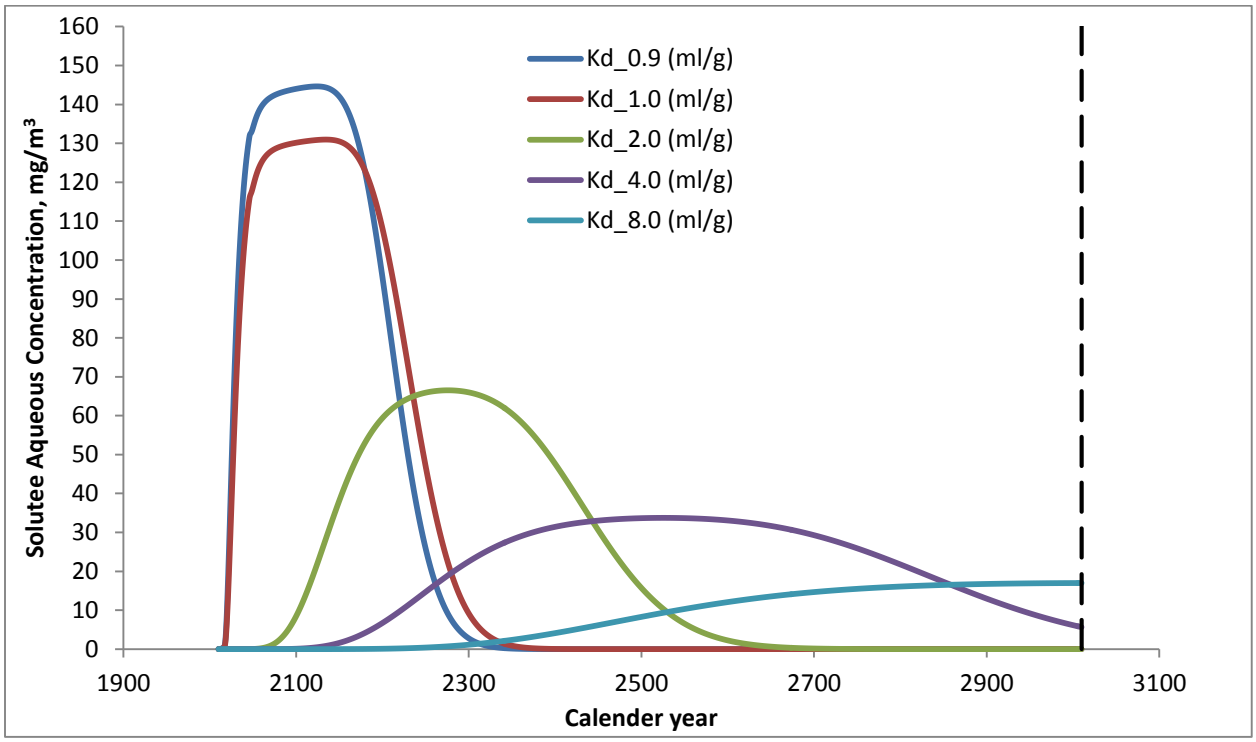


Figure 14. Breakthrough Curves for Different Distribution Coefficients with Irrigation Recharge

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Attachment A

Unit-Length Soil Screening Levels Protective of Groundwater and Soil Screening Levels Protective of Surface Water for the 100-FR-1, 100-FR-2, 100-IU-2, and 100-IU-6 Source Operable Units

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Table A-1. Unit-Length Soil Screening Levels for Non-Radionuclides Protective of Groundwater

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Unit-Length Soil Screening Level Protective of Groundwater [c,d] $\left(\frac{mg}{kg}\cdot m\right)$		
						100-FR-1,-2	100-IU-2	100-IU-6
16887-00-6	Chloride	chloride	0	2.5E+05	2.00E+00	9.97E+03	3.53E+04	6.30E+04
14797-55-8	Nitrate	Nitrate	0	4.5E+04	2.50E+00	1.79E+03	6.36E+03	1.13E+04
14797-65-0	Nitrite	Nitrite	0	3.3E+03	2.50E+00	1.32E+02	4.66E+02	8.32E+02
NO3-N	Nitrogen in Nitrate	Nitrogen in Nitrate	0	1.0E+04	7.50E-01	3.99E+02	1.41E+03	2.52E+03
NO2-N	Nitrogen in Nitrite	Nitrogen in Nitrite	0	1.0E+03	7.50E-01	3.99E+01	1.41E+02	2.52E+02
NO2+NO3-N	Nitrogen in Nitrite and Nitrate	Nitrogen in Nitrite and Nitrate	0	1.0E+04	---	3.99E+02	1.41E+03	2.52E+03
14808-79-8	Sulfate	sulfate	0	2.5E+05	5.00E+00	9.97E+03	3.53E+04	6.30E+04
51-28-5	2,4-Dinitrophenol	dinitrophenol;2,4 -	0.00001	3.2E+01	8.25E-01	1.28E+00	4.52E+00	8.07E+00
67-64-1	Acetone	Acetone	0.0006	7.2E+03	2.00E-02	2.89E+02	1.03E+03	1.84E+03
107-21-1	Ethylene Glychol	Ethylene Glychol	0.001	16,000	---	6.46E+02	2.31E+03	4.12E+03
111-76-2	2-Butoxyethanol	Ethylene Glychol Mono Butyl Ether	0.001	800	---	3.23E+01	1.15E+02	2.06E+02
75-99-0	Dalapon	Dalapon	0.0027	200	---	8.24E+00	2.97E+01	5.31E+01
111-91-1	Bis(2-Chloroethoxy)methane	bis(2-chloroethoxyl)methane	0.00277	4.8E+01	3.30E-01	1.98E+00	7.15E+00	1.27E+01
78-93-3	2-Butanone	methyl ethyl ketone (MEK; 2-butanone)	0.00451	4.8E+03	1.00E-02	2.02E+02	7.38E+02	1.32E+03
74-87-3	Chloromethane	chloromethane	0.006	No Value	1.00E-02	NA	NA	NA
74-83-9	Bromomethane	bromomethane	0.009	1.1E+01	1.00E-02	4.99E-01	1.88E+00	3.35E+00
60-29-7	Diethylether	Diethylether	0.009699	1600	---	7.20E+01	2.72E+02	4.85E+02
75-09-2	Methylene chloride	methylene chloride	0.01	5.0E+00	5.00E-03	2.26E-01	8.55E-01	1.53E+00
108-10-1	4-Methyl-2-pentanone	methyl isobutyl ketone	0.0126	6.4E+02	1.00E-02	2.97E+01	1.14E+02	2.03E+02
591-78-6	2-Hexanone	HEXANONE;2-[MBK, methyl butyl ketone]	0.01498	4.0E+01	2.00E-02	1.91E+00	7.39E+00	1.32E+01
75-01-4	Vinyl chloride	vinyl chloride [chloroethene; 1-]	0.019	6.1E-02	5.00E-03	5.00E-03	1.20E-02	2.14E-02
75-00-3	Chloroethane	ethyl chloride	0.0217	No Value	1.00E-02	NA	NA	NA
621-64-7	n-Nitrosodi-n-dipropylamine	nitroso-di-n-propylamine;N-	0.024	1.3E-02	3.30E-01	3.30E-01	3.30E-01	3.30E-01
10061-01-5	cis-1,3-Dichloropropene	dichloropropene; 1,2-,cis	0.027	4.4E-01	5.00E-03	2.35E-02	9.57E-02	1.71E-01
10061-02-6	trans-1,3-Dichloropropene	dichloropropene; 1,3-,trans	0.027	4.4E-01	5.00E-03	2.35E-02	9.57E-02	1.71E-01
108-95-2	Phenol	Phenol	0.0288	2.4E+03	3.30E-01	1.31E+02	5.37E+02	9.59E+02
94-75-7	2,4-D	2,4-Dichlorophenoxy acetic acid	0.029	70	---	3.84E+00	1.57E+01	2.80E+01
1918-00-9	Dicamba	Dicamba	0.029	480	---	2.63E+01	1.08E+02	1.92E+02
131-11-3	Dimethyl phthalate	dimethyl phthalate	0.0316	No Value	3.30E-01	NA	NA	NA
156-59-2	cis-1,2-Dichloroethylene	dichloroethylene; 1,2-,cis	0.036	1.6E+01	5.00E-03	9.39E-01	3.95E+00	7.05E+00
107-06-2	1,2-Dichloroethane	dichloroethane;1,2-	0.038	4.8E-01	5.00E-03	2.88E-02	1.22E-01	2.18E-01
156-60-5	trans-1,2-Dichloroethylene	dichloroethylene; 1,2-,trans	0.038	1.0E+02	5.00E-03	5.99E+00	2.54E+01	4.54E+01
1918-02-1	4-Amino-3,5,6-trichloropicolinic acid	4-Amino-3,5,6-trichloropicolinic acid	0.039	500	---	3.03E+01	1.29E+02	2.30E+02
108-60-1	Bis(2-chloro-1-methylethyl)ether	bis(2-chloro-1-methyl-ethyl)ether	0.0392	6.3E-01	3.30E-01	3.30E-01	3.30E-01	3.30E-01
540-59-0	1,2-Dichloroethene (Total)	dichloroethylene, 1,2- (mixed isomers)	0.0396	7.2E+01	5.00E-03	4.39E+00	1.87E+01	3.34E+01
75-69-4	Trichloromonofluoromethane	Trichloromonofluoromethane	0.04389	2400	---	1.51E+02	6.53E+02	1.17E+03
75-15-0	Carbon disulfide	carbon disulfide	0.046	8.0E+02	5.00E-03	5.13E+01	2.22E+02	3.96E+02
78-59-1	Isophorone	isophorone	0.0468	4.6E+01	3.30E-01	2.97E+00	1.29E+01	2.30E+01

Table A-1. Unit-Length Soil Screening Levels for Non-Radionuclides Protective of Groundwater

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Unit-Length Soil Screening Level Protective of Groundwater [c,d] $\left(\frac{mg}{kg}\cdot m\right)$ 100-FR-1,-2	100-IU-2	100-IU-6
78-87-5	1,2-Dichloropropane	dichloropropane; 1,2-	0.047	1.2E+00	5.00E-03	7.85E-02	3.40E-01	6.07E-01
93-65-2	2-(2-methyl-4-chlorophenoxy) propionic acid	2-(2-methyl-4-chlorophenoxy) propionic acid	0.04851	1.6E+01	---	1.03E+00	4.48E+00	7.99E+00
93-76-5	2,4,5-T	2,4,5-Trichlorophenoxyacetic acid	0.049	160	---	1.05E+01	4.57E+01	8.15E+01
99-09-2	3-Nitroaniline	nitroaniline, 3-	0.0516	4.2E+00	3.30E-01	3.30E-01	1.22E+00	2.17E+00
100-01-6	4-Nitroaniline	nitroaniline, 4-	0.0516	4.4E+00	3.30E-01	3.30E-01	1.28E+00	2.28E+00
88-74-4	2-Nitroaniline	nitroaniline, 2-	0.0527	1.6E+02	3.30E-01	1.08E+01	4.73E+01	8.44E+01
75-34-3	1,1-Dichloroethane	dichloroethane;1,1-	0.053	7.7E+00	1.00E-02	5.21E-01	2.28E+00	4.06E+00
67-66-3	Chloroform	chloroform	0.053	1.4E+00	5.00E-03	9.57E-02	4.19E-01	7.47E-01
75-27-4	Bromodichloromethane	bromodichloromethane	0.055	7.1E-01	5.00E-03	4.86E-02	2.13E-01	3.81E-01
71-43-2	Benzene	Benzene	0.062	8.0E-01	5.00E-03	5.80E-02	2.57E-01	4.59E-01
124-48-1	Dibromochloromethane	chlorodibromomethane [dibromochloromethane]	0.063	5.2E-01	5.00E-03	3.82E-02	1.70E-01	3.03E-01
75-35-4	1,1-Dichloroethene	Dichloroethene;1,1-	0.065	7.0E+00	1.00E-02	5.21E-01	2.32E+00	4.13E+00
606-20-2	2,6-Dinitrotoluene	dinitrotoluene;2,6-	0.0692	1.6E+01	3.30E-01	1.22E+00	5.47E+00	9.76E+00
106-47-8	4-Chloroaniline	chloroaniline;p-	0.0725	2.2E-01	3.30E-01	3.30E-01	3.30E-01	3.30E-01
79-00-5	1,1,2-Trichloroethane	trichloroethane;1,1,2-	0.075	7.7E-01	5.00E-03	6.12E-02	2.75E-01	4.91E-01
111-44-4	Bis(2-chloroethyl) ether	bis(2-chloroethyl)ether	0.076	4.0E-02	3.30E-01	3.30E-01	3.30E-01	3.30E-01
79-34-5	1,1,2,2-Tetrachloroethane	tetrachloroethane;1,1,2,2-	0.079	2.2E-01	5.00E-03	1.80E-02	8.12E-02	1.45E-01
93-72-1	2,4,5-TP	(2-(2,4,5-Trichlorophenoxy)propionic acid)Silvex	0.08	50	---	4.14E+00	1.87E+01	3.34E+01
84-66-2	Diethylphthalate	diethyl phthalate	0.082	1.3E+04	3.30E-01	1.07E+03	4.86E+03	8.66E+03
79-01-6	Trichloroethene	trichloroethylene (TCE)	0.094	9.5E-01	5.00E-03	8.55E-02	3.92E-01	6.99E-01
121-14-2	2,4-Dinitrotoluene	dinitrotoluene;2,4-	0.0955	2.8E-01	3.30E-01	3.30E-01	3.30E-01	3.30E-01
94-82-6	2,4-DB	(4-(2,4-Dichlorophenoxy)butanoic acid)	0.1	128	---	1.20E+01	5.51E+01	9.84E+01
98-95-3	Nitrobenzene	Nitrobenzene	0.119	1.6E+01	3.30E-01	1.61E+00	7.46E+00	1.33E+01
75-25-2	Bromoform	bromoform	0.13	5.5E+00	5.00E-03	5.82E-01	2.71E+00	4.83E+00
71-55-6	1,1,1-Trichloroethane	Trichloroethane; 1,1,1-	0.14	2.0E+02	5.00E-03	2.19E+01	1.02E+02	1.83E+02
108-88-3	Toluene	Toluene	0.14	6.4E+02	5.00E-03	7.02E+01	3.28E+02	5.85E+02
120-83-2	2,4-Dichlorophenol	dichlorophenol;2,4-	0.147	2.4E+01	3.30E-01	2.71E+00	1.27E+01	2.27E+01
56-23-5	Carbon tetrachloride	carbon tetrachloride	0.152	6.3E-01	5.00E-03	7.28E-02	3.42E-01	6.11E-01
100-41-4	Ethylbenzene	ethylbenzene	0.2	4.0E+00	5.00E-03	5.88E-01	2.85E+00	5.08E+00
108-38-3	m-Xylene	Xylene, m-	0.2	1.6E+03	---	2.36E+02	1.15E+03	2.05E+03
105-67-9	2,4-Dimethylphenol	dimethylphenol;2,4-	0.209	1.6E+02	3.30E-01	2.43E+01	1.18E+02	2.10E+02
108-90-7	Chlorobenzene	chlorobenzene	0.22	1.0E+02	5.00E-03	1.57E+01	7.60E+01	1.36E+02
1330-20-7	Xylenes (total)	Xylenes (total)	0.23	1.6E+03	1.00E-02	2.58E+02	1.25E+03	2.24E+03
95-47-6	o-Xylene	xylene,o-	0.24	1.6E+03	---	2.67E+02	1.30E+03	2.31E+03
127-18-4	Tetrachloroethene	tetrachloroethylene	0.27	5.0E+00	5.00E-03	9.21E-01	4.49E+00	8.01E+00
88-75-5	2-Nitrophenol	nitrophenol;2-	0.297	No Value	6.60E-01	NA	NA	NA
100-02-7	4-Nitrophenol	nitrophenol;4-	0.309	No Value	6.60E-01	NA	NA	NA
95-50-1	1,2-Dichlorobenzene	dichlorobenzene; 1,2- (ortho-Dichlorobenzene)	0.379	6.0E+02	3.30E-01	1.50E+02	7.34E+02	1.31E+03

Table A-1. Unit-Length Soil Screening Levels for Non-Radionuclides Protective of Groundwater

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Unit-Length Soil Screening Level Protective of Groundwater [c,d] $\left(\frac{mg}{kg}\cdot m\right)$		
						100-FR-1,-2	100-IU-2	100-IU-6
88-06-2	2,4,6-Trichlorophenol	Trichlorophenol2,4,6-	0.381	4.0E+00	3.30E-01	9.99E-01	4.89E+00	8.72E+00
95-57-8	2-Chlorophenol	Chlorophenol;2-	0.388	4.0E+01	3.30E-01	1.02E+01	5.01E+01	8.94E+01
541-73-1	1,3-Dichlorobenzene	dichlorobenzene;1,3	0.434	No Value	3.30E-01	NA	NA	NA
95-48-7	2-Methylphenol (cresol, o-)	cresol;o-	0.434	4.0E+02	3.30E-01	1.13E+02	5.53E+02	9.87E+02
106-44-5	4-Methylphenol (cresol, p-)	cresol;p-	0.434	8.0E+02	---	2.26E+02	1.11E+03	1.97E+03
59-50-7	4-Chloro-3-methylphenol	chloro-3-methylphenol;4-	0.4918	1.6E+03	3.30E-01	5.08E+02	2.50E+03	4.45E+03
87-86-5	Pentachlorophenol	pentachlorophenol	0.592	2.2E-01	3.30E-01	3.30E-01	4.08E-01	7.28E-01
534-52-1	4,6-Dinitro-2-methylphenol	dinitro-2-methylphenol;4,6-	0.6015	1.3E+00	3.30E-01	4.91E-01	2.42E+00	4.31E+00
106-46-7	1,4-Dichlorobenzene	dichlorobenzene;1,4- (para-Dichlorobenzene)	0.616	8.1E+00	5.00E-03	3.17E+00	1.56E+01	2.78E+01
91-94-1	3,3'-Dichlorobenzidine	dichlorobenzidine;3,3'-	0.724	1.9E-01	3.30E-01	3.30E-01	4.38E-01	7.82E-01
18540-29-9	Hexavalent Chromium	chromium(VI)	0.8	4.8E+01	---	6 [e]	6 [e]	6 [e]
100-42-5	Styrene	styrene	0.91	1.0E+02	5.00E-03	5.60E+01	2.82E+02	5.02E+02
91-20-3	Naphthalene	naphthalene	1.19	1.6E+02	1.00E-01	1.08E+02	5.43E+02	9.69E+02
86-30-6	n-Nitrosodiphenylamine	nitrosodiphenylamine;N-	1.29	1.8E+01	3.30E-01	1.27E+01	6.41E+01	1.14E+02
58-89-9	Gamma-BHC (Lindane)	lindane [gamma-BHC] (see hexachlorocyclohexane)	1.35	8.0E-02	1.65E-03	5.87E-02	2.95E-01	5.27E-01
84-74-2	Di-n-butylphthalate	di-butyl phthalate	1.57	1.6E+03	3.30E-01	1.36E+03	6.82E+03	1.22E+04
95-95-4	2,4,5-Trichlorophenol	Trichlorophenol;2,4,5-	1.6	8.0E+02	3.30E-01	6.93E+02	3.48E+03	6.21E+03
120-82-1	1,2,4-Trichlorobenzene	trichlorobenzene;1,2,4-	1.66	1.5E+00	3.30E-01	1.36E+00	6.85E+00	1.22E+01
319-84-6	Alpha-BHC	hexachlorocyclohexane;alpha (alpha-BHC, HCH)	1.76	1.4E-02	1.65E-03	1.35E-02	6.79E-02	1.21E-01
67-72-1	Hexachloroethane	hexachloroethane	1.78	1.1E+00	3.30E-01	1.09E+00	5.46E+00	9.75E+00
126-73-8	Tributyl phosphate	Tributyl phosphate	1.89	9.51	---	1.03E+01	5.17E+01	9.22E+01
7440-61-1	Uranium	Uranium	2	3.0E+01	---	3.59E+01	1.80E+02	3.21E+02
959-98-8	Endosulfan I	Endosulfan I	2.04	9.6E+01	1.65E-03	1.16E+02	5.87E+02	1.05E+03
33213-65-9	Endosulfan II	Endosulfan II	2.04	9.6E+01	3.30E-03	1.16E+02	5.87E+02	1.05E+03
1031-07-8	Endosulfan sulfate	Endosulfan sulfate	2.04	No Value	3.30E-03	NA	NA	NA
319-85-7	beta-1,2,3,4,5,6-Hexachlorocyclohexane (beta-BHC)	hexachlorocyclohexane;beta-	2.14	4.9E-02	1.65E-03	6.02E-02	3.12E-01	5.56E-01
319-86-8	Delta-BHC	hexachlorocyclohexane;delta-	2.81	No Value	1.65E-03	NA	NA	NA
91-58-7	2-Chloronaphthalene	beta-chloronaphthalene	2.98	6.4E+02	3.30E-01	1.01E+03	5.99E+03	1.07E+04
91-57-6	2-Methylnaphthalene	methylnapthalene;2-	2.98	3.2E+01	3.30E-01	5.04E+01	3.00E+02	5.35E+02
7440-42-8	Boron	Boron	3	3.2E+03	2.00E+00	5.07E+03	3.02E+04	5.38E+04
7005-72-3	4-Chlorophenylphenyl ether	chlorodiphenyl ether;4-	3.08	No Value	3.30E-01	NA	NA	NA
86-74-8	Carbazole	carbazole	3.39	4.4E+00	3.30E-01	7.94E+00	4.73E+01	8.44E+01
7723-14-0	Phosphorus	phosphorus	3.5	0.0E+00	5.00E+01	5.00E+01	5.00E+01	5.00E+01
88-85-7	Dinoseb	2-secButyl-4,6-dinitrophenol	3.5	7	---	1.33E+01	7.89E+01	1.41E+02

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CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Unit-Length Soil Screening Level Protective of Groundwater [c,d] $\left(\frac{mg}{kg}\cdot m\right)$		
						100-FR-1,-2	100-IU-2	100-IU-6
7440-36-0	Antimony	antimony	3.76	6.0E+00	6.00E-01	1.26E+01	7.53E+01	1.34E+02
7782-49-2	Selenium	selenium and compounds	5	5.0E+01	1.00E+00	1.41E+02	8.61E+02	1.54E+03
208-96-8	Acenaphthylene	acenaphthylene (Not in CLARC database tables; use acenaphthene as surrogate)	5.03	No Value	1.00E-01	NA	NA	NA
83-32-9	Acenaphthene	acenaphthene	6.12	4.8E+02	1.00E-01	1.71E+03	1.05E+04	1.87E+04
86-73-7	Fluorene	fluorene	7.71	3.2E+02	3.00E-02	1.42E+03	8.72E+03	1.56E+04
76-44-8	Heptachlor	heptachlor	9.53	1.9E-02	1.65E-03	1.11E-01	6.52E-01	1.17E+00
53494-70-5	Endrin ketone	Endrin ketone	9.72	No Value	3.30E-03	NA	NA	NA
57-12-5	Cyanide	cyanide	9.9	5.0E+00	---	3.03E+01	1.74E+02	3.14E+02
11104-28-2	Aroclor-1221	aroclor 1221 [PCB]	10.3	2.2E-02	1.65E-02	1.42E-01	7.93E-01	1.43E+00
11141-16-5	Aroclor-1232	aroclor 1232 [PCB]	10.3	2.2E-02	1.65E-02	1.42E-01	7.93E-01	1.43E+00
72-20-8	Endrin	endrin	10.8	2.0E+00	3.30E-03	1.40E+01	7.56E+01	1.36E+02
7421-93-4	Endrin aldehyde	Endrin aldehyde	10.8	No Value	3.30E-03	NA	NA	NA
132-64-9	Dibenzofuran	dibenzofuran	11.3	8.0E+00	3.30E-01	6.09E+01	1.17E+02	5.70E+02
85-68-7	Butylbenzylphthalate	butyl benzyl phthalate	13.8	4.6E+01	3.30E-01	5.25E+02	8.66E+02	4.13E+03
85-01-8	Phenanthrene	Phenanthrene	16.7	No Value	5.00E-02	NA	NA	NA
7439-98-7	Molybdenum	molybdenum	20	8.0E+01	2.00E+00	2.47E+03	2.78E+03	1.18E+04
7440-50-8	Copper	copper	22	6.4E+02	1.00E+00	2.34E+04	2.71E+04	1.11E+05
120-12-7	Anthracene	anthracene	23.5	2.4E+03	5.00E-02	NR	NR	NR
7440-39-3	Barium	Barium	25	2.0E+03	5.00E-01	NR	NR	NR
7439-89-6	Iron	Iron	25	1.1E+04	5.00E+00	NR	NR	NR
7440-24-6	Strontium	strontium	25	9.6E+03	1.00E+00	NR	NR	NR
60-57-1	Dieldrin	dieldrin	25.6	5.5E-03	3.30E-03	NR	NR	NR
7440-38-2	Arsenic	arsenic, inorganic	29	5.8E-02	1.00E+00	NR	NR	NR
7440-43-9	Cadmium	cadmium	30	5.0E+00	2.00E-01	NR	NR	NR
7439-92-1	Lead	lead	30	1.5E+01	5.00E-01	NR	NR	NR
7439-97-6	Mercury	mercury	30	2.0E+00	---	NR	NR	NR
7440-66-6	Zinc	zinc	30	4.8E+03	1.00E+00	NR	NR	NR
12672-29-6	Aroclor-1248	aroclor 1248 [PCB]	43.9	4.4E-02	1.65E-02	NR	NR	NR
53469-21-9	Aroclor-1242	aroclor 1242 [PCB]	44.8	4.4E-02	1.65E-02	NR	NR	NR
72-54-8	4,4'-DDD (Dichlorodiphenyldichloroethane)	ddd	45.8	3.6E-01	3.30E-03	NR	NR	NR
309-00-2	Aldrin	aldrin	48.7	2.6E-03	1.65E-03	NR	NR	NR
206-44-0	Fluoranthene	fluoranthene	49.1	6.4E+02	5.00E-02	NR	NR	NR
7440-48-4	Cobalt	Cobalt	50	4.8E+00	2.00E+00	NR	NR	NR
7439-93-2	Lithium	Lithium	50	3.2E+01	2.50E+00	NR	NR	NR
7439-96-5	Manganese	manganese	50	3.8E+02	5.00E+00	NR	NR	NR
5103-71-9	Alpha-Chlordane	Alpha-Chlordane	51	2.5E-01	1.65E-02	NR	NR	NR
57-74-9	Chlordane	chlordane	51	2.5E-01	1.65E-02	NR	NR	NR
87-68-3	Hexachlorobutadiene	hexachlorobutadiene	53.7	5.6E-01	3.30E-01	NR	NR	NR
7440-02-0	Nickel	nickel soluble salts	65	1.0E+02	4.00E+00	NR	NR	NR
129-00-0	Pyrene	pyrene	68	2.4E+02	5.00E-02	NR	NR	NR
7440-28-0	Thallium	Thallium, soluable salts	71	1.6E-01	5.00E-01	NR	NR	NR
11097-69-1	Aroclor-1254	aroclor 1254 (PCB)	75.6	4.4E-02	1.65E-02	NR	NR	NR
118-74-1	Hexachlorobenzene	hexachlorobenzene	80	5.5E-02	3.30E-01	NR	NR	NR
72-43-5	Methoxychlor	methoxychlor	80	4.0E+01	1.65E-02	NR	NR	NR
1024-57-3	Heptachlor epoxide	Heptachlor epoxide	83.2	4.8E-03	1.65E-03	NR	NR	NR

Table A-1. Unit-Length Soil Screening Levels for Non-Radionuclides Protective of Groundwater

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Unit-Length Soil Screening Level Protective of Groundwater [c,d] $\left(\frac{mg}{kg}\cdot m\right)$		
						100-FR-1,-2	100-IU-2	100-IU-6
72-55-9	4,4'-DDE (Dichlorodiphenyldichloroethylene)	dde	86.4	2.6E-01	3.30E-03	NR	NR	NR
7440-22-4	Silver	silver	90	8.0E+01	2.00E-01	NR	NR	NR
8001-35-2	Toxaphene	toxaphene	95.8	8.0E-02	1.65E-01	NR	NR	NR
12674-11-2	Aroclor-1016	aroclor 1016 (PCB)	107	5.0E-01	1.65E-02	NR	NR	NR
117-81-7	Bis(2-ethylhexyl) phthalate	bis(2-ethylhexyl) phthalate	110	6.0E+00	3.30E-01	NR	NR	NR
7440-31-5	Tin	tin	130	9.6E+03	1.00E+01	NR	NR	NR
16984-48-8	Fluoride	fluoride (using fluorine)	150	9.6E+02	5.00E+00	NR	NR	NR
7440-47-3	Chromium	chromium (total)	200	1.0E+02	2.00E-01	NR	NR	NR
218-01-9	Chrysene	Chrysene	200	1.2E+00	1.00E-01	NR	NR	NR
77-47-4	Hexachlorocyclopentadiene	hexachlorocyclopentadiene	200	4.8E+01	3.30E-01	NR	NR	NR
56-55-3	Benzo(a)anthracene	Benzo(a)anthracene	360	1.2E-01	1.50E-02	NR	NR	NR
50-29-3	4,4'-DDT (Dichlorodiphenyltrichloroethane)	ddt	678	2.6E-01	3.30E-03	NR	NR	NR
7440-41-7	Beryllium	beryllium	790	4.0E+00	2.00E-01	NR	NR	NR
205-99-2	Benzo(b)fluoranthene	Benzo(b)fluoranthene	803	1.2E-01	1.50E-02	NR	NR	NR
11096-82-5	Aroclor-1260	aroclor 1260 (PCB)	822	4.4E-02	1.65E-02	NR	NR	NR
7440-62-2	Vanadium	vanadium	1000	8.0E+01	2.50E+00	NR	NR	NR
207-08-9	Benzo(k)fluoranthene	Benzo(k)fluoranthene	1230	1.2E-01	1.50E-02	NR	NR	NR
7429-90-5	Aluminum	Aluminum (soluble)	1500	5.0E+01	5.00E+00	NR	NR	NR
53-70-3	Dibenz[a,h]anthracene	Dibenz[a,h]anthracene	1790	1.2E-01	3.00E-02	NR	NR	NR
191-24-2	Benzo(ghi)perylene	BENZO(g,h,i)PERYLENE (using pyrene as a surrogate)	1950	No Value	3.00E-02	NA	NA	NA
193-39-5	Indeno(1,2,3-cd)pyrene	Indeno(1,2,3-cd)pyrene	3470	1.2E-01	3.00E-02	NR	NR	NR
50-32-8	Benzo(a)pyrene	Benzo(a)pyrene	5500	1.2E-02	1.50E-02	NR	NR	NR
117-84-0	Di-n-octylphthalate	di-n-octyl phthalate	83000	1.9E+02	3.30E-01	NR	NR	NR
65794-96-9	3+4 Methylphenol (cresol, m+p)	methylphenol,3+4 (cresol, m+p)	No Value	No Value	3.30E-01	NA	NA	NA
101-55-3	4-Bromophenylphenyl ether	bromodiphenyl ether;4-	No Value	No Value	3.30E-01	NA	NA	NA
7440-69-9	Bismuth	Bismuth	No Value	No Value	1.00E+01	NA	NA	NA
24959-67-9	Bromide	Bromide	No Value	No Value	2.50E+00	NA	NA	NA
7440-70-2	Calcium	Calcium	No Value	No Value	1.00E+02	NA	NA	NA
PCB1242/1016	Co-elution of Aroclor 1242 and Aroclor 1016	Co-elution of Aroclor 1242 and Aroclor 1017	No Value	No Value	---	NA	NA	NA
7439-95-4	Magnesium	Magnesium (Not in CLARC database Tables)	No Value	No Value	7.50E+01	NA	NA	NA
14265-44-2	Phosphate	Phosphate	No Value	No Value	5.00E+00	NA	NA	NA
PO4-P	Phosphorus in phosphate	Phosphorus in phosphate	No Value	No Value	---	NA	NA	NA
7440-09-7	Potassium	Potassium	No Value	No Value	4.00E+02	NA	NA	NA
7440-21-3	Silicon	Silicon	No Value	No Value	2.00E+00	NA	NA	NA
7440-23-5	Sodium	Sodium	No Value	No Value	5.00E+01	NA	NA	NA
TPHDIESEL	Total petroleum hydrocarbons - diesel range	Total petroleum hydrocarbons - diesel range	No Value	5.0E+02	---	NA	NA	NA
TPH/OILH	Total petroleum hydrocarbons - motor oil (high boiling)	Total petroleum hydrocarbons - motor oil (high boiling)	No Value	5.0E+02	---	NA	NA	NA

Table A-1. Unit-Length Soil Screening Levels for Non-Radionuclides Protective of Groundwater

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a]	Ground Water Standard [a]	Estimated Quantitation Limit [b]	Unit-Length Soil Screening Level Protective of Groundwater [c,d] $\left(\frac{mg}{kg} \cdot m\right)$		
			(mL/g)	(µg/L)	(mg/kg)	100-FR-1,-2	100-IU-2	100-IU-6

a. ECF-HANFORD-10-0442, *Calculation of Nonradiological Soil Concentrations Protective of Groundwater Using the Fixed Parameter 3-Phase Equilibrium Partitioning Equation for the 100 Areas and 300 Area*, Revision 1, CH2M-HILL Plateau Remediation Company, Richland, Washington.

b. DOE/RL-2009-43 (Appendix A), *Sampling and Analysis Plan for the 100 FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

c. The following restrictions were applied to soil screening levels:

- "NA" was assigned where no applicable water quality standard was available.
- "NR" was assigned where a non-representative result was obtained in cases where breakthrough was not simulated to occur in more than one representative stratigraphic column within 1000 years, where breakthrough is defined as groundwater concentration exceeding 0.0001 µg/L (a value set as the lower limit of numerical significance).
- Value defaults to the estimated quantitation limit for any analyte where the calculated value is less than the estimated quantitation limit.
- Value was limited to a physical upper bound of 384,000 mg/kg, based on the maximum pore space contaminant mass capacity.

d. Soil screening levels protective of groundwater and protective of surface water are provided on a unit-length basis. To apply these soil screening levels, divide the listed value by a representative length across the waste site decision unit in the general direction of groundwater flow to obtain the soil screening value for evaluation use.

e. The soil screening level for hexavalent chromium is set to 6.0 mg/kg based on the evaluation in ECF-Hanford-11-0165; this value is not dependent on waste site size.

Cyan highlight denotes calculated values that changed because of incorporating updated IRIS (EPA's Integrated Risk Information System) groundwater standard values.

Table A-2. Unit-Length Soil Screening Levels for Non-Radionuclides Protective of Surface Water

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Unit-Length Soil Screening Level Protective of Surface Water [c,d] $\left(\frac{mg}{kg}\cdot m\right)$		
						100-FR-1,-2	100-IU-2	100-IU-6
16887-00-6	Chloride	chloride	0	2.3E+05	2.00E+00	9.17E+03	3.25E+04	5.80E+04
14797-55-8	Nitrate	Nitrate	0	4.5E+04	2.50E+00	1.79E+03	6.36E+03	1.13E+04
14797-65-0	Nitrite	Nitrite	0	No Value	2.50E+00	NA	NA	NA
NO3-N	Nitrogen in Nitrate	Nitrogen in Nitrate	0	1.0E+04	7.50E-01	3.99E+02	1.41E+03	2.52E+03
NO2-N	Nitrogen in Nitrite	Nitrogen in Nitrite	0	No Value	7.50E-01	NA	NA	NA
NO2+NO3-N	Nitrogen in Nitrite and Nitrate	Nitrogen in Nitrite and Nitrate	0	1.0E+04	---	3.99E+02	1.41E+03	2.52E+03
14808-79-8	Sulfate	sulfate	0	No Value	5.00E+00	NA	NA	NA
51-28-5	2,4-Dinitrophenol	dinitrophenol;2,4-	0.00001	6.9E+01	8.25E-01	2.75E+00	9.75E+00	1.74E+01
67-64-1	Acetone	Acetone	0.0006	7.4E+05	2.00E-02	2.97E+04	1.06E+05	1.89E+05
107-21-1	Ethylene Glychol	Ethylene Glychol	0.001	1,640,000	---	6.62E+04	2.37E+05	NR
111-76-2	2-Butoxyethanol	Ethylene Glychol Mono Butyl Ether	0.001	82044	---	3.31E+03	1.18E+04	2.11E+04
75-99-0	Dalapon	Dalapon	0.0027	10773	---	4.44E+02	1.60E+03	2.86E+03
111-91-1	Bis(2-Chloroethoxy)methane	bis(2-chloroethoxyl)methane	0.00277	2.3E+03	3.30E-01	9.66E+01	3.49E+02	6.22E+02
78-93-3	2-Butanone	methyl ethyl ketone (MEK; 2-butanone)	0.00451	4.9E+05	1.00E-02	2.07E+04	7.56E+04	1.35E+05
74-87-3	Chloromethane	chloromethane	0.006	No Value	1.00E-02	NA	NA	NA
74-83-9	Bromomethane	bromomethane	0.009	4.7E+01	1.00E-02	2.09E+00	7.88E+00	1.41E+01
60-29-7	Diethylether	Diethylether	0.009699	96000	---	4.32E+03	1.63E+04	2.91E+04
75-09-2	Methylene chloride	methylene chloride	0.01	4.6E+00	5.00E-03	2.08E-01	7.87E-01	1.40E+00
108-10-1	4-Methyl-2-pentanone	methyl isobutyl ketone	0.0126	6.1E+04	1.00E-02	2.83E+03	1.09E+04	1.94E+04
591-78-6	2-Hexanone	HEXANONE;2-[MBK, methyl butyl ketone]	0.01498	3.4E+03	2.00E-02	1.63E+02	6.34E+02	1.13E+03
75-01-4	Vinyl chloride	vinyl chloride [chloroethene; 1-]	0.019	2.5E-02	5.00E-03	5.00E-03	5.00E-03	8.81E-03
75-00-3	Chloroethane	ethyl chloride	0.0217	No Value	1.00E-02	NA	NA	NA
621-64-7	n-Nitrosodi-n-dipropylamine	nitroso-di-n-propylamine;N-	0.024	5.0E-03	3.30E-01	3.30E-01	3.30E-01	3.30E-01
10061-01-5	cis-1,3-Dichloropropene	dichloropropene; 1,2-,cis	0.027	3.4E-01	5.00E-03	1.83E-02	7.44E-02	1.33E-01
10061-02-6	trans-1,3-Dichloropropene	dichloropropene; 1,3-,trans	0.027	3.4E-01	5.00E-03	1.83E-02	7.44E-02	1.33E-01
108-95-2	Phenol	Phenol	0.0288	1.0E+04	3.30E-01	5.47E+02	2.24E+03	4.00E+03
94-75-7	2,4-D	2,4-Dichlorophenoxy acetic acid	0.029	100	---	5.48E+00	2.25E+01	4.01E+01
1918-00-9	Dicamba	Dicamba	0.029	24613	---	1.35E+03	5.53E+03	9.86E+03
131-11-3	Dimethyl phthalate	dimethyl phthalate	0.0316	2.7E+05	3.30E-01	1.52E+04	6.27E+04	1.12E+05
156-59-2	cis-1,2-Dichloroethylene	dichloroethylene; 1,2-,cis	0.036	4.7E+02	5.00E-03	2.74E+01	1.15E+02	2.06E+02
107-06-2	1,2-Dichloroethane	dichloroethane;1,2-	0.038	3.8E-01	5.00E-03	2.28E-02	9.66E-02	1.72E-01
156-60-5	trans-1,2-Dichloroethylene	dichloroethylene; 1,2-,trans	0.038	1.4E+02	5.00E-03	8.39E+00	3.56E+01	6.35E+01
1918-02-1	4-Amino-3,5,6-trichloropicolinic acid	4-Amino-3,5,6-trichloropicolinic acid	0.039	57431	---	3.48E+03	1.48E+04	2.64E+04
108-60-1	Bis(2-chloro-1-methylethyl)ether	bis(2-chloro-1-methyl-ethyl)ether	0.0392	3.7E+01	3.30E-01	2.27E+00	9.70E+00	1.73E+01
540-59-0	1,2-Dichloroethene (Total)	dichloroethylene, 1,2- (mixed isomers)	0.0396	2.1E+03	5.00E-03	1.28E+02	5.47E+02	9.76E+02
75-69-4	Trichloromonofluoromethane	Trichloromonofluoromethane	0.04389	35800	---	2.26E+03	9.74E+03	1.74E+04
75-15-0	Carbon disulfide	carbon disulfide	0.046	1.3E+04	5.00E-03	8.52E+02	3.69E+03	6.58E+03
78-59-1	Isophorone	isophorone	0.0468	8.4E+00	3.30E-01	5.42E-01	2.35E+00	4.19E+00
78-87-5	1,2-Dichloropropane	dichloropropane; 1,2-	0.047	5.0E-01	5.00E-03	3.23E-02	1.40E-01	2.50E-01

Table A-2. Unit-Length Soil Screening Levels for Non-Radionuclides Protective of Surface Water

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Unit-Length Soil Screening Level Protective of Surface Water [c,d] $\left(\frac{mg}{kg}\cdot m\right)$		
						100-FR-1,-2	100-IU-2	100-IU-6
93-65-2	2-(2-methyl-4-chlorophenoxy) propionic acid	2-(2-methyl-4-chlorophenoxy) propionic acid	0.04851	8.2E+02	---	5.30E+01	2.30E+02	4.10E+02
93-76-5	2,4,5-T	2,4,5-Trichlorophenoxy acetic acid	0.049	No Value	---	NA	NA	NA
99-09-2	3-Nitroaniline	nitroaniline, 3-	0.0516	1.0E+02	3.30E-01	6.89E+00	3.01E+01	5.37E+01
100-01-6	4-Nitroaniline	nitroaniline, 4-	0.0516	8.1E+01	3.30E-01	5.43E+00	2.37E+01	4.23E+01
88-74-4	2-Nitroaniline	nitroaniline, 2-	0.0527	2.6E+03	3.30E-01	1.75E+02	7.67E+02	1.37E+03
75-34-3	1,1-Dichloroethane	dichloroethane;1,1-	0.053	7.4E+04	1.00E-02	4.99E+03	2.18E+04	3.89E+04
67-66-3	Chloroform	chloroform	0.053	5.7E+00	5.00E-03	3.86E-01	1.69E+00	3.02E+00
75-27-4	Bromodichloromethane	bromodichloromethane	0.055	2.7E-01	5.00E-03	1.86E-02	8.17E-02	1.46E-01
71-43-2	Benzene	Benzene	0.062	1.2E+00	5.00E-03	8.75E-02	3.88E-01	6.92E-01
124-48-1	Dibromochloromethane	chlorodibromomethane [dibromochloromethane]	0.063	4.0E-01	5.00E-03	2.94E-02	1.30E-01	2.33E-01
75-35-4	1,1-Dichloroethene	Dichloroethene;1,1-	0.065	5.7E-02	1.00E-02	1.00E-02	1.89E-02	3.37E-02
606-20-2	2,6-Dinitrotoluene	dinitrotoluene;2,6-	0.0692	1.2E+02	3.30E-01	9.02E+00	4.03E+01	7.19E+01
106-47-8	4-Chloroaniline	chloroaniline;p-	0.0725	4.6E+00	3.30E-01	3.64E-01	1.63E+00	2.91E+00
79-00-5	1,1,2-Trichloroethane	trichloroethane;1,1,2-	0.075	5.9E-01	5.00E-03	4.71E-02	2.12E-01	3.78E-01
111-44-4	Bis(2-chloroethyl) ether	bis(2-chloroethyl)ether	0.076	3.0E-02	3.30E-01	3.30E-01	3.30E-01	3.30E-01
79-34-5	1,1,2,2-Tetrachloroethane	tetrachloroethane;1,1,2,2-	0.079	1.7E-01	5.00E-03	1.40E-02	6.31E-02	1.13E-01
93-72-1	2,4,5-TP	(2-(2,4,5-Trichlorophenoxy)propionic acid)Silvex	0.08	10	---	8.27E-01	3.74E+00	6.68E+00
84-66-2	Diethylphthalate	diethyl phthalate	0.082	1.7E+04	3.30E-01	1.42E+03	6.45E+03	1.15E+04
79-01-6	Trichloroethene	trichloroethylene (TCE)	0.094	2.5E+00	5.00E-03	2.25E-01	1.03E+00	1.84E+00
121-14-2	2,4-Dinitrotoluene	dinitrotoluene;2,4-	0.0955	1.1E-01	3.30E-01	3.30E-01	3.30E-01	3.30E-01
94-82-6	2,4-DB	(4-(2,4-Dichlorophenoxy)butanoic acid)	0.1	6564	---	6.14E+02	2.83E+03	5.04E+03
98-95-3	Nitrobenzene	Nitrobenzene	0.119	1.7E+01	3.30E-01	1.71E+00	7.92E+00	1.41E+01
75-25-2	Bromoform	bromoform	0.13	4.3E+00	5.00E-03	4.52E-01	2.10E+00	3.75E+00
71-55-6	1,1,1-Trichloroethane	Trichloroethane; 1,1,1-	0.14	9.3E+05	5.00E-03	1.02E+05	NR	NR
108-88-3	Toluene	Toluene	0.14	1.3E+03	5.00E-03	1.43E+02	6.66E+02	1.19E+03
120-83-2	2,4-Dichlorophenol	dichlorophenol;2,4-	0.147	7.7E+01	3.30E-01	8.70E+00	4.08E+01	7.28E+01
56-23-5	Carbon tetrachloride	carbon tetrachloride	0.152	2.3E-01	5.00E-03	2.66E-02	1.25E-01	2.23E-01
100-41-4	Ethylbenzene	ethylbenzene	0.2	1.6E+01	5.00E-03	2.32E+00	1.13E+01	2.01E+01
108-38-3	m-Xylene	Xylene, m-	0.2	No Value	---	NA	NA	NA
105-67-9	2,4-Dimethylphenol	dimethylphenol;2,4-	0.209	3.8E+02	3.30E-01	5.76E+01	2.80E+02	4.99E+02
108-90-7	Chlorobenzene	chlorobenzene	0.22	1.3E+02	5.00E-03	2.04E+01	9.88E+01	1.76E+02
1330-20-7	Xylenes (total)	Xylenes (total)	0.23	No Value	1.00E-02	NA	NA	NA
95-47-6	o-Xylene	xylene,o-	0.24	No Value	---	NA	NA	NA
127-18-4	Tetrachloroethene	tetrachloroethylene	0.27	6.9E-01	5.00E-03	1.27E-01	6.19E-01	1.10E+00
88-75-5	2-Nitrophenol	nitrophenol;2-	0.297	No Value	6.60E-01	NA	NA	NA
100-02-7	4-Nitrophenol	nitrophenol;4-	0.309	No Value	6.60E-01	NA	NA	NA
95-50-1	1,2-Dichlorobenzene	dichlorobenzene; 1,2- (ortho-Dichlorobenzene)	0.379	4.2E+02	3.30E-01	1.05E+02	5.14E+02	9.16E+02
88-06-2	2,4,6-Trichlorophenol	Trichlorophenol2,4,6-	0.381	1.4E+00	3.30E-01	3.52E-01	1.72E+00	3.07E+00
95-57-8	2-Chlorophenol	Chlorophenol;2-	0.388	8.1E+01	3.30E-01	2.07E+01	1.02E+02	1.81E+02

Table A-2. Unit-Length Soil Screening Levels for Non-Radionuclides Protective of Surface Water

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Unit-Length Soil Screening Level Protective of Surface Water [c,d] $\left(\frac{mg}{kg}\cdot m\right)$		
						100-FR-1,-2	100-IU-2	100-IU-6
541-73-1	1,3-Dichlorobenzene	dichlorobenzene; 1,3	0.434	3.2E+02	3.30E-01	9.03E+01	4.43E+02	7.90E+02
95-48-7	2-Methylphenol (cresol, o-)	cresol;o-	0.434	1.2E+04	3.30E-01	3.42E+03	1.68E+04	2.99E+04
106-44-5	4-Methylphenol (cresol, p-)	cresol;p-	0.434	2.9E+04	---	8.26E+03	4.05E+04	7.23E+04
59-50-7	4-Chloro-3-methylphenol	chloro-3-methylphenol;4-	0.4918	3.1E+04	3.30E-01	9.68E+03	4.76E+04	8.49E+04
87-86-5	Pentachlorophenol	pentachlorophenol	0.592	2.7E-01	3.30E-01	3.30E-01	5.01E-01	8.94E-01
534-52-1	4,6-Dinitro-2-methylphenol	dinitro-2-methylphenol;4,6-	0.6015	1.3E+01	3.30E-01	4.99E+00	2.45E+01	4.38E+01
106-46-7	1,4-Dichlorobenzene	dichlorobenzene; 1,4- (para-Dichlorobenzene)	0.616	2.2E+01	5.00E-03	8.44E+00	4.16E+01	7.42E+01
91-94-1	3,3'-Dichlorobenzidine	dichlorobenzidine;3,3'-	0.724	2.1E-02	3.30E-01	3.30E-01	3.30E-01	3.30E-01
18540-29-9	Hexavalent Chromium	chromium(VI)	0.8	1.0E+01	---	6 [e]	6 [e]	6 [e]
100-42-5	Styrene	styrene	0.91	3.8E+04	5.00E-03	2.15E+04	1.08E+05	1.93E+05
91-20-3	Naphthalene	naphthalene	1.19	4.9E+03	1.00E-01	3.33E+03	1.68E+04	2.99E+04
86-30-6	n-Nitrosodiphenylamine	nitrosodiphenylamine;N-	1.29	3.3E+00	3.30E-01	2.35E+00	1.18E+01	2.11E+01
58-89-9	Gamma-BHC (Lindane)	lindane [gamma-BHC] (see hexachlorocyclohexane)	1.35	1.9E-02	1.65E-03	1.40E-02	7.06E-02	1.26E-01
84-74-2	Di-n-butylphthalate	di-butyl phthalate	1.57	2.0E+03	3.30E-01	1.70E+03	8.53E+03	1.52E+04
95-95-4	2,4,5-Trichlorophenol	Trichlorophenol;2,4,5-	1.6	4.9E+02	3.30E-01	4.21E+02	2.12E+03	3.78E+03
120-82-1	1,2,4-Trichlorobenzene	trichlorobenzene; 1,2,4-	1.66	2.0E+00	3.30E-01	1.77E+00	8.90E+00	1.59E+01
319-84-6	Alpha-BHC	hexachlorocyclohexane;alpha (alpha-BHC, HCH)	1.76	2.6E-03	1.65E-03	2.53E-03	1.27E-02	2.27E-02
67-72-1	Hexachloroethane	hexachloroethane	1.78	1.4E+00	3.30E-01	1.38E+00	6.95E+00	1.24E+01
126-73-8	Tributyl phosphate	Tributyl phosphate	1.89	24.3	---	2.63E+01	1.32E+02	2.36E+02
7440-61-1	Uranium	Uranium	2	7.8E+02	---	9.30E+02	4.67E+03	8.33E+03
959-98-8	Endosulfan I	Endosulfan I	2.04	5.6E-02	1.65E-03	6.76E-02	3.42E-01	6.11E-01
33213-65-9	Endosulfan II	Endosulfan II	2.04	5.6E-02	3.30E-03	6.76E-02	3.42E-01	6.11E-01
1031-07-8	Endosulfan sulfate	Endosulfan sulfate	2.04	9.3E-01	3.30E-03	1.12E+00	5.69E+00	1.01E+01
319-85-7	beta-1,2,3,4,5,6-Hexachlorocyclohexane (beta-BHC)	hexachlorocyclohexane;beta-	2.14	9.1E-03	1.65E-03	1.13E-02	5.84E-02	1.04E-01
319-86-8	Delta-BHC	hexachlorocyclohexane;delta-	2.81	No Value	1.65E-03	NA	NA	NA
91-58-7	2-Chloronaphthalene	beta-chloronaphthalene	2.98	1.0E+03	3.30E-01	1.58E+03	9.36E+03	1.67E+04
91-57-6	2-Methylnaphthalene	methylnapthalene;2-	2.98	1.4E+02	3.30E-01	2.19E+02	1.30E+03	2.32E+03
7440-42-8	Boron	Boron	3	No Value	2.00E+00	NA	NA	NA
7005-72-3	4-Chlorophenylphenyl ether	chlorodiphenyl ether;4-	3.08	No Value	3.30E-01	NA	NA	NA
86-74-8	Carbazole	carbazole	3.39	No Value	3.30E-01	NA	NA	NA
7723-14-0	Phosphorus	phosphorus	3.5	No Value	5.00E+01	NA	NA	NA
88-85-7	Dinoseb	2-secButyl-4,6-dinitrophenol	3.5	No Value	---	NA	NA	NA
7440-36-0	Antimony	antimony	3.76	5.6E+00	6.00E-01	1.18E+01	7.03E+01	1.25E+02
7782-49-2	Selenium	selenium and compounds	5	5.0E+00	1.00E+00	1.41E+01	8.61E+01	1.54E+02

Table A-2. Unit-Length Soil Screening Levels for Non-Radionuclides Protective of Surface Water

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Unit-Length Soil Screening Level Protective of Surface Water [c,d] $\left(\frac{mg}{kg}\cdot m\right)$		
						100-FR-1,-2	100-IU-2	100-IU-6
208-96-8	Acenaphthylene	acenaphthylene (Not in CLARC database tables; use acenaphthene as surrogate)	5.03	No Value	1.00E-01	NA	NA	NA
83-32-9	Acenaphthene	acenaphthene	6.12	6.4E+02	1.00E-01	2.29E+03	1.40E+04	2.50E+04
86-73-7	Fluorene	fluorene	7.71	1.1E+03	3.00E-02	4.89E+03	3.00E+04	5.35E+04
76-44-8	Heptachlor	heptachlor	9.53	7.9E-05	1.65E-03	1.65E-03	2.65E-03	4.74E-03
53494-70-5	Endrin ketone	Endrin ketone	9.72	No Value	3.30E-03	NA	NA	NA
57-12-5	Cyanide	cyanide	9.9	5.2E+00	---	3.15E+01	1.80E+02	3.26E+02
11104-28-2	Aroclor-1221	aroclor 1221 [PCB]	10.3	6.4E-05	1.65E-02	1.65E-02	1.65E-02	1.65E-02
11141-16-5	Aroclor-1232	aroclor 1232 [PCB]	10.3	6.4E-05	1.65E-02	1.65E-02	1.65E-02	1.65E-02
72-20-8	Endrin	endrin	10.8	2.3E-03	3.30E-03	1.61E-02	8.70E-02	1.57E-01
7421-93-4	Endrin aldehyde	Endrin aldehyde	10.8	2.9E-01	3.30E-03	2.03E+00	1.10E+01	1.97E+01
132-64-9	Dibenzofuran	dibenzofuran	11.3	1.7E+00	3.30E-01	1.30E+01	2.50E+01	1.22E+02
85-68-7	Butylbenzylphthalate	butyl benzyl phthalate	13.8	8.2E+00	3.30E-01	9.40E+01	1.55E+02	7.39E+02
85-01-8	Phenanthrene	Phenanthrene	16.7	No Value	5.00E-02	NA	NA	NA
7439-98-7	Molybdenum	molybdenum	20	1.3E+03	2.00E+00	3.99E+04	4.51E+04	1.92E+05
7440-50-8	Copper	copper	22	9.0E+00	1.00E+00	3.29E+02	3.82E+02	1.56E+03
120-12-7	Anthracene	anthracene	23.5	8.3E+03	5.00E-02	NR	NR	NR
7440-39-3	Barium	Barium	25	1.0E+03	5.00E-01	NR	NR	NR
7439-89-6	Iron	Iron	25	3.0E+02	5.00E+00	NR	NR	NR
7440-24-6	Strontium	strontium	25	2.6E+04	1.00E+00	NR	NR	NR
60-57-1	Dieldrin	dieldrin	25.6	5.2E-05	3.30E-03	NR	NR	NR
7440-38-2	Arsenic	arsenic, inorganic	29	1.8E-02	1.00E+00	NR	NR	NR
7440-43-9	Cadmium	cadmium	30	2.5E-01	2.00E-01	NR	NR	NR
7439-92-1	Lead	lead	30	2.1E+00	5.00E-01	NR	NR	NR
7439-97-6	Mercury	mercury	30	1.2E-02	---	NR	NR	NR
7440-66-6	Zinc	zinc	30	9.1E+01	1.00E+00	NR	NR	NR
12672-29-6	Aroclor-1248	aroclor 1248 [PCB]	43.9	6.4E-05	1.65E-02	NR	NR	NR
53469-21-9	Aroclor-1242	aroclor 1242 [PCB]	44.8	6.4E-05	1.65E-02	NR	NR	NR
72-54-8	4,4'-DDD (Dichlorodiphenyl dichloroethane)	ddd	45.8	3.1E-04	3.30E-03	NR	NR	NR
309-00-2	Aldrin	aldrin	48.7	4.9E-05	1.65E-03	NR	NR	NR
206-44-0	Fluoranthene	fluoranthene	49.1	9.0E+01	5.00E-02	NR	NR	NR
7440-48-4	Cobalt	Cobalt	50	2.6E+00	2.00E+00	NR	NR	NR
7439-93-2	Lithium	Lithium	50	No Value	2.50E+00	NA	NA	NA
7439-96-5	Manganese	manganese	50	5.0E+01	5.00E+00	NR	NR	NR
5103-71-9	Alpha-Chlordane	Alpha-Chlordane	51	5.7E-04	1.65E-02	NR	NR	NR
57-74-9	Chlordane	chlordane	51	5.7E-04	1.65E-02	NR	NR	NR
87-68-3	Hexachlorobutadiene	hexachlorobutadiene	53.7	4.4E-01	3.30E-01	NR	NR	NR
7440-02-0	Nickel	nickel soluble salts	65	5.2E+01	4.00E+00	NR	NR	NR
129-00-0	Pyrene	pyrene	68	8.3E+02	5.00E-02	NR	NR	NR
7440-28-0	Thallium	Thallium, soluable salts	71	2.2E-01	5.00E-01	NR	NR	NR
11097-69-1	Aroclor-1254	aroclor 1254 (PCB)	75.6	6.4E-05	1.65E-02	NR	NR	NR
118-74-1	Hexachlorobenzene	hexachlorobenzene	80	2.8E-04	3.30E-01	NR	NR	NR
72-43-5	Methoxychlor	methoxychlor	80	3.0E-02	1.65E-02	NR	NR	NR
1024-57-3	Heptachlor epoxide	Heptachlor epoxide	83.2	3.9E-05	1.65E-03	NR	NR	NR
72-55-9	4,4'-DDE (Dichlorodiphenyl dichloroethylene)	dde	86.4	2.2E-04	3.30E-03	NR	NR	NR

Table A-2. Unit-Length Soil Screening Levels for Non-Radionuclides Protective of Surface Water

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Unit-Length Soil Screening Level Protective of Surface Water [c,d] $\left(\frac{mg}{kg}\cdot m\right)$		
						100-FR-1,-2	100-IU-2	100-IU-6
7440-22-4	Silver	silver	90	2.6E+00	2.00E-01	NR	NR	NR
8001-35-2	Toxaphene	toxaphene	95.8	2.0E-04	1.65E-01	NR	NR	NR
12674-11-2	Aroclor-1016	aroclor 1016 (PCB)	107	6.4E-05	1.65E-02	NR	NR	NR
117-81-7	Bis(2-ethylhexyl) phthalate	bis(2-ethylhexyl) phthalate	110	1.2E+00	3.30E-01	NR	NR	NR
7440-31-5	Tin	tin	130	5.2E+02	1.00E+01	NR	NR	NR
16984-48-8	Fluoride	fluoride (using fluorine)	150	1.6E+04	5.00E+00	NR	NR	NR
7440-47-3	Chromium	chromium (total)	200	6.5E+01	2.00E-01	NR	NR	NR
218-01-9	Chrysene	Chrysene	200	2.8E-03	1.00E-01	NR	NR	NR
77-47-4	Hexachlorocyclo pentadiene	hexachlorocyclop entadiene	200	4.0E+01	3.30E-01	NR	NR	NR
56-55-3	Benzo(a)anthrac ene	Benzo(a)anthrac ene	360	2.8E-03	1.50E-02	NR	NR	NR
50-29-3	4,4'-DDT (Dichlorodiphenyl trichloroethane)	ddt	678	2.2E-04	3.30E-03	NR	NR	NR
7440-41-7	Beryllium	beryllium	790	2.7E+02	2.00E-01	NR	NR	NR
205-99-2	Benzo(b)fluorant hene	Benzo(b)fluorant hene	803	2.8E-03	1.50E-02	NR	NR	NR
11096-82-5	Aroclor-1260	aroclor 1260 (PCB)	822	6.4E-05	1.65E-02	NR	NR	NR
7440-62-2	Vanadium	vanadium	1000	No Value	2.50E+00	NA	NA	NA
207-08-9	Benzo(k)fluorant hene	Benzo(k)fluorant hene	1230	2.8E-03	1.50E-02	NR	NR	NR
7429-90-5	Aluminum	Aluminum (soluble)	1500	8.7E+01	5.00E+00	NR	NR	NR
53-70-3	Dibenz[a,h]anthr acene	Dibenz[a,h]anthr acene	1790	2.8E-03	3.00E-02	NR	NR	NR
191-24-2	Benzo(ghi)peryle ne	BENZO(g,h,i)PE RYLENE (using pyrene as a surrogate)	1950	No Value	3.00E-02	NA	NA	NA
193-39-5	Indeno(1,2,3-cd)pyrene	Indeno(1,2,3-cd)pyrene	3470	2.8E-03	3.00E-02	NR	NR	NR
50-32-8	Benzo(a)pyrene	Benzo(a)pyrene	5500	2.8E-03	1.50E-02	NR	NR	NR
117-84-0	Di-n-octylphthalate	di-n-octyl phthalate	83000	No Value	3.30E-01	NA	NA	NA
65794-96-9	3+4 Methylphenol (cresol, m+p)	methylphenol,3+4 (cresol, m+p)	No Value	No Value	3.30E-01	NA	NA	NA
101-55-3	4-Bromophenylphe nyl ether	bromodiphenyl ether;4-	No Value	No Value	3.30E-01	NA	NA	NA
7440-69-9	Bismuth	Bismuth	No Value	No Value	1.00E+01	NA	NA	NA
24959-67-9	Bromide	Bromide	No Value	No Value	2.50E+00	NA	NA	NA
7440-70-2	Calcium	Calcium	No Value	No Value	1.00E+02	NA	NA	NA
PCB1242/1016	Co-elution of Aroclor 1242 and Aroclor 1016	Co-elution of Aroclor 1242 and Aroclor 1017	No Value	No Value	---	NA	NA	NA
7439-95-4	Magnesium	Magnesium (Not in CLARC database Tables)	No Value	No Value	7.50E+01	NA	NA	NA
14265-44-2	Phosphate	Phosphate	No Value	No Value	5.00E+00	NA	NA	NA
PO4-P	Phosphorus in phosphate	Phosphorus in phosphate	No Value	No Value	---	NA	NA	NA
7440-09-7	Potassium	Potassium	No Value	No Value	4.00E+02	NA	NA	NA
7440-21-3	Silicon	Silicon	No Value	No Value	2.00E+00	NA	NA	NA
7440-23-5	Sodium	Sodium	No Value	No Value	5.00E+01	NA	NA	NA
TPHDIESEL	Total petroleum hydrocarbons - diesel range	Total petroleum hydrocarbons - diesel range	No Value	No Value	---	NA	NA	NA
TPH/OILH	Total petroleum hydrocarbons - motor oil (high boiling)	Total petroleum hydrocarbons - motor oil (high boiling)	No Value	No Value	---	NA	NA	NA

Table A-2. Unit-Length Soil Screening Levels for Non-Radionuclides Protective of Surface Water

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a]	Ground Water Standard [a]	Estimated Quantitation Limit [b]	Unit-Length Soil Screening Level Protective of Surface Water [c,d] $\left(\frac{mg}{kg} \cdot m\right)$		
			(mL/g)	(µg/L)	(mg/kg)	100-FR-1,-2	100-IU-2	100-IU-6

a. ECF-HANFORD-10-0442, *Calculation of Nonradiological Soil Concentrations Protective of Groundwater Using the Fixed Parameter 3-Phase Equilibrium Partitioning Equation for the 100 Areas and 300 Area*, Revision 1, CH2M-HILL Plateau Remediation Company, Richland, Washington.

b. DOE/RL-2009-43 (Appendix A), *Sampling and Analysis Plan for the 100 FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

c. The following restrictions were applied to soil screening levels:

- "NA" was assigned where no applicable water quality standard was available.
- "NR" was assigned where a non-representative result was obtained in cases where breakthrough was not simulated to occur in more than one representative stratigraphic column within 1000 years, where breakthrough is defined as groundwater concentration exceeding 0.0001 µg/L (a value set as the lower limit of numerical significance).
- Value defaults to the estimated quantitation limit for any analyte where the calculated value is less than the estimated quantitation limit.
- Value was limited to a physical upper bound of 384,000 mg/kg, based on the maximum pore space contaminant mass capacity.

d. Soil screening levels protective of groundwater and protective of surface water are provided on a unit-length basis. To apply these soil screening levels, divide the listed value by a representative length across the waste site decision unit in the general direction of groundwater flow to obtain the soil screening value for evaluation use.

e. The soil screening level for hexavalent chromium is set to 6.0 mg/kg based on the evaluation in ECF-Hanford-11-0165; this value is not dependent on waste site size.

Cyan highlight denotes calculated values that changed because of incorporating updated IRIS (EPA's Integrated Risk Information System) groundwater standard values.

Table A-3. Unit-Length Soil Screening Levels for Radionuclides Protective of Groundwater

Radionuclide	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Maximum Contaminant Level [a] (pCi/L)	Half-life [b] (yr)	Estimated Quantitation Limit [c] (mg/kg)	Unit-Length Soil Screening Level Protective of Groundwater [d,e] $\left(\frac{pCi}{g}\cdot m\right)$		
					100-FR-1,-2	100-IU-2	100-IU-6
Carbon-14 [f]	0	2000	5.7300E+03	---	7.99E+01	2.84E+02	5.07E+02
Technetium-99	0	900	2.1300E+05	---	3.59E+01	1.27E+02	2.27E+02
Tritium	0	20000	1.2350E+01	---	1.66E+03	7.46E+03	1.33E+04
Iodine-129	1	1	1.5700E+07	---	6.12E-01	3.08E+00	5.50E+00
Uranium-233/234	2	No Value	2.4450E+05	1.00E+00	NA	NA	NA
Uranium-235	2	No Value	7.0380E+08	5.00E-01	NA	NA	NA
Uranium-238	2	No Value	4.4680E+09	1.00E+00	NA	NA	NA
Neptunium-237	15	15	2.1400E+06	---	2.09E+02	8.42E+02	1.50E+03
Strontium-90 [g]	25	8	2.9120E+01	---	2.46E+04	6.42E+04	1.04E+05
Nickel-63	30	50	9.6000E+01	---	NR	NR	NR
Cesium-137	50	200	3.0000E+01	1.00E-01	NR	NR	NR
Cobalt-60	50	100	5.7210E+00	5.00E-02	NR	NR	NR
Americium-241	200	15	4.32E+02	1.00E+00	NR	NR	NR
Carbon-14 [h]	200	2,000	5.73E+03	---	NR	NR	NR
Curium-243	200	15	2.85E+01	---	NR	NR	NR
Curium-244	200	15	1.81E+01	---	NR	NR	NR
Europium-152	200	200	1.33E+01	1.00E-01	NR	NR	NR
Europium-154	200	60	8.80E+00	1.00E-01	NR	NR	NR
Europium-155	200	600	4.96E+00	1.00E-01	NR	NR	NR
Niobium-94	200	No Value	2.03E+04	---	NR	NR	NR
Plutonium-238	200	15	8.77E+01	1.00E+00	NA	NA	NA
Plutonium-239	200	15	2.41E+04	1.00E+00	NR	NR	NR
Plutonium-240	200	15	6.54E+03	1.00E+00	NR	NR	NR
Plutonium-241	200	300	1.40E+01	---	NR	NR	NR
Radium-226	200	5	1.60E+03	---	NR	NR	NR
Radium-228	200	5	5.75E+00	2.00E-01	NR	NR	NR
Thorium-228	200	15	1.91E+00	---	NR	NR	NR
Thorium-230	200	15	7.70E+04	---	NR	NR	NR
Thorium-232	200	15	1.41E+10	---	NR	NR	NR

a. ECF-HANFORD-10-0442, *Calculation of Nonradiological Soil Concentrations Protective of Groundwater Using the Fixed Parameter 3-Phase Equilibrium Partitioning Equation for the 100 Areas and 300 Area*, Revision 1, CH2M-HILL Plateau Remediation Company, Richland, Washington.

b. Radiochemistry Society website, Available at: http://www.radiochemistry.org/.

c. DOE/RL-2009-43 (Appendix A), *Sampling and Analysis Plan for the 100 FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

d. The following restrictions were applied to soil screening levels:

- "NA" was assigned where no applicable water quality standard was available.
- "NR" was assigned where a non-representative result was obtained in cases where breakthrough was not simulated to occur in more than one representative stratigraphic column within 1000 years, where breakthrough is defined as groundwater concentration exceeding 0.0001 pCi/L (a value set as the lower limit of numerical significance).
- Value defaults to the estimated quantitation limit for any analyte where the calculated value is less than the estimated quantitation limit.

e. Soil screening levels protective of groundwater and protective of surface water are provided on a unit-length basis. To apply these soil screening levels, divide the listed value by a representative length across the waste site decision unit in the general direction of groundwater flow to obtain the soil screening value for evaluation use.

f. Carbon-14 in liquid form (typically associated with reactor gas condensate).

g. Strontium-90 is calculated based on a 100:0 initial source distribution, an exception to the convention that analytes with $K_d \geq 2$ were calculated based on a 70:30 initial source distribution, because of data that indicated strontium-90 distributed throughout the vadose zone at some locations in these OUs.

h. Carbon-14 in solid form (typically associated with graphite).

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Attachment B

Unit-Length Preliminary Remediation Goals Protective of Groundwater and Preliminary Remediation Goals Protective of Surface Water for the 100-FR-1, 100-FR-2, 100-IU-2, and 100-IU-6 Source Operable Units

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Table B-1. Unit-Length Preliminary Remediation Goals for Non-Radionuclides Protective of Groundwater

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Unit-Length Preliminary Remediation Goal Protective of Groundwater [c,d] $\left(\frac{mg}{kg}\cdot m\right)$		
						100-FR-1,-2	100-IU-2	100-IU-6
16887-00-6	Chloride	chloride	0	2.5E+05	2.00E+00	2.43E+04	6.47E+04	1.15E+05
14797-55-8	Nitrate	Nitrate	0	4.5E+04	2.50E+00	4.37E+03	1.16E+04	2.08E+04
14797-65-0	Nitrite	Nitrite	0	3.3E+03	2.50E+00	3.21E+02	8.54E+02	1.52E+03
NO3-N	Nitrogen in Nitrate	Nitrogen in Nitrate	0	1.0E+04	7.50E-01	9.72E+02	2.59E+03	4.62E+03
NO2-N	Nitrogen in Nitrite	Nitrogen in Nitrite	0	1.0E+03	7.50E-01	9.72E+01	2.59E+02	4.62E+02
NO2+NO3-N	Nitrogen in Nitrite and Nitrate	Nitrogen in Nitrite and Nitrate	0	1.0E+04	---	9.72E+02	2.59E+03	4.62E+03
14808-79-8	Sulfate	sulfate	0	2.5E+05	5.00E+00	2.43E+04	6.47E+04	1.15E+05
51-28-5	2,4-Dinitrophenol	dinitrophenol;2,4 -	0.00001	3.2E+01	8.25E-01	3.11E+00	8.28E+00	1.48E+01
67-64-1	Acetone	Acetone	0.0006	7.2E+03	2.00E-02	7.05E+02	1.89E+03	3.36E+03
107-21-1	Ethylene Glychol	Ethylene Glychol	0.001	16,000	---	1.58E+03	4.22E+03	7.53E+03
111-76-2	2-Butoxyethanol	Ethylene Glychol Mono Butyl Ether	0.001	800	---	7.88E+01	2.11E+02	3.76E+02
75-99-0	Dalapon	Dalapon	0.0027	200	---	2.01E+01	5.43E+01	9.68E+01
111-91-1	Bis(2-Chloroethoxy)methane	bis(2-chloroethoxyl)methane	0.00277	4.8E+01	3.30E-01	4.83E+00	1.30E+01	2.33E+01
78-93-3	2-Butanone	methyl ethyl ketone (MEK; 2-butanone)	0.00451	4.8E+03	1.00E-02	4.94E+02	1.34E+03	2.40E+03
74-87-3	Chloromethane	chloromethane	0.006	No Value	1.00E-02	NA	NA	NA
74-83-9	Bromomethane	bromomethane	0.009	1.1E+01	1.00E-02	1.22E+00	3.40E+00	6.06E+00
60-29-7	Diethylether	Diethylether	0.009699	1600	---	1.76E+02	4.92E+02	8.78E+02
75-09-2	Methylene chloride	methylene chloride	0.01	5.0E+00	5.00E-03	5.52E-01	1.55E+00	2.76E+00
108-10-1	4-Methyl-2-pentanone	methyl isobutyl ketone	0.0126	6.4E+02	1.00E-02	7.28E+01	2.06E+02	3.67E+02
591-78-6	2-Hexanone	HEXANONE;2-[MBK, methyl butyl ketone]	0.01498	4.0E+01	2.00E-02	4.68E+00	1.33E+01	2.37E+01
75-01-4	Vinyl chloride	vinyl chloride [chloroethene; 1-]	0.019	6.1E-02	5.00E-03	7.45E-03	2.15E-02	3.84E-02
75-00-3	Chloroethane	ethyl chloride	0.0217	No Value	1.00E-02	NA	NA	NA
621-64-7	n-Nitrosodi-n-dipropylamine	nitroso-di-n-propylamine;N-	0.024	1.3E-02	3.30E-01	3.30E-01	3.30E-01	3.30E-01
10061-01-5	cis-1,3-Dichloropropene	dichloropropene; 1,2-,cis	0.027	4.4E-01	5.00E-03	5.83E-02	1.71E-01	3.04E-01
10061-02-6	trans-1,3-Dichloropropene	dichloropropene; 1,3-,trans	0.027	4.4E-01	5.00E-03	5.83E-02	1.71E-01	3.04E-01
108-95-2	Phenol	Phenol	0.0288	2.4E+03	3.30E-01	3.26E+02	9.57E+02	1.71E+03
94-75-7	2,4-D	2,4-Dichlorophenoxy acetic acid	0.029	70	---	9.52E+00	2.80E+01	4.99E+01
1918-00-9	Dicamba	Dicamba	0.029	480	---	6.53E+01	1.92E+02	3.42E+02
131-11-3	Dimethyl phthalate	dimethyl phthalate	0.0316	No Value	3.30E-01	NA	NA	NA
156-59-2	cis-1,2-Dichloroethylene	dichloroethylene; 1,2-,cis	0.036	1.6E+01	5.00E-03	2.35E+00	6.99E+00	1.25E+01
107-06-2	1,2-Dichloroethane	dichloroethane;1,2-	0.038	4.8E-01	5.00E-03	7.22E-02	2.16E-01	3.85E-01
156-60-5	trans-1,2-Dichloroethylene	dichloroethylene; 1,2-,trans	0.038	1.0E+02	5.00E-03	1.50E+01	4.49E+01	8.00E+01
1918-02-1	4-Amino-3,5,6-trichloropicolinic acid	4-Amino-3,5,6-trichloropicolinic acid	0.039	500	---	7.60E+01	2.27E+02	4.05E+02
108-60-1	Bis(2-chloro-1-methylethyl)ether	bis(2-chloro-1-methyl-ethyl)ether	0.0392	6.3E-01	3.30E-01	3.30E-01	3.30E-01	5.08E-01
540-59-0	1,2-Dichloroethene (Total)	dichloroethylene, 1,2- (mixed isomers)	0.0396	7.2E+01	5.00E-03	1.10E+01	3.30E+01	5.89E+01
75-69-4	Trichloromonofluoromethane	Trichloromonofluoromethane	0.04389	2400	---	3.82E+02	1.15E+03	2.04E+03
75-15-0	Carbon disulfide	carbon disulfide	0.046	8.0E+02	5.00E-03	1.30E+02	3.90E+02	6.95E+02
78-59-1	Isophorone	isophorone	0.0468	4.6E+01	3.30E-01	7.53E+00	2.26E+01	4.03E+01

Table B-1. Unit-Length Preliminary Remediation Goals for Non-Radionuclides Protective of Groundwater

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Unit-Length Preliminary Remediation Goal Protective of Groundwater [c,d] $\left(\frac{mg}{kg}\cdot m\right)$		
						100-FR-1,-2	100-IU-2	100-IU-6
78-87-5	1,2-Dichloropropane	dichloropropane; 1,2-	0.047	1.2E+00	5.00E-03	1.99E-01	5.98E-01	1.07E+00
93-65-2	2-(2-methyl-4-chlorophenoxy) propionic acid	2-(2-methyl-4-chlorophenoxy) propionic acid	0.04851	1.6E+01	---	2.62E+00	7.87E+00	1.40E+01
93-76-5	2,4,5-T	2,4,5-Trichlorophenoxyacetic acid	0.049	160	---	2.67E+01	8.02E+01	1.43E+02
99-09-2	3-Nitroaniline	nitroaniline, 3-	0.0516	4.2E+00	3.30E-01	7.13E-01	2.14E+00	3.82E+00
100-01-6	4-Nitroaniline	nitroaniline, 4-	0.0516	4.4E+00	3.30E-01	7.49E-01	2.25E+00	4.01E+00
88-74-4	2-Nitroaniline	nitroaniline, 2-	0.0527	1.6E+02	3.30E-01	2.77E+01	8.32E+01	1.48E+02
75-34-3	1,1-Dichloroethane	dichloroethane;1,1-	0.053	7.7E+00	1.00E-02	1.33E+00	4.01E+00	7.15E+00
67-66-3	Chloroform	chloroform	0.053	1.4E+00	5.00E-03	2.45E-01	7.36E-01	1.31E+00
75-27-4	Bromodichloromethane	bromodichloromethane	0.055	7.1E-01	5.00E-03	1.25E-01	3.76E-01	6.70E-01
71-43-2	Benzene	Benzene	0.062	8.0E-01	5.00E-03	1.51E-01	4.54E-01	8.09E-01
124-48-1	Dibromochloromethane	chlorodibromomethane [dibromochloromethane]	0.063	5.2E-01	5.00E-03	9.96E-02	2.99E-01	5.34E-01
75-35-4	1,1-Dichloroethene	Dichloroethene;1,1-	0.065	7.0E+00	1.00E-02	1.36E+00	4.09E+00	7.29E+00
606-20-2	2,6-Dinitrotoluene	dinitrotoluene;2,6-	0.0692	1.6E+01	3.30E-01	3.23E+00	9.66E+00	1.72E+01
106-47-8	4-Chloroaniline	chloroaniline;p-	0.0725	2.2E-01	3.30E-01	3.30E-01	3.30E-01	3.30E-01
79-00-5	1,1,2-Trichloroethane	trichloroethane;1,1,2-	0.075	7.7E-01	5.00E-03	1.63E-01	4.87E-01	8.68E-01
111-44-4	Bis(2-chloroethyl) ether	bis(2-chloroethyl)ether	0.076	4.0E-02	3.30E-01	3.30E-01	3.30E-01	3.30E-01
79-34-5	1,1,2,2-Tetrachloroethane	tetrachloroethane;1,1,2,2-	0.079	2.2E-01	5.00E-03	4.83E-02	1.44E-01	2.56E-01
93-72-1	2,4,5-TP	(2-(2,4,5-Trichlorophenoxy)propionic acid)Silvex	0.08	50	---	1.11E+01	3.31E+01	5.91E+01
84-66-2	Diethylphthalate	diethyl phthalate	0.082	1.3E+04	3.30E-01	2.90E+03	8.59E+03	1.53E+04
79-01-6	Trichloroethene	trichloroethylene (TCE)	0.094	9.5E-01	5.00E-03	2.38E-01	6.94E-01	1.24E+00
121-14-2	2,4-Dinitrotoluene	dinitrotoluene;2,4-	0.0955	2.8E-01	3.30E-01	3.30E-01	3.30E-01	3.72E-01
94-82-6	2,4-DB	(4-(2,4-Dichlorophenoxy)butanoic acid)	0.1	128	---	3.38E+01	9.79E+01	1.75E+02
98-95-3	Nitrobenzene	Nitrobenzene	0.119	1.6E+01	3.30E-01	4.68E+00	1.33E+01	2.37E+01
75-25-2	Bromoform	bromoform	0.13	5.5E+00	5.00E-03	1.73E+00	4.85E+00	8.65E+00
71-55-6	1,1,1-Trichloroethane	Trichloroethane; 1,1,1-	0.14	2.0E+02	5.00E-03	6.65E+01	1.84E+02	3.28E+02
108-88-3	Toluene	Toluene	0.14	6.4E+02	5.00E-03	2.13E+02	5.89E+02	1.05E+03
120-83-2	2,4-Dichlorophenol	dichlorophenol;2,4-	0.147	2.4E+01	3.30E-01	8.36E+00	2.29E+01	4.09E+01
56-23-5	Carbon tetrachloride	carbon tetrachloride	0.152	6.3E-01	5.00E-03	2.27E-01	6.18E-01	1.10E+00
100-41-4	Ethylbenzene	ethylbenzene	0.2	4.0E+00	5.00E-03	2.17E+00	5.28E+00	9.41E+00
108-38-3	m-Xylene	Xylene, m-	0.2	1.6E+03	---	8.74E+02	2.12E+03	3.79E+03
105-67-9	2,4-Dimethylphenol	dimethylphenol;2,4-	0.209	1.6E+02	3.30E-01	9.11E+01	2.19E+02	3.91E+02
108-90-7	Chlorobenzene	chlorobenzene	0.22	1.0E+02	5.00E-03	6.00E+01	1.42E+02	2.54E+02
1330-20-7	Xylenes (total)	Xylenes (total)	0.23	1.6E+03	1.00E-02	1.01E+03	2.37E+03	4.22E+03
95-47-6	o-Xylene	xylene,o-	0.24	1.6E+03	---	1.07E+03	2.46E+03	4.39E+03
127-18-4	Tetrachloroethene	tetrachloroethylene	0.27	5.0E+00	5.00E-03	3.99E+00	8.73E+00	1.56E+01
88-75-5	2-Nitrophenol	nitrophenol;2-	0.297	No Value	6.60E-01	NA	NA	NA
100-02-7	4-Nitrophenol	nitrophenol;4-	0.309	No Value	6.60E-01	NA	NA	NA
95-50-1	1,2-Dichlorobenzene	dichlorobenzene; 1,2- (ortho-Dichlorobenzene)	0.379	6.0E+02	3.30E-01	8.76E+02	1.58E+03	2.83E+03

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						100-FR-1,-2	100-IU-2	100-IU-6
88-06-2	2,4,6-Trichlorophenol	Trichlorophenol2,4,6-	0.381	4.0E+00	3.30E-01	5.88E+00	1.06E+01	1.89E+01
95-57-8	2-Chlorophenol	Chlorophenol;2-	0.388	4.0E+01	3.30E-01	6.17E+01	1.09E+02	1.95E+02
541-73-1	1,3-Dichlorobenzene	dichlorobenzene;1,3	0.434	No Value	3.30E-01	NA	NA	NA
95-48-7	2-Methylphenol (cresol, o-)	cresol;o-	0.434	4.0E+02	3.30E-01	7.60E+02	1.27E+03	2.26E+03
106-44-5	4-Methylphenol (cresol, p-)	cresol;p-	0.434	8.0E+02	---	1.52E+03	2.53E+03	4.52E+03
59-50-7	4-Chloro-3-methylphenol	chloro-3-methylphenol;4-	0.4918	1.6E+03	3.30E-01	4.00E+03	6.11E+03	1.09E+04
87-86-5	Pentachlorophenol	pentachlorophenol	0.592	2.2E-01	3.30E-01	8.26E-01	1.12E+00	1.99E+00
534-52-1	4,6-Dinitro-2-methylphenol	dinitro-2-methylphenol;4,6-	0.6015	1.3E+00	3.30E-01	5.02E+00	6.69E+00	1.19E+01
106-46-7	1,4-Dichlorobenzene	dichlorobenzene;1,4- (para-Dichlorobenzene)	0.616	8.1E+00	5.00E-03	3.32E+01	4.38E+01	7.80E+01
91-94-1	3,3'-Dichlorobenzidine	dichlorobenzidine;3,3'-	0.724	1.9E-01	3.30E-01	1.17E+00	1.38E+00	2.45E+00
18540-29-9	Hexavalent Chromium	chromium(VI)	0.8	4.8E+01	---	6 [e]	6 [e]	6 [e]
100-42-5	Styrene	styrene	0.91	1.0E+02	5.00E-03	1.03E+03	1.08E+03	1.92E+03
91-20-3	Naphthalene	naphthalene	1.19	1.6E+02	1.00E-01	NR	NR	NR
86-30-6	n-Nitrosodiphenylamine	nitrosodiphenylamine;N-	1.29	1.8E+01	3.30E-01	NR	NR	NR
58-89-9	Gamma-BHC (Lindane)	lindane [gamma-BHC] (see hexachlorocyclohexane)	1.35	8.0E-02	1.65E-03	NR	NR	NR
84-74-2	Di-n-butylphthalate	di-butyl phthalate	1.57	1.6E+03	3.30E-01	NR	NR	NR
95-95-4	2,4,5-Trichlorophenol	Trichlorophenol;2,4,5-	1.6	8.0E+02	3.30E-01	NR	NR	NR
120-82-1	1,2,4-Trichlorobenzene	trichlorobenzene;1,2,4-	1.66	1.5E+00	3.30E-01	NR	NR	NR
319-84-6	Alpha-BHC	hexachlorocyclohexane;alpha (alpha-BHC, HCH)	1.76	1.4E-02	1.65E-03	NR	NR	NR
67-72-1	Hexachloroethane	hexachloroethane	1.78	1.1E+00	3.30E-01	NR	NR	NR
126-73-8	Tributyl phosphate	Tributyl phosphate	1.89	9.51	---	NR	NR	NR
7440-61-1	Uranium	Uranium	2	3.0E+01	---	NR	NR	NR
959-98-8	Endosulfan I	Endosulfan I	2.04	9.6E+01	1.65E-03	NR	NR	NR
33213-65-9	Endosulfan II	Endosulfan II	2.04	9.6E+01	3.30E-03	NR	NR	NR
1031-07-8	Endosulfan sulfate	Endosulfan sulfate	2.04	No Value	3.30E-03	NA	NA	NA
319-85-7	beta-1,2,3,4,5,6-Hexachlorocyclohexane (beta-BHC)	hexachlorocyclohexane;beta-	2.14	4.9E-02	1.65E-03	NR	NR	NR
319-86-8	Delta-BHC	hexachlorocyclohexane;delta-	2.81	No Value	1.65E-03	NA	NA	NA
91-58-7	2-Chloronaphthalene	beta-chloronaphthalene	2.98	6.4E+02	3.30E-01	NR	NR	NR
91-57-6	2-Methylnaphthalene	methylnapthalene;2-	2.98	3.2E+01	3.30E-01	NR	NR	NR
7440-42-8	Boron	Boron	3	3.2E+03	2.00E+00	NR	NR	NR
7005-72-3	4-Chlorophenylphenyl ether	chlorodiphenyl ether;4-	3.08	No Value	3.30E-01	NA	NA	NA
86-74-8	Carbazole	carbazole	3.39	4.4E+00	3.30E-01	NR	NR	NR
7723-14-0	Phosphorus	phosphorus	3.5	0.0E+00	5.00E+01	NR	NR	NR
88-85-7	Dinoseb	2-secButyl-4,6-dinitrophenol	3.5	7	---	NR	NR	NR

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						100-FR-1,-2	100-IU-2	100-IU-6
7440-36-0	Antimony	antimony	3.76	6.0E+00	6.00E-01	NR	NR	NR
7782-49-2	Selenium	selenium and compounds	5	5.0E+01	1.00E+00	NR	NR	NR
208-96-8	Acenaphthylene	acenaphthylene (Not in CLARC database tables; use acenaphthene as surrogate)	5.03	No Value	1.00E-01	NA	NA	NA
83-32-9	Acenaphthene	acenaphthene	6.12	4.8E+02	1.00E-01	NR	NR	NR
86-73-7	Fluorene	fluorene	7.71	3.2E+02	3.00E-02	NR	NR	NR
76-44-8	Heptachlor	heptachlor	9.53	1.9E-02	1.65E-03	NR	NR	NR
53494-70-5	Endrin ketone	Endrin ketone	9.72	No Value	3.30E-03	NA	NA	NA
57-12-5	Cyanide	cyanide	9.9	5.0E+00	---	NR	NR	NR
11104-28-2	Aroclor-1221	aroclor 1221 [PCB]	10.3	2.2E-02	1.65E-02	NR	NR	NR
11141-16-5	Aroclor-1232	aroclor 1232 [PCB]	10.3	2.2E-02	1.65E-02	NR	NR	NR
72-20-8	Endrin	endrin	10.8	2.0E+00	3.30E-03	NR	NR	NR
7421-93-4	Endrin aldehyde	Endrin aldehyde	10.8	No Value	3.30E-03	NA	NA	NA
132-64-9	Dibenzofuran	dibenzofuran	11.3	8.0E+00	3.30E-01	NR	NR	NR
85-68-7	Butylbenzylphthalate	butyl benzyl phthalate	13.8	4.6E+01	3.30E-01	NR	NR	NR
85-01-8	Phenanthrene	Phenanthrene	16.7	No Value	5.00E-02	NA	NA	NA
7439-98-7	Molybdenum	molybdenum	20	8.0E+01	2.00E+00	NR	NR	NR
7440-50-8	Copper	copper	22	6.4E+02	1.00E+00	NR	NR	NR
120-12-7	Anthracene	anthracene	23.5	2.4E+03	5.00E-02	NR	NR	NR
7440-39-3	Barium	Barium	25	2.0E+03	5.00E-01	NR	NR	NR
7439-89-6	Iron	Iron	25	1.1E+04	5.00E+00	NR	NR	NR
7440-24-6	Strontium	strontium	25	9.6E+03	1.00E+00	NR	NR	NR
60-57-1	Dieldrin	dieldrin	25.6	5.5E-03	3.30E-03	NR	NR	NR
7440-38-2	Arsenic	arsenic, inorganic	29	5.8E-02	1.00E+00	NR	NR	NR
7440-43-9	Cadmium	cadmium	30	5.0E+00	2.00E-01	NR	NR	NR
7439-92-1	Lead	lead	30	1.5E+01	5.00E-01	NR	NR	NR
7439-97-6	Mercury	mercury	30	2.0E+00	---	NR	NR	NR
7440-66-6	Zinc	zinc	30	4.8E+03	1.00E+00	NR	NR	NR
12672-29-6	Aroclor-1248	aroclor 1248 [PCB]	43.9	4.4E-02	1.65E-02	NR	NR	NR
53469-21-9	Aroclor-1242	aroclor 1242 [PCB]	44.8	4.4E-02	1.65E-02	NR	NR	NR
72-54-8	4,4'-DDD (Dichlorodiphenyldichloroethane)	ddd	45.8	3.6E-01	3.30E-03	NR	NR	NR
309-00-2	Aldrin	aldrin	48.7	2.6E-03	1.65E-03	NR	NR	NR
206-44-0	Fluoranthene	fluoranthene	49.1	6.4E+02	5.00E-02	NR	NR	NR
7440-48-4	Cobalt	Cobalt	50	4.8E+00	2.00E+00	NR	NR	NR
7439-93-2	Lithium	Lithium	50	3.2E+01	2.50E+00	NR	NR	NR
7439-96-5	Manganese	manganese	50	3.8E+02	5.00E+00	NR	NR	NR
5103-71-9	Alpha-Chlordane	Alpha-Chlordane	51	2.5E-01	1.65E-02	NR	NR	NR
57-74-9	Chlordane	chlordane	51	2.5E-01	1.65E-02	NR	NR	NR
87-68-3	Hexachlorobutadiene	hexachlorobutadiene	53.7	5.6E-01	3.30E-01	NR	NR	NR
7440-02-0	Nickel	nickel soluble salts	65	1.0E+02	4.00E+00	NR	NR	NR
129-00-0	Pyrene	pyrene	68	2.4E+02	5.00E-02	NR	NR	NR
7440-28-0	Thallium	Thallium, soluable salts	71	1.6E-01	5.00E-01	NR	NR	NR
11097-69-1	Aroclor-1254	aroclor 1254 (PCB)	75.6	4.4E-02	1.65E-02	NR	NR	NR
118-74-1	Hexachlorobenzene	hexachlorobenzene	80	5.5E-02	3.30E-01	NR	NR	NR
72-43-5	Methoxychlor	methoxychlor	80	4.0E+01	1.65E-02	NR	NR	NR
1024-57-3	Heptachlor epoxide	Heptachlor epoxide	83.2	4.8E-03	1.65E-03	NR	NR	NR

Table B-1. Unit-Length Preliminary Remediation Goals for Non-Radionuclides Protective of Groundwater

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Unit-Length Preliminary Remediation Goal Protective of Groundwater [c,d] $\left(\frac{mg}{kg}\cdot m\right)$		
						100-FR-1,-2	100-IU-2	100-IU-6
72-55-9	4,4'-DDE (Dichlorodiphenyldichloroethylene)	dde	86.4	2.6E-01	3.30E-03	NR	NR	NR
7440-22-4	Silver	silver	90	8.0E+01	2.00E-01	NR	NR	NR
8001-35-2	Toxaphene	toxaphene	95.8	8.0E-02	1.65E-01	NR	NR	NR
12674-11-2	Aroclor-1016	aroclor 1016 (PCB)	107	5.0E-01	1.65E-02	NR	NR	NR
117-81-7	Bis(2-ethylhexyl) phthalate	bis(2-ethylhexyl) phthalate	110	6.0E+00	3.30E-01	NR	NR	NR
7440-31-5	Tin	tin	130	9.6E+03	1.00E+01	NR	NR	NR
16984-48-8	Fluoride	fluoride (using fluorine)	150	9.6E+02	5.00E+00	NR	NR	NR
7440-47-3	Chromium	chromium (total)	200	1.0E+02	2.00E-01	NR	NR	NR
218-01-9	Chrysene	Chrysene	200	1.2E+00	1.00E-01	NR	NR	NR
77-47-4	Hexachlorocyclopentadiene	hexachlorocyclopentadiene	200	4.8E+01	3.30E-01	NR	NR	NR
56-55-3	Benzo(a)anthracene	Benzo(a)anthracene	360	1.2E-01	1.50E-02	NR	NR	NR
50-29-3	4,4'-DDT (Dichlorodiphenyltrichloroethane)	ddt	678	2.6E-01	3.30E-03	NR	NR	NR
7440-41-7	Beryllium	beryllium	790	4.0E+00	2.00E-01	NR	NR	NR
205-99-2	Benzo(b)fluoranthene	Benzo(b)fluoranthene	803	1.2E-01	1.50E-02	NR	NR	NR
11096-82-5	Aroclor-1260	aroclor 1260 (PCB)	822	4.4E-02	1.65E-02	NR	NR	NR
7440-62-2	Vanadium	vanadium	1000	8.0E+01	2.50E+00	NR	NR	NR
207-08-9	Benzo(k)fluoranthene	Benzo(k)fluoranthene	1230	1.2E-01	1.50E-02	NR	NR	NR
7429-90-5	Aluminum	Aluminum (soluble)	1500	5.0E+01	5.00E+00	NR	NR	NR
53-70-3	Dibenz[a,h]anthracene	Dibenz[a,h]anthracene	1790	1.2E-01	3.00E-02	NR	NR	NR
191-24-2	Benzo(ghi)perylene	BENZO(g,h,i)PERYLENE (using pyrene as a surrogate)	1950	No Value	3.00E-02	NA	NA	NA
193-39-5	Indeno(1,2,3-cd)pyrene	Indeno(1,2,3-cd)pyrene	3470	1.2E-01	3.00E-02	NR	NR	NR
50-32-8	Benzo(a)pyrene	Benzo(a)pyrene	5500	1.2E-02	1.50E-02	NR	NR	NR
117-84-0	Di-n-octylphthalate	di-n-octyl phthalate	83000	1.9E+02	3.30E-01	NR	NR	NR
65794-96-9	3+4 Methylphenol (cresol, m+p)	methylphenol,3+4 (cresol, m+p)	No Value	No Value	3.30E-01	NA	NA	NA
101-55-3	4-Bromophenylphenyl ether	bromodiphenyl ether;4-	No Value	No Value	3.30E-01	NA	NA	NA
7440-69-9	Bismuth	Bismuth	No Value	No Value	1.00E+01	NA	NA	NA
24959-67-9	Bromide	Bromide	No Value	No Value	2.50E+00	NA	NA	NA
7440-70-2	Calcium	Calcium	No Value	No Value	1.00E+02	NA	NA	NA
PCB1242/1016	Co-elution of Aroclor 1242 and Aroclor 1016	Co-elution of Aroclor 1242 and Aroclor 1017	No Value	No Value	---	NA	NA	NA
7439-95-4	Magnesium	Magnesium (Not in CLARC database Tables)	No Value	No Value	7.50E+01	NA	NA	NA
14265-44-2	Phosphate	Phosphate	No Value	No Value	5.00E+00	NA	NA	NA
PO4-P	Phosphorus in phosphate	Phosphorus in phosphate	No Value	No Value	---	NA	NA	NA
7440-09-7	Potassium	Potassium	No Value	No Value	4.00E+02	NA	NA	NA
7440-21-3	Silicon	Silicon	No Value	No Value	2.00E+00	NA	NA	NA
7440-23-5	Sodium	Sodium	No Value	No Value	5.00E+01	NA	NA	NA
TPHDIESEL	Total petroleum hydrocarbons - diesel range	Total petroleum hydrocarbons - diesel range	No Value	5.0E+02	---	NA	NA	NA
TPH/OILH	Total petroleum hydrocarbons - motor oil (high boiling)	Total petroleum hydrocarbons - motor oil (high boiling)	No Value	5.0E+02	---	NA	NA	NA

Table B-1. Unit-Length Preliminary Remediation Goals for Non-Radionuclides Protective of Groundwater

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Ground Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Unit-Length Preliminary Remediation Goal Protective of Groundwater [c,d] $\left(\frac{mg}{kg}\cdot m\right)$		
						100-FR-1,-2	100-IU-2	100-IU-6

a. ECF-HANFORD-10-0442, *Calculation of Nonradiological Soil Concentrations Protective of Groundwater Using the Fixed Parameter 3-Phase Equilibrium Partitioning Equation for the 100 Areas and 300 Area*, Revision 1, CH2M-HILL Plateau Remediation Company, Richland, Washington.

b. DOE/RL-2009-43 (Appendix A), *Sampling and Analysis Plan for the 100 FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

c. The following restrictions were applied to preliminary remediation goals:

- "NA" was assigned where no applicable water quality standard was available.
- "NR" was assigned where a non-representative result was obtained in cases where breakthrough was not simulated to occur in more than one representative stratigraphic column within 1000 years, where breakthrough is defined as groundwater concentration exceeding 0.0001 µg/L (a value set as the lower limit of numerical significance).
- Value defaults to the estimated quantitation limit for any analyte where the calculated value is less than the estimated quantitation limit.
- Value was limited to a physical upper bound of 384,000 mg/kg, based on the maximum pore space contaminant mass capacity.

d. Preliminary remediation goals levels protective of groundwater and protective of surface water are provided on a unit-length basis. To apply these preliminary remediation goals, divide the listed value by a representative length across the waste site decision unit in the general direction of groundwater flow to obtain the preliminary remediation goal value for evaluation use.

e. The preliminary remediation goal for hexavalent chromium is set to 6.0 mg/kg based on the evaluation in ECF-Hanford-11-0165; this value is not dependent on waste site size.

Cyan highlight denotes calculated values that changed because of incorporating updated IRIS (EPA's Integrated Risk Information System) groundwater standard values.

Table B-2. Unit-Length Preliminary Remediation Goals for Non-Radionuclides Protective of Surface Water

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Surface Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Unit-Length Preliminary Remediation Goal Protective of Surface Water [c,d] $\left(\frac{mg}{kg}\cdot m\right)$		
						100-FR-1,-2	100-IU-2	100-IU-6
16887-00-6	Chloride	chloride	0	2.3E+05	2.00E+00	2.24E+04	5.95E+04	1.06E+05
14797-55-8	Nitrate	Nitrate	0	4.5E+04	2.50E+00	4.37E+03	1.16E+04	2.08E+04
14797-65-0	Nitrite	Nitrite	0	No Value	2.50E+00	NA	NA	NA
NO3-N	Nitrogen in Nitrate	Nitrogen in Nitrate	0	1.0E+04	7.50E-01	9.72E+02	2.59E+03	4.62E+03
NO2-N	Nitrogen in Nitrite	Nitrogen in Nitrite	0	No Value	7.50E-01	NA	NA	NA
NO2+NO3-N	Nitrogen in Nitrite and Nitrate	Nitrogen in Nitrite and Nitrate	0	1.0E+04	---	9.72E+02	2.59E+03	4.62E+03
14808-79-8	Sulfate	sulfate	0	No Value	5.00E+00	NA	NA	NA
51-28-5	2,4-Dinitrophenol	dinitrophenol;2,4 -	0.00001	6.9E+01	8.25E-01	6.71E+00	1.79E+01	3.19E+01
67-64-1	Acetone	Acetone	0.0006	7.4E+05	2.00E-02	7.23E+04	1.93E+05	3.45E+05
107-21-1	Ethylene Glychol	Ethylene Glychol	0.001	1,640,000	---	1.62E+05	NR	NR
111-76-2	2-Butoxyethanol	Ethylene Glychol Mono Butyl Ether	0.001	82044	---	8.08E+03	2.16E+04	3.86E+04
75-99-0	Dalapon	Dalapon	0.0027	10773	---	1.08E+03	2.92E+03	5.21E+03
111-91-1	Bis(2-Chloroethoxy)methane	bis(2-chloroethoxyl)methane	0.00277	2.3E+03	3.30E-01	2.36E+02	6.37E+02	1.14E+03
78-93-3	2-Butanone	methyl ethyl ketone (MEK; 2-butanone)	0.00451	4.9E+05	1.00E-02	5.06E+04	1.38E+05	2.46E+05
74-87-3	Chloromethane	chloromethane	0.006	No Value	1.00E-02	NA	NA	NA
74-83-9	Bromomethane	bromomethane	0.009	4.7E+01	1.00E-02	5.12E+00	1.43E+01	2.55E+01
60-29-7	Diethylether	Diethylether	0.009699	96000	---	1.06E+04	2.95E+04	5.27E+04
75-09-2	Methylene chloride	methylene chloride	0.01	4.6E+00	5.00E-03	5.08E-01	1.42E+00	2.54E+00
108-10-1	4-Methyl-2-pentanone	methyl isobutyl ketone	0.0126	6.1E+04	1.00E-02	6.94E+03	1.96E+04	3.49E+04
591-78-6	2-Hexanone	HEXANONE;2-[MBK, methyl butyl ketone]	0.01498	3.4E+03	2.00E-02	4.01E+02	1.14E+03	2.04E+03
75-01-4	Vinyl chloride	vinyl chloride [chloroethene; 1-]	0.019	2.5E-02	5.00E-03	5.00E-03	8.86E-03	1.58E-02
75-00-3	Chloroethane	ethyl chloride	0.0217	No Value	1.00E-02	NA	NA	NA
621-64-7	n-Nitrosodi-n-dipropylamine	nitroso-di-n-propylamine;N-	0.024	5.0E-03	3.30E-01	3.30E-01	3.30E-01	3.30E-01
10061-01-5	cis-1,3-Dichloropropene	dichloropropene; 1,2-,cis	0.027	3.4E-01	5.00E-03	4.53E-02	1.33E-01	2.36E-01
10061-02-6	trans-1,3-Dichloropropene	dichloropropene; 1,3-,trans	0.027	3.4E-01	5.00E-03	4.53E-02	1.33E-01	2.36E-01
108-95-2	Phenol	Phenol	0.0288	1.0E+04	3.30E-01	1.36E+03	3.99E+03	7.11E+03
94-75-7	2,4-D	2,4-Dichlorophenoxy acetic acid	0.029	100	---	1.36E+01	4.00E+01	7.12E+01
1918-00-9	Dicamba	Dicamba	0.029	24613	---	3.35E+03	9.83E+03	1.75E+04
131-11-3	Dimethyl phthalate	dimethyl phthalate	0.0316	2.7E+05	3.30E-01	3.77E+04	1.11E+05	1.99E+05
156-59-2	cis-1,2-Dichloroethylene	dichloroethylene; 1,2-,cis	0.036	4.7E+02	5.00E-03	6.85E+01	2.04E+02	3.64E+02
107-06-2	1,2-Dichloroethane	dichloroethane;1,2-	0.038	3.8E-01	5.00E-03	5.71E-02	1.70E-01	3.04E-01
156-60-5	trans-1,2-Dichloroethylene	dichloroethylene; 1,2-,trans	0.038	1.4E+02	5.00E-03	2.10E+01	6.28E+01	1.12E+02
1918-02-1	4-Amino-3,5,6-trichloropicolinic acid	4-Amino-3,5,6-trichloropicolinic acid	0.039	57431	---	8.72E+03	2.61E+04	4.66E+04
108-60-1	Bis(2-chloro-1-methylethyl)ether	bis(2-chloro-1-methyl-ethyl)ether	0.0392	3.7E+01	3.30E-01	5.71E+00	1.71E+01	3.05E+01
540-59-0	1,2-Dichloroethene (Total)	dichloroethylene, 1,2- (mixed isomers)	0.0396	2.1E+03	5.00E-03	3.22E+02	9.64E+02	1.72E+03
75-69-4	Trichloromonofluoromethane	Trichloromonofluoromethane	0.04389	35800	---	5.70E+03	1.71E+04	3.05E+04
75-15-0	Carbon disulfide	carbon disulfide	0.046	1.3E+04	5.00E-03	2.16E+03	6.48E+03	1.16E+04
78-59-1	Isophorone	isophorone	0.0468	8.4E+00	3.30E-01	1.37E+00	4.12E+00	7.35E+00

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						100-FR-1,-2	100-IU-2	100-IU-6
78-87-5	1,2-Dichloropropane	dichloropropane; 1,2-	0.047	5.0E-01	5.00E-03	8.19E-02	2.46E-01	4.39E-01
93-65-2	2-(2-methyl-4-chlorophenoxy) propionic acid	2-(2-methyl-4-chlorophenoxy) propionic acid	0.04851	8.2E+02	---	1.34E+02	4.03E+02	7.19E+02
93-76-5	2,4,5-T	2,4,5-Trichlorophenoxyacetic acid	0.049	No Value	---	NA	NA	NA
99-09-2	3-Nitroaniline	nitroaniline, 3-	0.0516	1.0E+02	3.30E-01	1.76E+01	5.29E+01	9.44E+01
100-01-6	4-Nitroaniline	nitroaniline, 4-	0.0516	8.1E+01	3.30E-01	1.39E+01	4.17E+01	7.43E+01
88-74-4	2-Nitroaniline	nitroaniline, 2-	0.0527	2.6E+03	3.30E-01	4.49E+02	1.35E+03	2.40E+03
75-34-3	1,1-Dichloroethane	dichloroethane;1,1-	0.053	7.4E+04	1.00E-02	1.28E+04	3.84E+04	6.84E+04
67-66-3	Chloroform	chloroform	0.053	5.7E+00	5.00E-03	9.89E-01	2.97E+00	5.30E+00
75-27-4	Bromodichloromethane	bromodichloromethane	0.055	2.7E-01	5.00E-03	4.78E-02	1.44E-01	2.56E-01
71-43-2	Benzene	Benzene	0.062	1.2E+00	5.00E-03	2.27E-01	6.84E-01	1.22E+00
124-48-1	Dibromochloromethane	chlorodibromomethane [dibromochloromethane]	0.063	4.0E-01	5.00E-03	7.65E-02	2.30E-01	4.10E-01
75-35-4	1,1-Dichloroethene	Dichloroethene;1,1-	0.065	5.7E-02	1.00E-02	1.11E-02	3.33E-02	5.93E-02
606-20-2	2,6-Dinitrotoluene	dinitrotoluene;2,6-	0.0692	1.2E+02	3.30E-01	2.38E+01	7.12E+01	1.27E+02
106-47-8	4-Chloroaniline	chloroaniline;p-	0.0725	4.6E+00	3.30E-01	9.64E-01	2.88E+00	5.14E+00
79-00-5	1,1,2-Trichloroethane	trichloroethane;1,1,2-	0.075	5.9E-01	5.00E-03	1.25E-01	3.74E-01	6.67E-01
111-44-4	Bis(2-chloroethyl) ether	bis(2-chloroethyl)ether	0.076	3.0E-02	3.30E-01	3.30E-01	3.30E-01	3.30E-01
79-34-5	1,1,2,2-Tetrachloroethane	tetrachloroethane;1,1,2,2-	0.079	1.7E-01	5.00E-03	3.75E-02	1.12E-01	1.99E-01
93-72-1	2,4,5-TP	(2-(2,4,5-Trichlorophenoxy)propionic acid)Silvex	0.08	10	---	2.23E+00	6.62E+00	1.18E+01
84-66-2	Diethylphthalate	diethyl phthalate	0.082	1.7E+04	3.30E-01	3.85E+03	1.14E+04	2.04E+04
79-01-6	Trichloroethene	trichloroethylene (TCE)	0.094	2.5E+00	5.00E-03	6.25E-01	1.83E+00	3.26E+00
121-14-2	2,4-Dinitrotoluene	dinitrotoluene;2,4-	0.0955	1.1E-01	3.30E-01	3.30E-01	3.30E-01	3.30E-01
94-82-6	2,4-DB	(4-(2,4-Dichlorophenoxy)butanoic acid)	0.1	6564	---	1.73E+03	5.02E+03	8.95E+03
98-95-3	Nitrobenzene	Nitrobenzene	0.119	1.7E+01	3.30E-01	4.97E+00	1.41E+01	2.52E+01
75-25-2	Bromoform	bromoform	0.13	4.3E+00	5.00E-03	1.34E+00	3.77E+00	6.72E+00
71-55-6	1,1,1-Trichloroethane	Trichloroethane; 1,1,1-	0.14	9.3E+05	5.00E-03	3.08E+05	NR	NR
108-88-3	Toluene	Toluene	0.14	1.3E+03	5.00E-03	4.32E+02	1.20E+03	2.13E+03
120-83-2	2,4-Dichlorophenol	dichlorophenol;2,4-	0.147	7.7E+01	3.30E-01	2.68E+01	7.35E+01	1.31E+02
56-23-5	Carbon tetrachloride	carbon tetrachloride	0.152	2.3E-01	5.00E-03	8.30E-02	2.26E-01	4.02E-01
100-41-4	Ethylbenzene	ethylbenzene	0.2	1.6E+01	5.00E-03	8.58E+00	2.08E+01	3.72E+01
108-38-3	m-Xylene	Xylene, m-	0.2	No Value	---	NA	NA	NA
105-67-9	2,4-Dimethylphenol	dimethylphenol;2,4-	0.209	3.8E+02	3.30E-01	2.16E+02	5.20E+02	9.28E+02
108-90-7	Chlorobenzene	chlorobenzene	0.22	1.3E+02	5.00E-03	7.80E+01	1.85E+02	3.30E+02
1330-20-7	Xylenes (total)	Xylenes (total)	0.23	No Value	1.00E-02	NA	NA	NA
95-47-6	o-Xylene	xylene,o-	0.24	No Value	---	NA	NA	NA
127-18-4	Tetrachloroethene	tetrachloroethylene	0.27	6.9E-01	5.00E-03	5.51E-01	1.20E+00	2.15E+00
88-75-5	2-Nitrophenol	nitrophenol;2-	0.297	No Value	6.60E-01	NA	NA	NA
100-02-7	4-Nitrophenol	nitrophenol;4-	0.309	No Value	6.60E-01	NA	NA	NA
95-50-1	1,2-Dichlorobenzene	dichlorobenzene; 1,2- (ortho-Dichlorobenzene)	0.379	4.2E+02	3.30E-01	6.13E+02	1.11E+03	1.98E+03

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						100-FR-1,-2	100-IU-2	100-IU-6
88-06-2	2,4,6-Trichlorophenol	Trichlorophenol2,4,6-	0.381	1.4E+00	3.30E-01	2.07E+00	3.73E+00	6.64E+00
95-57-8	2-Chlorophenol	Chlorophenol;2-	0.388	8.1E+01	3.30E-01	1.25E+02	2.22E+02	3.95E+02
541-73-1	1,3-Dichlorobenzene	dichlorobenzene;1,3	0.434	3.2E+02	3.30E-01	6.08E+02	1.01E+03	1.81E+03
95-48-7	2-Methylphenol (cresol, o-)	cresol;o-	0.434	1.2E+04	3.30E-01	2.30E+04	3.84E+04	6.84E+04
106-44-5	4-Methylphenol (cresol, p-)	cresol;p-	0.434	2.9E+04	---	5.57E+04	9.28E+04	1.65E+05
59-50-7	4-Chloro-3-methylphenol	chloro-3-methylphenol;4-	0.4918	3.1E+04	3.30E-01	7.62E+04	1.16E+05	2.08E+05
87-86-5	Pentachlorophenol	pentachlorophenol	0.592	2.7E-01	3.30E-01	1.01E+00	1.37E+00	2.44E+00
534-52-1	4,6-Dinitro-2-methylphenol	dinitro-2-methylphenol;4,6-	0.6015	1.3E+01	3.30E-01	5.10E+01	6.79E+01	1.21E+02
106-46-7	1,4-Dichlorobenzene	dichlorobenzene;1,4- (para-Dichlorobenzene)	0.616	2.2E+01	5.00E-03	8.86E+01	1.17E+02	2.08E+02
91-94-1	3,3'-Dichlorobenzidine	dichlorobenzidine;3,3'-	0.724	2.1E-02	3.30E-01	3.30E-01	3.30E-01	3.30E-01
18540-29-9	Hexavalent Chromium	chromium(VI)	0.8	1.0E+01	---	6 [e]	6 [e]	6 [e]
100-42-5	Styrene	styrene	0.91	3.8E+04	5.00E-03	NR	NR	NR
91-20-3	Naphthalene	naphthalene	1.19	4.9E+03	1.00E-01	NR	NR	NR
86-30-6	n-Nitrosodiphenylamine	nitrosodiphenylamine;N-	1.29	3.3E+00	3.30E-01	NR	NR	NR
58-89-9	Gamma-BHC (Lindane)	lindane [gamma-BHC] (see hexachlorocyclohexane)	1.35	1.9E-02	1.65E-03	NR	NR	NR
84-74-2	Di-n-butylphthalate	di-butyl phthalate	1.57	2.0E+03	3.30E-01	NR	NR	NR
95-95-4	2,4,5-Trichlorophenol	Trichlorophenol;2,4,5-	1.6	4.9E+02	3.30E-01	NR	NR	NR
120-82-1	1,2,4-Trichlorobenzene	trichlorobenzene;1,2,4-	1.66	2.0E+00	3.30E-01	NR	NR	NR
319-84-6	Alpha-BHC	hexachlorocyclohexane;alpha (alpha-BHC, HCH)	1.76	2.6E-03	1.65E-03	NR	NR	NR
67-72-1	Hexachloroethane	hexachloroethane	1.78	1.4E+00	3.30E-01	NR	NR	NR
126-73-8	Tributyl phosphate	Tributyl phosphate	1.89	24.3	---	NR	NR	NR
7440-61-1	Uranium	Uranium	2	7.8E+02	---	NR	NR	NR
959-98-8	Endosulfan I	Endosulfan I	2.04	5.6E-02	1.65E-03	NR	NR	NR
33213-65-9	Endosulfan II	Endosulfan II	2.04	5.6E-02	3.30E-03	NR	NR	NR
1031-07-8	Endosulfan sulfate	Endosulfan sulfate	2.04	9.3E-01	3.30E-03	NR	NR	NR
319-85-7	beta-1,2,3,4,5,6-Hexachlorocyclohexane (beta-BHC)	hexachlorocyclohexane;beta-	2.14	9.1E-03	1.65E-03	NR	NR	NR
319-86-8	Delta-BHC	hexachlorocyclohexane;delta-	2.81	No Value	1.65E-03	NA	NA	NA
91-58-7	2-Chloronaphthalene	beta-chloronaphthalene	2.98	1.0E+03	3.30E-01	NR	NR	NR
91-57-6	2-Methylnaphthalene	methylnapthalene;2-	2.98	1.4E+02	3.30E-01	NR	NR	NR
7440-42-8	Boron	Boron	3	No Value	2.00E+00	NA	NA	NA
7005-72-3	4-Chlorophenylphenyl ether	chlorodiphenyl ether;4-	3.08	No Value	3.30E-01	NA	NA	NA
86-74-8	Carbazole	carbazole	3.39	No Value	3.30E-01	NA	NA	NA
7723-14-0	Phosphorus	phosphorus	3.5	No Value	5.00E+01	NA	NA	NA
88-85-7	Dinoseb	2-secButyl-4,6-dinitrophenol	3.5	No Value	---	NA	NA	NA

Table B-2. Unit-Length Preliminary Remediation Goals for Non-Radionuclides Protective of Surface Water

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Surface Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Unit-Length Preliminary Remediation Goal Protective of Surface Water [c,d] $\left(\frac{mg}{kg}\cdot m\right)$		
						100-FR-1,-2	100-IU-2	100-IU-6
7440-36-0	Antimony	antimony	3.76	5.6E+00	6.00E-01	NR	NR	NR
7782-49-2	Selenium	selenium and compounds	5	5.0E+00	1.00E+00	NR	NR	NR
208-96-8	Acenaphthylene	acenaphthylene (Not in CLARC database tables; use acenaphthene as surrogate)	5.03	No Value	1.00E-01	NA	NA	NA
83-32-9	Acenaphthene	acenaphthene	6.12	6.4E+02	1.00E-01	NR	NR	NR
86-73-7	Fluorene	fluorene	7.71	1.1E+03	3.00E-02	NR	NR	NR
76-44-8	Heptachlor	heptachlor	9.53	7.9E-05	1.65E-03	NR	NR	NR
53494-70-5	Endrin ketone	Endrin ketone	9.72	No Value	3.30E-03	NA	NA	NA
57-12-5	Cyanide	cyanide	9.9	5.2E+00	---	NR	NR	NR
11104-28-2	Aroclor-1221	aroclor 1221 [PCB]	10.3	6.4E-05	1.65E-02	NR	NR	NR
11141-16-5	Aroclor-1232	aroclor 1232 [PCB]	10.3	6.4E-05	1.65E-02	NR	NR	NR
72-20-8	Endrin	endrin	10.8	2.3E-03	3.30E-03	NR	NR	NR
7421-93-4	Endrin aldehyde	Endrin aldehyde	10.8	2.9E-01	3.30E-03	NR	NR	NR
132-64-9	Dibenzofuran	dibenzofuran	11.3	1.7E+00	3.30E-01	NR	NR	NR
85-68-7	Butylbenzylphthalate	butyl benzyl phthalate	13.8	8.2E+00	3.30E-01	NR	NR	NR
85-01-8	Phenanthrene	Phenanthrene	16.7	No Value	5.00E-02	NA	NA	NA
7439-98-7	Molybdenum	molybdenum	20	1.3E+03	2.00E+00	NR	NR	NR
7440-50-8	Copper	copper	22	9.0E+00	1.00E+00	NR	NR	NR
120-12-7	Anthracene	anthracene	23.5	8.3E+03	5.00E-02	NR	NR	NR
7440-39-3	Barium	Barium	25	1.0E+03	5.00E-01	NR	NR	NR
7439-89-6	Iron	Iron	25	3.0E+02	5.00E+00	NR	NR	NR
7440-24-6	Strontium	strontium	25	2.6E+04	1.00E+00	NR	NR	NR
60-57-1	Dieldrin	dieldrin	25.6	5.2E-05	3.30E-03	NR	NR	NR
7440-38-2	Arsenic	arsenic, inorganic	29	1.8E-02	1.00E+00	NR	NR	NR
7440-43-9	Cadmium	cadmium	30	2.5E-01	2.00E-01	NR	NR	NR
7439-92-1	Lead	lead	30	2.1E+00	5.00E-01	NR	NR	NR
7439-97-6	Mercury	mercury	30	1.2E-02	---	NR	NR	NR
7440-66-6	Zinc	zinc	30	9.1E+01	1.00E+00	NR	NR	NR
12672-29-6	Aroclor-1248	aroclor 1248 [PCB]	43.9	6.4E-05	1.65E-02	NR	NR	NR
53469-21-9	Aroclor-1242	aroclor 1242 [PCB]	44.8	6.4E-05	1.65E-02	NR	NR	NR
72-54-8	4,4'-DDD (Dichlorodiphenyldichloroethane)	ddd	45.8	3.1E-04	3.30E-03	NR	NR	NR
309-00-2	Aldrin	aldrin	48.7	4.9E-05	1.65E-03	NR	NR	NR
206-44-0	Fluoranthene	fluoranthene	49.1	9.0E+01	5.00E-02	NR	NR	NR
7440-48-4	Cobalt	Cobalt	50	2.6E+00	2.00E+00	NR	NR	NR
7439-93-2	Lithium	Lithium	50	No Value	2.50E+00	NA	NA	NA
7439-96-5	Manganese	manganese	50	5.0E+01	5.00E+00	NR	NR	NR
5103-71-9	Alpha-Chlordane	Alpha-Chlordane	51	5.7E-04	1.65E-02	NR	NR	NR
57-74-9	Chlordane	chlordane	51	5.7E-04	1.65E-02	NR	NR	NR
87-68-3	Hexachlorobutadiene	hexachlorobutadiene	53.7	4.4E-01	3.30E-01	NR	NR	NR
7440-02-0	Nickel	nickel soluble salts	65	5.2E+01	4.00E+00	NR	NR	NR
129-00-0	Pyrene	pyrene	68	8.3E+02	5.00E-02	NR	NR	NR
7440-28-0	Thallium	Thallium, soluable salts	71	2.2E-01	5.00E-01	NR	NR	NR
11097-69-1	Aroclor-1254	aroclor 1254 (PCB)	75.6	6.4E-05	1.65E-02	NR	NR	NR
118-74-1	Hexachlorobenzene	hexachlorobenzene	80	2.8E-04	3.30E-01	NR	NR	NR
72-43-5	Methoxychlor	methoxychlor	80	3.0E-02	1.65E-02	NR	NR	NR
1024-57-3	Heptachlor epoxide	Heptachlor epoxide	83.2	3.9E-05	1.65E-03	NR	NR	NR

Table B-2. Unit-Length Preliminary Remediation Goals for Non-Radionuclides Protective of Surface Water

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Surface Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Unit-Length Preliminary Remediation Goal Protective of Surface Water [c,d] $\left(\frac{mg}{kg}\cdot m\right)$		
						100-FR-1,-2	100-IU-2	100-IU-6
72-55-9	4,4'-DDE (Dichlorodiphenyldichloroethylene)	dde	86.4	2.2E-04	3.30E-03	NR	NR	NR
7440-22-4	Silver	silver	90	2.6E+00	2.00E-01	NR	NR	NR
8001-35-2	Toxaphene	toxaphene	95.8	2.0E-04	1.65E-01	NR	NR	NR
12674-11-2	Aroclor-1016	aroclor 1016 (PCB)	107	6.4E-05	1.65E-02	NR	NR	NR
117-81-7	Bis(2-ethylhexyl) phthalate	bis(2-ethylhexyl) phthalate	110	1.2E+00	3.30E-01	NR	NR	NR
7440-31-5	Tin	tin	130	5.2E+02	1.00E+01	NR	NR	NR
16984-48-8	Fluoride	fluoride (using fluorine)	150	1.6E+04	5.00E+00	NR	NR	NR
7440-47-3	Chromium	chromium (total)	200	6.5E+01	2.00E-01	NR	NR	NR
218-01-9	Chrysene	Chrysene	200	2.8E-03	1.00E-01	NR	NR	NR
77-47-4	Hexachlorocyclopentadiene	hexachlorocyclopentadiene	200	4.0E+01	3.30E-01	NR	NR	NR
56-55-3	Benzo(a)anthracene	Benzo(a)anthracene	360	2.8E-03	1.50E-02	NR	NR	NR
50-29-3	4,4'-DDT (Dichlorodiphenyltrichloroethane)	ddt	678	2.2E-04	3.30E-03	NR	NR	NR
7440-41-7	Beryllium	beryllium	790	2.7E+02	2.00E-01	NR	NR	NR
205-99-2	Benzo(b)fluoranthene	Benzo(b)fluoranthene	803	2.8E-03	1.50E-02	NR	NR	NR
11096-82-5	Aroclor-1260	aroclor 1260 (PCB)	822	6.4E-05	1.65E-02	NR	NR	NR
7440-62-2	Vanadium	vanadium	1000	No Value	2.50E+00	NA	NA	NA
207-08-9	Benzo(k)fluoranthene	Benzo(k)fluoranthene	1230	2.8E-03	1.50E-02	NR	NR	NR
7429-90-5	Aluminum	Aluminum (soluble)	1500	8.7E+01	5.00E+00	NR	NR	NR
53-70-3	Dibenz[a,h]anthracene	Dibenz[a,h]anthracene	1790	2.8E-03	3.00E-02	NR	NR	NR
191-24-2	Benzo(ghi)perylene	BENZO(g,h,i)PERYLENE (using pyrene as a surrogate)	1950	No Value	3.00E-02	NA	NA	NA
193-39-5	Indeno(1,2,3-cd)pyrene	Indeno(1,2,3-cd)pyrene	3470	2.8E-03	3.00E-02	NR	NR	NR
50-32-8	Benzo(a)pyrene	Benzo(a)pyrene	5500	2.8E-03	1.50E-02	NR	NR	NR
117-84-0	Di-n-octylphthalate	di-n-octyl phthalate	83000	No Value	3.30E-01	NA	NA	NA
65794-96-9	3+4 Methylphenol (cresol, m+p)	methylphenol,3+4 (cresol, m+p)	No Value	No Value	3.30E-01	NA	NA	NA
101-55-3	4-Bromophenylphenyl ether	bromodiphenyl ether;4-	No Value	No Value	3.30E-01	NA	NA	NA
7440-69-9	Bismuth	Bismuth	No Value	No Value	1.00E+01	NA	NA	NA
24959-67-9	Bromide	Bromide	No Value	No Value	2.50E+00	NA	NA	NA
7440-70-2	Calcium	Calcium	No Value	No Value	1.00E+02	NA	NA	NA
PCB1242/1016	Co-elution of Aroclor 1242 and Aroclor 1016	Co-elution of Aroclor 1242 and Aroclor 1017	No Value	No Value	---	NA	NA	NA
7439-95-4	Magnesium	Magnesium (Not in CLARC database Tables)	No Value	No Value	7.50E+01	NA	NA	NA
14265-44-2	Phosphate	Phosphate	No Value	No Value	5.00E+00	NA	NA	NA
PO4-P	Phosphorus in phosphate	Phosphorus in phosphate	No Value	No Value	---	NA	NA	NA
7440-09-7	Potassium	Potassium	No Value	No Value	4.00E+02	NA	NA	NA
7440-21-3	Silicon	Silicon	No Value	No Value	2.00E+00	NA	NA	NA
7440-23-5	Sodium	Sodium	No Value	No Value	5.00E+01	NA	NA	NA
TPHDIESEL	Total petroleum hydrocarbons - diesel range	Total petroleum hydrocarbons - diesel range	No Value	No Value	---	NA	NA	NA
TPH/OILH	Total petroleum hydrocarbons - motor oil (high boiling)	Total petroleum hydrocarbons - motor oil (high boiling)	No Value	No Value	---	NA	NA	NA

Table B-2. Unit-Length Preliminary Remediation Goals for Non-Radionuclides Protective of Surface Water

CAS No.	Analyte	Alternate Name Referenced In EPA Regional Screening Table	100 Areas K_d Value used to Calculate Groundwater Protection [a] (mL/g)	Surface Water Standard [a] (µg/L)	Estimated Quantitation Limit [b] (mg/kg)	Unit-Length Preliminary Remediation Goal Protective of Surface Water [c,d] $\left(\frac{mg}{kg}\cdot m\right)$		
						100-FR-1,-2	100-IU-2	100-IU-6

a. ECF-HANFORD-10-0442, *Calculation of Nonradiological Soil Concentrations Protective of Groundwater Using the Fixed Parameter 3-Phase Equilibrium Partitioning Equation for the 100 Areas and 300 Area*, Revision 1, CH2M-HILL Plateau Remediation Company, Richland, Washington.

b. DOE/RL-2009-43 (Appendix A), *Sampling and Analysis Plan for the 100 FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

c. The following restrictions were applied to preliminary remediation goals:

- "NA" was assigned where no applicable water quality standard was available.
- "NR" was assigned where a non-representative result was obtained in cases where breakthrough was not simulated to occur in more than one representative stratigraphic column within 1000 years, where breakthrough is defined as groundwater concentration exceeding 0.0001 µg/L (a value set as the lower limit of numerical significance).
- Value defaults to the estimated quantitation limit for any analyte where the calculated value is less than the estimated quantitation limit.
- Value was limited to a physical upper bound of 384,000 mg/kg, based on the maximum pore space contaminant mass capacity.

d. Preliminary remediation goals protective of groundwater and protective of surface water are provided on a unit-length basis. To apply these preliminary remediation goals, divide the listed value by a representative length across the waste site decision unit in the general direction of groundwater flow to obtain the preliminary remediation goal for evaluation use.

e. The preliminary remediation goal for hexavalent chromium is set to 6.0 mg/kg based on the evaluation in ECF-Hanford-11-0165; this value is not dependent on waste site size.

Cyan highlight denotes calculated values that changed because of incorporating updated IRIS (EPA's Integrated Risk Information System) groundwater standard values.

Table B-3. Unit-Length Preliminary Remediation Goals for Radionuclides Protective of Groundwater

Radionuclide	100 Areas Kd Value used to Calculate Groundwater Protection [a]	Maximum Contaminant Level [a]	Half-life [b]	Estimated Quantitation Limit [c]	Unit-Length Preliminary Remediation Goal Protective of Groundwater [d,e] $\left(\frac{pCi}{g}\cdot m\right)$		
	(mL/g)	(pCi/L)	(yr)	(mg/kg)	100-FR-1,-2	100-IU-2	100-IU-6
Carbon-14 [f]	0	2000	5.73E+03	---	1.95E+02	5.18E+02	9.24E+02
Technetium-99	0	900	2.13E+05	---	8.75E+01	2.33E+02	4.15E+02
Tritium	0	20000	1.24E+01	---	2.67E+03	9.11E+03	1.62E+04
Iodine-129	1	1	1.57E+07	---	NR	NR	NR
Uranium-233/234	2	No Value	2.45E+05	1.00E+00	NA	NA	NA
Uranium-235	2	No Value	7.04E+08	5.00E-01	NA	NA	NA
Uranium-238	2	No Value	4.47E+09	1.00E+00	NA	NA	NA
Neptunium-237	15	15	2.14E+06	---	NR	NR	NR
Strontium-90 [g]	25	8	2.91E+01	---	NR	NR	NR
Nickel-63	30	50	9.60E+01	---	NR	NR	NR
Cesium-137	50	200	3.00E+01	1.00E-01	NR	NR	NR
Cobalt-60	50	100	5.72E+00	5.00E-02	NR	NR	NR
Americium-241	200	15	4.32E+02	1.00E+00	NR	NR	NR
Carbon-14 [h]	200	2,000	5.73E+03	---	NR	NR	NR
Curium-243	200	15	2.85E+01	---	NR	NR	NR
Curium-244	200	15	1.81E+01	---	NR	NR	NR
Europium-152	200	200	1.33E+01	1.00E-01	NR	NR	NR
Europium-154	200	60	8.80E+00	1.00E-01	NR	NR	NR
Europium-155	200	600	4.96E+00	1.00E-01	NR	NR	NR
Niobium-94	200	No Value	2.03E+04	---	NA	NA	NA
Plutonium-238	200	15	8.77E+01	1.00E+00	NR	NR	NR
Plutonium-239	200	15	2.41E+04	1.00E+00	NR	NR	NR
Plutonium-240	200	15	6.54E+03	1.00E+00	NR	NR	NR
Plutonium-241	200	300	1.40E+01	---	NR	NR	NR
Radium-226	200	5	1.60E+03	---	NR	NR	NR
Radium-228	200	5	5.75E+00	2.00E-01	NR	NR	NR
Thorium-228	200	15	1.91E+00	---	NR	NR	NR
Thorium-230	200	15	7.70E+04	---	NR	NR	NR
Thorium-232	200	15	1.41E+10	---	NR	NR	NR

a. ECF-HANFORD-10-0442, *Calculation of Nonradiological Soil Concentrations Protective of Groundwater Using the Fixed Parameter 3-Phase Equilibrium Partitioning Equation for the 100 Areas and 300 Area*, Revision 1, CH2M-HILL Plateau Remediation Company, Richland, Washington.

b. Radiochemistry Society website, Available at: http://www.radiochemistry.org/.

c. DOE/RL-2009-43 (Appendix A), *Sampling and Analysis Plan for the 100 FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

d. The following restrictions were applied to preliminary remediation goals:

- "NA" was assigned where no applicable water quality standard was available.
- "NR" was assigned where a non-representative result was obtained in cases where breakthrough was not simulated to occur in more than one representative stratigraphic column within 1000 years, where breakthrough is defined as groundwater concentration exceeding 0.0001 pCi/L (a value set as the lower limit of numerical significance).
- Value defaults to the estimated quantitation limit for any analyte where the calculated value is less than the estimated quantitation limit.

e. Preliminary remediation goals protective of groundwater and protective of surface water are provided on a unit-length basis. To apply these preliminary remediation goals, divide the listed value by a representative length across the waste site decision unit in the general direction of groundwater flow to obtain the preliminary remediation goal for evaluation use.

f. Carbon-14 in liquid form (typically associated with reactor gas condensate).

g. Strontium-90 preliminary remediation goal was calculated based on a 100:0 initial source distribution, an exception to the convention that analytes with $K_d \geq 2$ were calculated based on a 70:30 initial source distribution, because of data that indicated strontium-90 distributed throughout the vadose zone at some locations in these OUs.

h. Carbon-14 in solid form (typically associated with graphite).

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Attachment C

Software Installation and Checkout Forms for STOMP

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CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM

Software Owner Instructions:
Complete Fields 1-13, then run test cases in Field 14. Compare test case results listed in Field 15 to corresponding Test Report outputs. If results are the same, sign and date Field 19. If not, resolve differences and repeat above steps.

Software Subject Matter Expert Instructions:
Assign test personnel. Approve the installation of the code by signing and dating Field 21, then maintain form as part of the software support documentation.

GENERAL INFORMATION:

1. Software Name: STOMP (Subsurface Transport Over Multiple Phases) Software Version No.: Build2

EXECUTABLE INFORMATION:

2. Executable Name (include path):

```
a51dc453e98a084b391c08ac2ac3a976  stomp-wae-bd-chprc02i.x
70fd1a594885ff9118d5802be8aaaa47  stomp-wae-cg-chprc02i.x
c2ddd7624276023bd4d3d0ef1817a40e  stomp-wae-cgs-chprc02i.x
21713e06e4676a0204d8292680911bdd  stomp-w-bd-chprc02i.x
7d712b548eea0326a6b3e5fd956ee61b  stomp-w-cg-chprc02i.x
32c15e8d89b508e78814ff091d2a49d0  stomp-w-cgs-chprc02i.x
6988abf48a371ec20ff652920f72d6c6  stomp-w-r-bd-chprc02i.x
```

3. Executable Size (bytes): MD5 signatures shown above uniquely identify executables

COMPILATION INFORMATION:

4. Hardware System (i.e., property number or ID):

RANSAC Linux Cluster (WD56054)

5. Operating System (include version number):

Redhat Enterprise Linux WS3 (Taroon Update)

INSTALLATION AND CHECKOUT INFORMATION:

6. Hardware System (i.e., property number or ID):

INTERA GREEN Linux File Server (INTERA-00469)

7. Operating System (include version number):

Linux green 2.6.32-30-server #59-Ubuntu SMP Tue Mar 1 22:46:09 UTC 2011 x86 64 GNU/Linux

8. Open Problem Report? (•) No ( ) Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

[redacted]/build-02

10. Procedure(s):

CHPRC-00211 Rev. 1, STOMP Software Test Plan

11. Libraries:

N/A (static linking)

12. Input Files:

Input files for ATC-STOMP-1, ATC-STOMP-2, and ATC-STOMP-2

13. Output Files:

plot.* files produced by STOMP executables

14. Test Cases:

ATC-STOMP-1, ATC-STOMP-2, and ATC-STOMP-3

15. Test Case Results:

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CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: STOMP (Subsurface Transport Over Multiple Phases) Software Version No.: Build2

PASS (diff all plot files showed no numerical differences)

16. Test Performed By: WE Nichols

17. Test Results: (•) Satisfactory, Accepted for Use ( ) Unsatisfactory

18. Disposition (include HISI update):

Installation added to STOMP HISI Entry. This is a multiuser server; approved software users include T Clemo, J Ludwig, T Budge, N Hasan, A Mayenna, H Rashid, C Courbet, W Nichols, T Dale, S Mehta.

Prepared By: William E. Nichols

19.	WE Nichols	
Software Owner (Signature)	Print	Date
20. Test Personnel: William E. Nichols	WE Nichols	
Sign	Print	Date
Sign	Print	Date
Sign	Print	Date
Approved By:		
21.	N/R	
Software SME (Signature)	Print	Date

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