1220824

ECF-100NR1-12-0017
Revision 2

STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for the 100-NR-1 Source Operable Unit

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

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CH2MHILL
Plateau Remediation Company
P.O. Box 1600
Richland, Washington 99352

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Document Type: ENV Program/Project: EP&SP

N. Hasan
INTERA

Date Published
July 2014

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APPROVED
By Lee Ann Snyder at 10:55 am, Aug 18, 2014

Release Approval Date

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ENVIRONMENTAL CALCULATION COVER PAGE

Part 1: Completed by the Responsible Manager

Project: 100-N RI/FS **Date:** 3/24/2014

Calculation Title & Description: STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for the 100-NR-1 Source Operable Unit

Preparer: N Hasan	**Basis of Qualification:** Education & experience. Software user qualification checked 5/7/14 WEN - confirmed that N. Hasan has an approved STOMP installation available, and have completed software-training requirements.
Checker: H Rashid	**Basis of Qualification:** Education & experience
Senior Reviewer: WE Nichols	**Basis of Qualification:** Education & experience

Part 2: Completed by Preparer

Calculation No.: ECF-100NR1-12-0017 **Revision No.:** 2

Revision History:

Revision No.	Description	Date	Affected Pages ADD ROW
0	Initial Issue	31 Jul 2012	All
1	Updates SSL and PRG values based on hydraulic conductivity derived from updated slug test data	24 Aug 2012	Attachements A and B ☒
2	Revision includes: • Revised recharge scenarios to implement comment resolution agreements with Dept. of Ecology for 100-D/H that also apply to this calculation. • Eliminated linear interpolation approach for non-radioactive COPCs; used direct simulation of all COPCs with breakthrough instead. • Recalculated SSL and PRG values to incorporate revised recharge scenarios, revised Kd values per agreement with Dept. of Ecology in 100-D/H, IRIS update, and direct simulation of required Kd values. • Editorial and document structure changes to improve clarity of presentation.	## May 2014	All ☒

Part 3: Document Review & Approval:

Preparer: N Hasan / Hydrogeologic Modeler (INTERA, Inc.)

NAME/POSITION

Nazmul Hasan — 05-22-2014

SIGNATURE — DATE

Checker: H Rashid / Hydrogeologic Modeler (INTERA, Inc.)

NAME/POSITION

S.M. Hekmatullah Rashid — 05-22-2014

SIGNATURE — DATE

ENVIRONMENTAL CALCULATION COVER PAGE (CONTINUED)

Part 3: Document Review & Approval:

Senior Reviewer:	WE Nichols / Modeling Team Leader (CHPRC) NAME/POSITION		
	SIGNATURE		22 MAY 2014 DATE
Risk/Modeling Integration Manager: APPLICABLE IF CALCULATION IS A RISK ASSESSMENT OR USES AN ENVIRONMENTAL MODEL	AH Aly / Risk & Modeling Integration Manager (CHPRC) NAME/POSITION		
	SIGNATURE	HE NICHOLS, ACTING FOR AH ALY	21 JULY 2014 DATE
Responsible Manager:	AH Aly / Risk & Modeling Integration Manager (CHPRC) NAME/POSITION		
	SIGNATURE	HE NICHOLS, ACTING FOR AH ALY	21 JULY 2014 DATE

Environmental Calculation File

STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for the 100-NR-1 Source Operable Unit

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Terms

ARARs	applicable regulations and requirements
AWQLs	applicable water quality standards
CHPRC	CH2M HILL Plateau Remediation Company
COPC	contaminant of potential concern
CPK	peak groundwater concentration
ECF	environmental calculation file
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)
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 calculate soil screening levels (SSLs) and preliminary remediation goals (PRGs) protective of surface water and protective of groundwater in the 100-NR-1 source Operable Unit (OU), located in the Hanford Site's 100-N Area. The STOMP (Subsurface Transport Over Multiple Phases) fate and transport simulation software (PNNL-12030, *STOMP Subsurface Transport Over Multiple Phases: Theory Guide*; PNNL-15782, *STOMP Subsurface Transport Over Multiple Phases: User's Guide Version 4.0*; PNNL-11216, *STOMP Subsurface Transport Over Multiple Phases: Application Guide*) is used to implement the model used for this calculation. 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 in a screening step 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 conservative assumptions, PRGs specific to the 100-NR-1 OU were calculated for 187 non-radionuclides and 25 radionuclides in groundwater and 187 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 high recharge rates for an irrigated farming scenario (recognizing this is not the planned land use for this OU), while PRGs are calculated using low recharge rates for 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 this 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 observed at various waste sites within100-NR-1 OU. Conditions specific to the 100 Area or source areas 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 was developed assuming that aqueous-phase flow under variably saturated conditions follows the Richards equation (termed the water mass conservation equation in STOMP) and that transport of dilute solutes follows the advection-dispersion equation (termed the solute mass conservation equation in STOMP) with radioactive decay and linear sorption and no volatilization or hydrodynamic dispersion.

Contaminant migration from waste sites in the 100-N Area 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 and matric potential gradients. Recharge is the net result of competition between precipitation, evaporation, transpiration, infiltration, run-off, and run-on and anthropogenic 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 contaminant's concentration in the groundwater and its concentration in the downgradient Columbia River, including the peak concentration, 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 software code was used to implement the model for this calculation. The STOMP-W (water) operational mode solve 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. Volatilization and gas phase transport is conservatively neglected in this calculation to maximize the peak groundwater concentration predicted by the model. The governing equations and constitutive relationships solved by the STOMP code are presented in detail in PNNL-12030. The STOMP numerical simulations provided predictions of groundwater concentration and time of peak groundwater concentration for a list of contaminants based on a range of recharge rates, sediment types, vadose zone thicknesses, and properties appropriate to the 100-NR-1 source OU. The peak concentration within 1000 years was used in the SSL and PRG value calculation. The 1000-year timeframe was based on regulatory agreement.

2 Methodology

One-dimensional fate and transport simulations were used to calculate SSLs and PRGs for the 100-N Area source OU. The STOMP code was selected to implement the numerical model and perform these simulations on the basis of its ability to adequately simulate the vadose zone features, events, and processes (FEPs) relevant to calculating 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.

The methodology described here constitutes the use of an alternative fate and transport model as defined in the Washington Administrative Code (WAC), WAC 173-340-747 (Deriving soil concentrations for groundwater protection). A crosswalk is provided in Attachment A of this ECF that demonstrates how this methodology meets the pertinent requirements of WAC 173-340-747.

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 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) but using a more conservative recharge rate based on an irrigated farming scenario (recognizing that this is not the planned land use for this OU). 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. 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 COPC under a native vegetation recharge scenario that is consistent with land used plan for 100-NR-1 (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 PRG for a particular COPC depends on a number of key factors, including:

- Waste site characteristics, 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 COPCs identified in ECF-Hanford-12-0023, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area.* SSL and PRG values protective of groundwater were calculated for all of these COPCs (non-radionuclide and radionuclide), and SSL and PRG values protective of surface water were calculated for all non-radionuclide COPCs.

2.2 Identification of Representative Stratigraphic Columns

Borehole data were used to identify representative stratigraphic columns for each source area. Two lithologic units are present in the 100-N Area vadose zone. These are the gravel-dominated Hanford formation and the Ringold Formation's E unit. The Ringold Formation's E unit 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 period (represented by June 2008 data) result in a conservative (smaller) thickness of the vadose zone for each well and borehole to develop the representative stratigraphic profiles. Imposing conservative bias towards a smaller thickness was done to reduce the travel distance for contaminants in the vadose zone, and thereby bias the resulting peak groundwater concentration calculated to arrive sooner with greater magnitude – resulting in more restrictive SSL and PRG values than would otherwise be the case. These well and borehole data were then used to estimate the thicknesses of each lithologic unit within the vadose zone and within the aquifer sediments. The wells and boreholes were grouped based on the proportion of each lithologic unit and the total vadose zone thickness. A representative stratigraphic column was selected for each resulting well and borehole group within the 100-NR-1 source OU. This process resulted in the selection of four representative stratigraphic columns to be used to support model construction (see Section 3.1).

The representative stratigraphic columns include the upper 5 m of the unconfined aquifer, such that the water flux through this downgradient aquifer boundary of the model domain represents a 5-m monitoring well screen. This is consistent with the requirements for aquifer mixing zone thickness in the WAC, specifically WAC 173-340-747[5][f][i], which specifies that the aquifer mixing zone thickness shall not exceed 5 m in depth. Aquifer dilution is thus directly simulated in the STOMP solution, based on the OU-specific hydraulic gradient imposed as a boundary condition across those nodes representing the aquifer portion of the representative stratigraphic column.

2.3 Calculation of Peak Groundwater Concentrations within 1000 Years

STOMP is used to solve for water flow and contaminant transport in each of the representative stratigraphic columns, under each recharge scenario (one for SSLs, one for PRGs; Section 3.2.1), for the appropriate initial uniform concentration of contaminant (Section 3.2.4), for each distribution coefficient (K_d) (Section 3.4), for a pair of sequential simulations. The first simulation in the sequential pair is 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 simulation in the sequential pair is of water flow and contaminant transport for future recharge scenarios, starting from the imposed initial contaminant distribution and the initial soil moisture conditions provided by the first simulation. The second simulation provided groundwater concentrations in the aquifer flux exiting the model domain at the downgradient boundary for each representative stratigraphic column under each recharge scenario and for each distribution coefficient.

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. Using the upper 5 m of the aquifer is consistent with the requirements for aquifer mixing zone thickness in WAC 173-340-747[5][f][i].

2.4 Point of Calculation and Protectiveness Metric

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 to determine the potential impacts and protectiveness of soil contamination (at the point of compliance), using (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. This peak groundwater concentration is then used in a back-calculation step to determine the maximum allowable soil concentration at the point of compliance (vadose zone soil). The protectiveness criteria is the set of 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 [AWQLs]) values for each contaminant. The applicable water quality standard for each

contaminant for protectiveness of groundwater and surface water in the 100-N Area are listed in the tables of SSL values in Attachment B, and in the tables of PRG values in Attachment C, of 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 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 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 SSL or PRG value (depending on the recharge scenario used). As a measure of maximum allowable contaminant concentration in the soil, SSLs and PRGs are expressed as contaminant mass per mass of soil for non-radionuclides (e.g., mg/kg) and as contaminant activity per mass of soil for radionuclides (e.g., pCi/g).

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

$$SSL = aC_I \frac{WQS}{CPK} \qquad \text{Equation 1}$$

where,

SSL = soil screening level, expressed in units of contaminant mass or activity per unit mass of soil

a = constant selected to balance units

C_I = initial soil concentration, expressed as contaminant mass or activity per unit mass of soil (note this is an arbitrary initial condition used in STOMP in the forward calculation, applied uniformly over the appropriate soil depth range – see Section 3.2.4)

WQS = water quality standard, expressed as contaminant mass or activity per unit volume of water

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, based on the initial soil concentration C_I)

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

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

$$PRG = aC_I \frac{WQS}{CPK} \qquad \text{Equation 2}$$

For PRG calculations with Equation 2, the *CPK* value is obtained from STOMP 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 SSLs and PRGs protective of surface water, whereas the groundwater quality standards as WQS values to compute SSLs and PRGs protective of groundwater. As seen from Equation 1 and Equation 2, the calculation of 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 PRG calculation. If a WQS was not available for a COPC, then the corresponding SSL or PRG values were encoded "NA" to signify that there was no applicable water quality standard available.

SSL and PRG values calculated using Equation 1 and Equation 2 are compared to upper and lower thresholds described in the subsections that follow; SSL and PRG values that exceed these thresholds are handled as described.

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, and 0.0001 pCi/m^3 for radionuclide COPCs. 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 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 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 SSL or PRG calculated for a given COPC is below the estimated quantitation limit (EQL) for the soil concentration of that COPC, then the EQL is substituted for the 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-2009-42, *Sampling and Analysis Plan for the 100 NR-1 and 100-NR-2 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

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 Equations 1a and 1b 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 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 total porosity of Hanford or Ringold is 0.28.Porosity of Hanford formation is used in this calculation because most of

the vadose zone is consists of Hanford formation. The particle density of the COPC is assumed equal the particle density of 2680 kg/m^3 for the Hanford formation (PNNL-18564). Substituting into Equation 3, the maximum mass of COPC in 1.0 kg soil is then calculated as

$$m_{max,p} = (0.28) \times (5.18 \times 10^{-4}\ \mathrm{m}^3) \times \left(2680\ \frac{\mathrm{kg}}{\mathrm{m}^3}\right) = 0.389\ \mathrm{kg} \times \left(\frac{1{,}000{,}000\ \mathrm{mg}}{1\ \mathrm{kg}}\right)$$
$$= 389{,}000\ \mathrm{mg}$$

Thus, the maximum screening or PRG value for non-radionuclides is 389,000 mg per kg of soil. Therefore, SSL or PRG values that exceed this physical upper bound are truncated at physical upper bound value 389,000 mg/kg. Note that this physical upper bound is not applied to radionuclide 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 Upper Threshold for Hexavalent Chromium Soil Screening Level and Preliminary Remediation Goal Values based on Limitation of Sorption Data

Hexavalent chromium soil concentrations for which the conservative-basis K_d was derived had a maximum value of 6.0 mg/kg (ECF-Hanford-11-0165 Rev. 1). Therefore, there is no basis to infer greater PRGs for Cr(VI) based on these data. Hence, SSL and PRG values calculated for hexavalent chromium using this K_d are restricted (truncated) to a maximum value of 6.0 mg/kg.

2.5.5 Site-specific Model Derived SSL and PRG Values for Strontium-90

Field data revealed that strontium-90 was found throughout the vadose zone at several 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 report for this OU. Given this consideration, the general conceptual site model used for first-level (1-D) modeling under the graded approach (DOE/RL-2011-50) was evaluated to be non-representative for this COPC. SSL and PRG values were instead calculated for strontium-90 using a multi-dimensional, site-specific model, consistent with elevated treatment under the graded approach (DOE/RL-2011-50). This site-specific model is separately documented in ECF-100NR1-12-0056, *Vadose Zone Transport Modeling to Calculate Strontium-90 Flux to Groundwater and Preliminary Remediation Goal in Support of the 100-N Remedial Investigation/Feasibility Study*.

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 flow in the representative stratigraphic columns for a 2010-year period ending in calendar year 2010. The purpose of this first long simulation period was first to achieve equilibrium (steady state) in the flow conditions in the model domain (by simulating for an arbitrarily long time) and then to simulate subsequent flow conditions and moisture content resulting from changes in surface conditions through calendar year 2010.. Review of the first-stage matric potential and volumetric water content values at the end of the arbitrarily long period simulated with native vegetation 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 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 is 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 head gradient drives horizontal flow. At the start of each 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. In 100-N Area, the vadose zone comprises a combination of Hanford formation and Ringold Unit E, whereas the saturated zone can comprise only Ringold E. If present, the contact between the Ringold Unit E and the Ringold upper mud (RUM) unit forms the bottom of the aquifer.

The model is represented numerically 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 reduce 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 provides 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 for partially saturated nodes; this feature of STOMP was used in this calculation. Following the simulation, the contaminant aqueous concentration output was scaled back to 1 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 at 100-N OU. Only the thickness of the clean back fill 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 3-1). 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 (conservatism here is with respect to minimizing the vadose zone travel distance for contaminants).

Because of natural variability in the thickness of various hydrostratigraphic units, it is impractical to calculate SSL and PRG values for all possible variations in thicknesses observed in the various boreholes. Instead, representative stratigraphic columns were identified to provide a representative range of stratigraphic conditions for the 100-NR-1 source OU. The objective of this process was to create a limited, practical number of representative stratigraphic columns so that the number of STOMP simulations would be reasonable, while capturing the range of variability throughout the 100-NR-1 source OU. Representative stratigraphic columns were identified by collecting and reviewing geologic data from 86 boreholes nearest to the waste sites in each geographic area (10 of these in 100-NR-1). All borehole data were taken from the HEIS borehole database. Boreholes from 100-NR-1 OU were grouped to represent the range of vadose zone thicknesses and lithologic composition (Table 3-1). The representative stratigraphic columns include geologic material in both the vadose zone and the unconfined aquifer. Using water table elevations representing the annually occurring highest water table, a minimum thickness of the vadose zone was computed for each borehole (minimum thickness is conservatively selected to reduce contaminant transport time, thereby biasing peak groundwater concentrations higher). These borehole data were then used to estimate the thickness of each lithologic unit. This process yielded four representative stratigraphic columns (Figure 3-1) with vadose zone thickness and lithologic composition derived from the grouped borehole data (Table 3-1).

The saturated zone thickness exceeded 5 m in all of these representative columns (Table 3-1), but was limited to a 5-m thickness for use in STOMP simulations in accordance with WAC 173-340-747(5)(f)(i) and equation 747-4 for A, aquifer mixing zone. Each representative stratigraphic column was assumed to include 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 stipulation of boundary and initial conditions. A complete set of boundary and initial conditions must be specified for each governing equation for input to STOMP. The boundary condition specifications for this model are graphically summarized in Figure 3-2.

Table 3-1. Determination of Vadose Zone Thickness and Geology for 100-NR-1 Operable Unit

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
1	20	85% Hanford, 15% Ringold E	17	3	199-K-150	85% Hanford, 15% Ringold E	19.46	14.68	13.44	100% Ringold E
					199-K-160		19.78	16.18		
					699-86-60		19.82	9.44		
2	21	60% Hanford, 40% Ringold E	12.5	8.5	199-N-105A	64% Hanford, 36% Ringold E	20.49	8.77	9.75	100% Ringold E
					199-N-69	59% Hanford, 41% Ringold E	21.62	9.16		
					199-N-70	56% Hanford, 44% Ringold E	20.37	11.33		
3	23	72% Hanford, 28% Ringold E	17	6	199-N-106A	70% Hanford, 30% Ringold E	25.36	10.91	10.80	100% Ringold E
					199-N-71	75% Hanford, 25% Ringold E	22.43	10.90		
					699-84-59	72% Hanford, 28% Ringold E	21.81	10.60		
4	19.5	95% Hanford, 5% Ringold E	18.5	1.0	199-K-159	95% Hanford, 5% Ringold E	19.21	14.31	14.31	100% Ringold E

Note: VZ = vadose zone, SZ = saturated zone

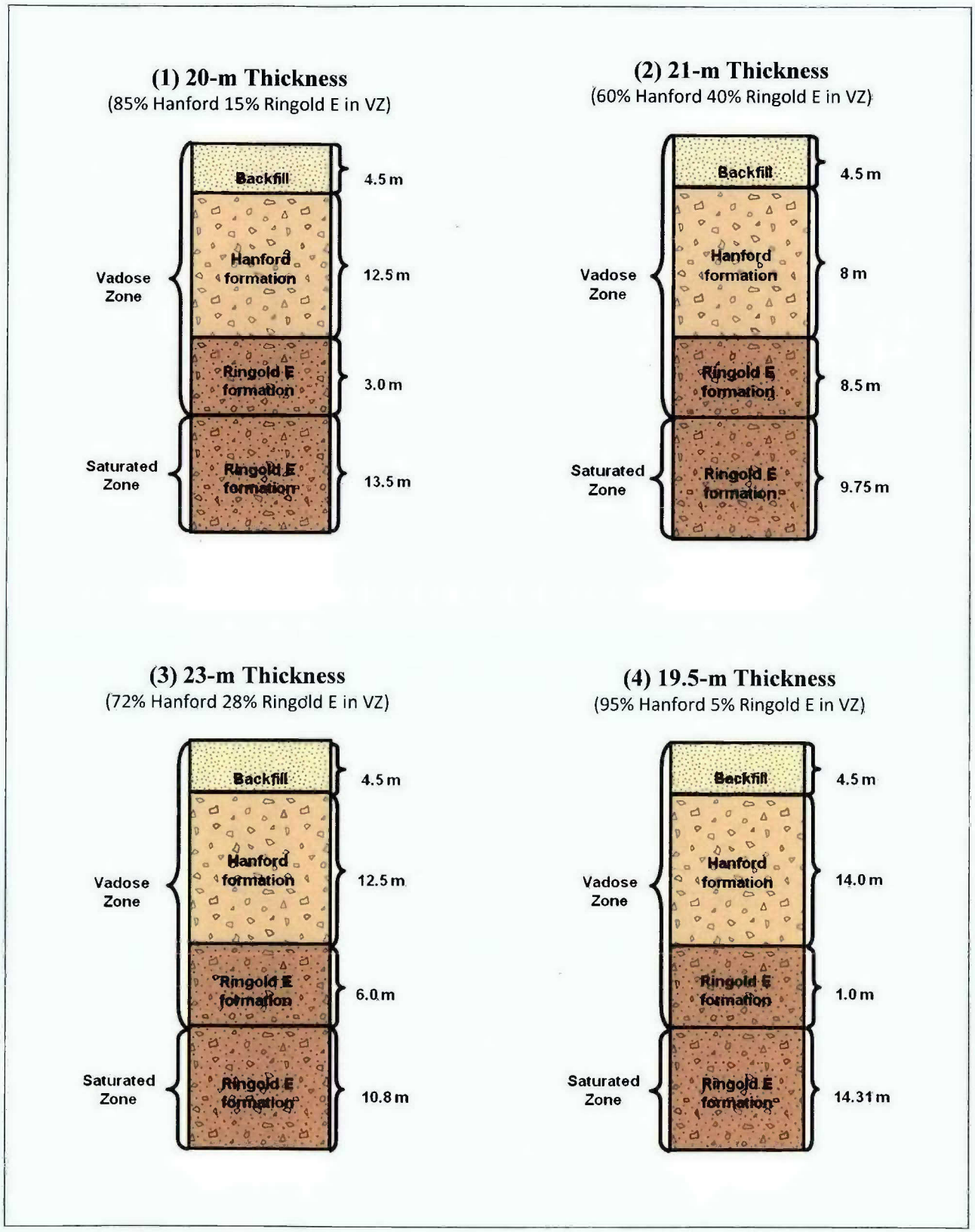

Figure 3-1. Representative Stratigraphic Columns for 100-NR-1 Operable Unit

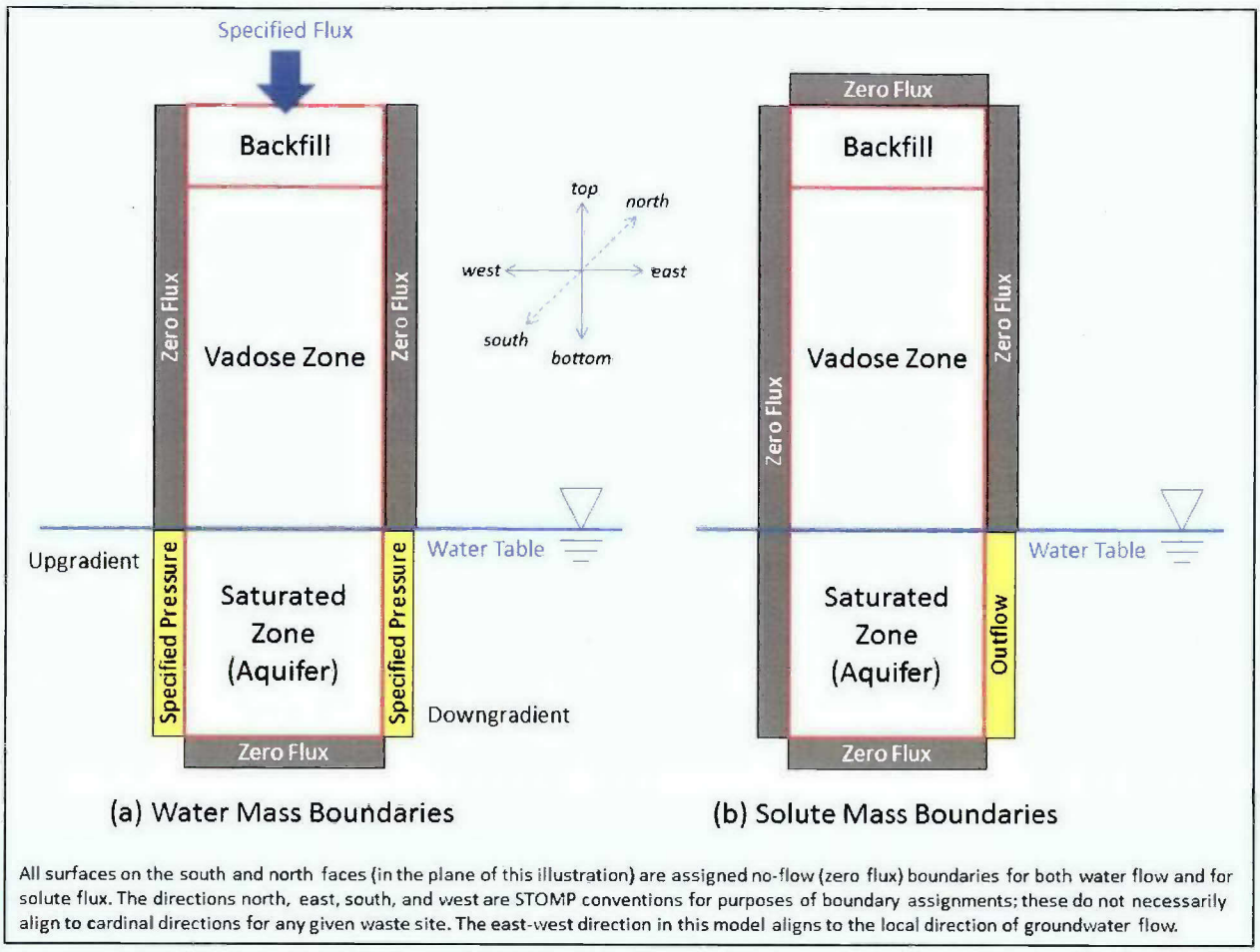

Figure 3-2. Boundary Conditions for (a) Water Mass and (b) Solute Mass Conservation Equations

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 3-2a). 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 3-2b). 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 boundary (ground surface) 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 (including snow), 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 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. Additionally, PNNL-14702 Rev. 1 also provides recharge rates for disturbed soil conditions: the disturbed soil rates were selected for use in calculation of SSLs and PRGs for the 100-NR-1 source OU.

Each calculation of a 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 3-2a) 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 consist of native vegetation (mature shrub-steppe) rates during pre-settlement phase before 1880, and continuing during the settlement phase from 1880 to 1944, then transitioning to a Hanford Site operational period with recharge rates reflective of bare soil from 1944 to 2010. The pre-settlement 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 1944 transition to bare soil conditions that persist to 2010. The recharge rates for each historic phase (pre-settlement and settlement phases with native vegetation, 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 DOE's 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 3-2b). 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 3-2b).

3.2.1.1 Native Vegetation Recharge Scenario

The native vegetation recharge scenario (Table 3-2; Figure 3-3) is used for calculation of PRG values. This recharge scenario represents DOE's planned land use with restoration and maintenance of a native shrub-steppe plant community. The scenario is comprised of three historic phases discussed previously and four future phases that represent recharge rates changes corresponding to postulated future land use/cover transitions. The first future phase (2010 to 2015) represents the period of continued bare soil cover. The second future phase (2015 to 2020) represents an invasive cheatgrass cover. The third phase represents grasses and developing shrubs as vegetation matures during a 30-year transition (transition period duration from DOE/RL-2011-50). The final phase is mature shrub steppe 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 annual issues of the *River Corridor Closure Contractor Revegetation and Mitigation Monitoring Report*, including 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 3-3; Figure 3-4) is used for calculation of SSL values. This recharge scenario represents an upper bound based on recharge rates from irrigated agriculture land use. This recharge scenario is comprised of transition from bare soil conditions to long-term irrigation 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.

Recharge rates for the irrigation phases of this recharge scenario were estimated using the same approach employed 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 non-irrigation (base case, in this case the native vegetation scenario) recharge rates. As the base case rates used in the RESRAD simulations differ from those adopted from for the native vegetation recharge scenario (from PNNL-14702 Rev. 1), the RESRAD equation for total recharge was back-solved to ascertain the recharge 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:

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

Table 3-2. Native Vegetation Recharge Scenario Phases and Recharge Rates (mm/yr)

	Historic Simulation (pre-2010) (calculation of initial hydraulic conditions)			Predictive Simulation (post-2010) (calculation of peak groundwater concentration)			
Surface Soil Type	**Pre-Settlement (< 1880)**	**Settlement [a] (1880-1944)**	**Hanford Operations (1944-2010)**	**Bare Soil (2010-2015)**	**Cheatgrass (2015-2020)**	**Developing Shrub-Steppe (2020-2050)**	**Mature Shrub-Steppe (2050 >)**
Hanford sand, disturbed	4.0 [b]	4.0 [b]	63.0 [c]	63.0 [c]	31.5 [d]	8.0 [e]	4.0 [f]

a. Pre-Hanford agricultural activities did not take place at 100-N, so no historic irrigation phase is included; shrub-steppe recharge rates are assumed to continue during the Settlement phase.

b. Source: PNNL-14702 Rev. 1, Table 4-15, all areas with soils disturbed by excavations; shrub steppe.

c. Source: PNNL-14702 Rev. 1, Table 4-15, all areas with soils disturbed by excavations; no vegetation.

d. Source: PNNL-14702 Rev. 1, Table 4-15, all areas with soils disturbed by excavations; cheatgrass.

e. Source: PNNL-14702 Rev. 1, Table 4-15, all areas with soils disturbed by excavations; young shrub steppe.

f. Source: PNNL-14702 Rev. 1, Table 4-15, all areas with soils disturbed by excavations; shrub steppe.

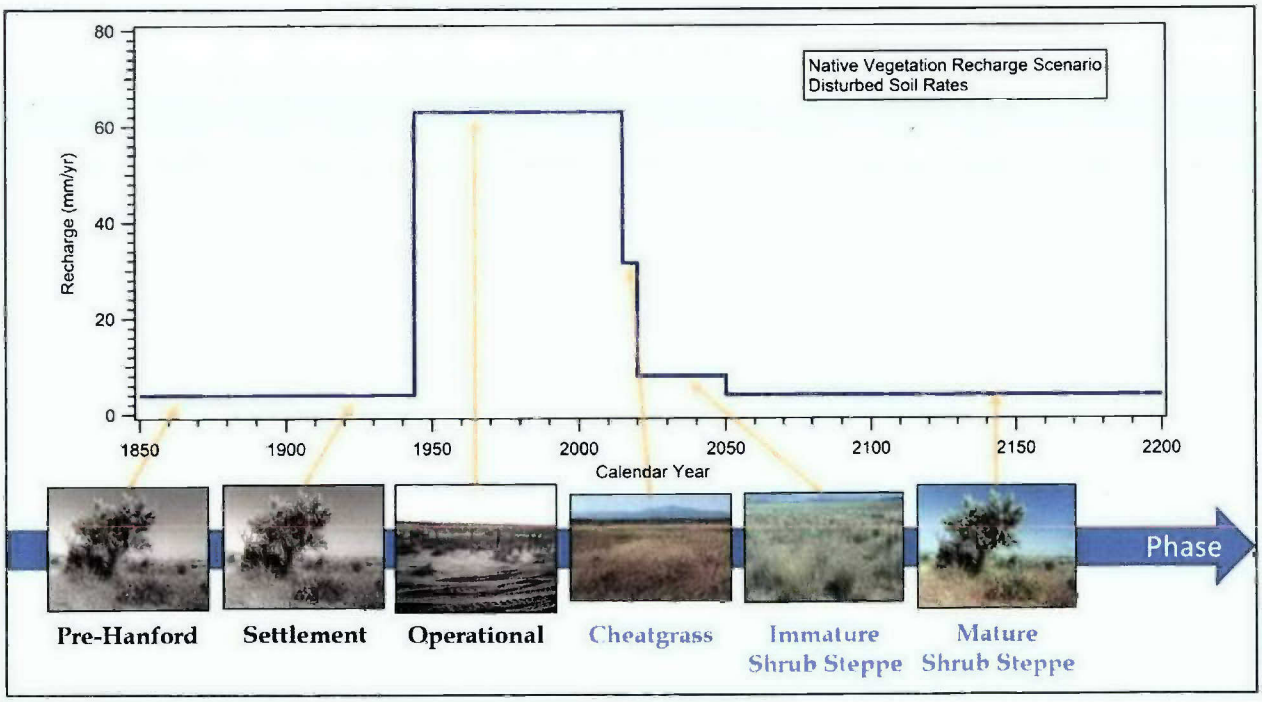

Figure 3-3. Native Vegetation Recharge Scenario

Table 3-3. 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-Settlement (< 1880)	Settlement [a] (1880-1944)	Hanford Operations (1944-2010)	Bare Soil (2010-2015)	Irrigation I (2015-2045)	Irrigation II (2045 >)
Hanford sand, disturbed	4.0 [b]	4.0 [b]	63.0 [c]	63.0 [c]	76.4 [d]	72.4 [d]

a. Pre-Hanford agricultural activities did not take place at 100-N, so no historic irrigation phase is included; shrub-steppe recharge rates are assumed to continue during the Settlement phase.

b. Source: PNNL-14702 Rev. 1, Table 4-15, all areas with soils disturbed by excavations; shrub steppe.

c. Source: PNNL-14702 Rev. 1, Table 4-15, all areas with soils disturbed by excavations; no vegetation.

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 3-2) to obtain the total recharge rate.

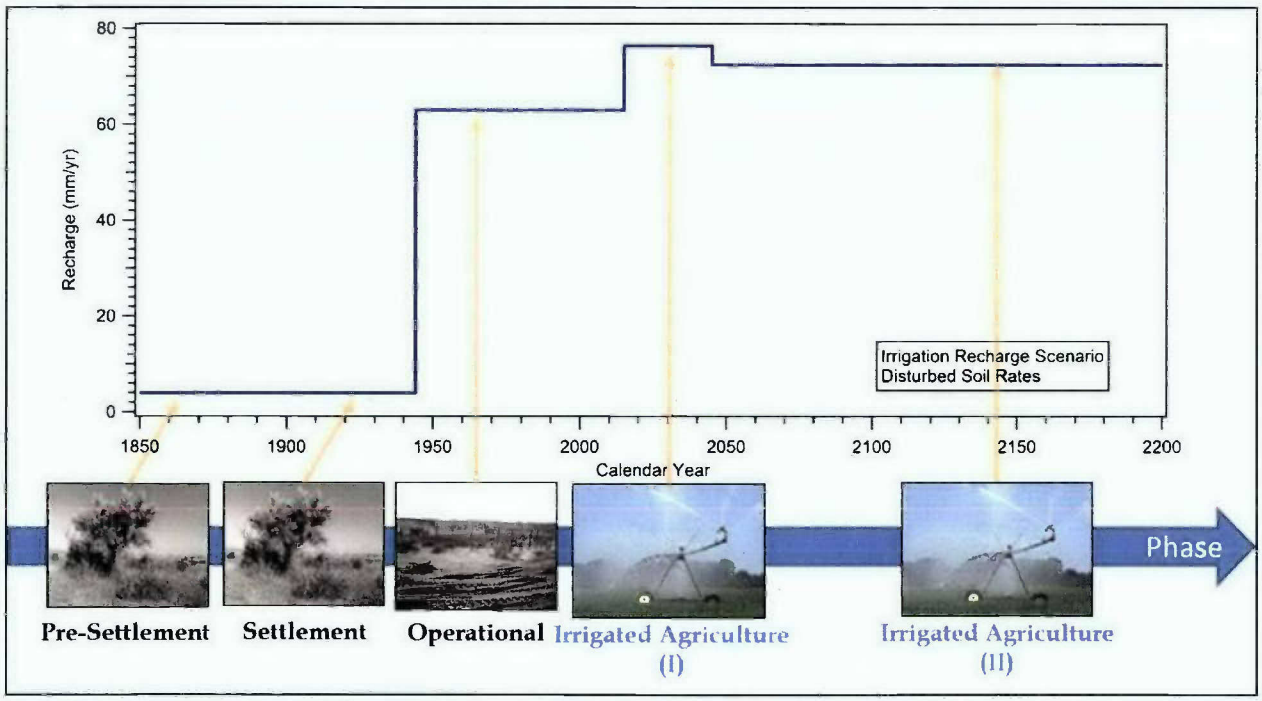

Figure 3-4. Irrigation Recharge Scenario

in which 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. Solving Equation 4 again with I_{rr} = 0 yielded the non-irrigation total recharge rate of 11.6 mm/yr. Therefore, the recharge attributable to irrigation alone was 68.4 mm/yr. This rate was then added to the native vegetation recharge rates for undisturbed soils to determine a rate for the irrigation phases (Table 3-3).

3.2.2 Lower Boundary Conditions

The bottom of the model domain is assigned a constant zero-flux boundary condition for both water mass and contaminant mass (solute) transport (Figure 3-2). 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 3-2a), 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 magnitude of peak concentration.

For the portion of the model domain in the saturated zone (aquifer), 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.

For the portion of the model domain in the saturated zone (aquifer; refer to Figure 3-2a), 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 used for the simulations were based on Automated Water Level Network (AWLN) data obtained from HEIS. Hydraulic head data from 2004 to present were used to calculate the hydraulic gradient for the 100-N area. Triangulated irregular networks (TINs) were fitted to the wells using ArcGIS®[1] and hydraulic gradients were computed for each TIN. 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 0.0020 m/m for 100-N. The details on the hydraulic gradient calculation are reported in ECF-Hanford-14-0028, *Median Hydraulic Gradient Calculation to Support Development of Soil Screening Levels and Preliminary Remediation Goals in the 100 Area*. Note the median gradients were less than the arithmetic average, leading to less dilution in groundwater than if arithmetic average gradients were used.

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 3-2b). The downgradient edges (Figure 3-2b) 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.

[1] ArcGIS is a registered trademark of registered trademarks, or service marks of ESRI in the United States, the European Community, or certain other jurisdictions.

3.2.4 Initial Conditions

For hydraulic 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) coupled flow and transport simulations.

Contaminant initial conditions are imposed based on the objective and methodology of the calculation. Determination of SSL and PRG values is accomplished in a two-step calculation process: first, STOMP is used in a forward calculation step to calculate peak groundwater concentration resulting from an uniform initial concentration over an appropriate vertical depth range of the vadose zone. For this forward calculation step, the initial concentration applied is a unit concentration (1.0 mg/kg for nonradionuclide COPCs, or 1.0 pCi/kg for radionuclide COPCs). The second, back-calculation, step (represented by use of Equation 1 and Equation 2), is where the peak groundwater concentration resulting from the initial uniform unit concentration is scaled by the appropriate regulatory compliance criterion to determine the maximum initial soil concentration that could be present and not result in an exceedance of that criterion. The maximum value obtained from this back-calculation step is assigned as the SSL or PRG value (these differ only with respect to the recharge scenario used; irrigation for SSLs versus native vegetation for PRGs). As a measure of maximum allowable contaminant concentration in the soil, SSLs and PRGs are expressed as contaminant mass per mass of soil for non-radionuclides (e.g., mg/kg) and as contaminant activity per mass of soil for radionuclides (e.g., pCi/g). The use of a unit initial concentration in the forward-calculation step with STOMP is therefore only a convenience to support calculation of SSLs and PRGs in the back-calculation step. The peak groundwater concentration that is calculated with STOMP will be proportional to the initial soil concentration value. Hence, any initial value for soil concentration could be used in the forward-calculation step, and when scaled against the resulting peak groundwater concentration in the back-calculation step in Equation 1 or Equation 2 will yield the same SSL or PRG. The unit concentration, therefore, is not to be confused as constituting an actual observed waste site residual soil concentration. Further detail on this calculation approach is provided in SGW-50776.

Based on SGW-51818, *Conceptual Basis for Distribution of Highly Sorbed Contaminants in 100 Areas Vadose Zone,* all contaminants were grouped into two groups, one with lower distribution coefficients in the range <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 below the clean backfill up to 0.5 m (two grid blocks) above the water table; this is termed the effective 100:0 initial source distribution (Figure 3-5). Initial concentration in the 0.5 m zone above the water table was not applied due to the physical 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 3-5). The 70:30 initial source distribution assumption is deemed conservative for the high K_d contaminants, with respect to peak groundwater concentration, based on observed limited vertical extent of such contaminants. Where borehole measurements of deeper contamination of higher K_d contaminants but of limited vertical extent are found, this conservatism can be tested using those data.

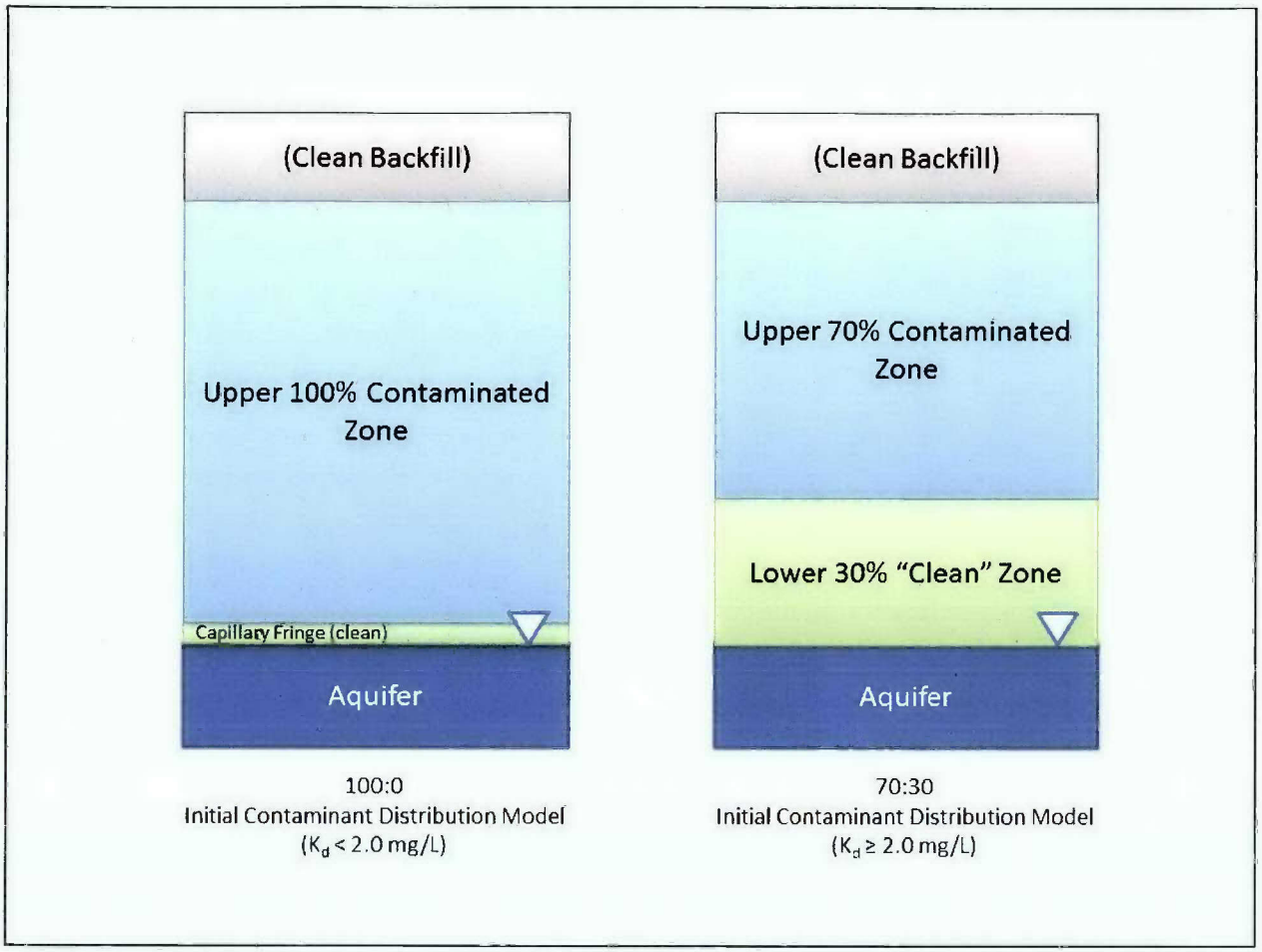

Figure 3-5. 100:0 and 70:30 Initial Contaminant Distribution Models

3.3 Hydraulic Parameters

To the extent possible, OU-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*).

Hanford and Ringold E units are well to poorly sorted sandy gravels or sandy silty gravels whereas the backfill consists 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-N area, the Hanford formation tends to be coarser grained than the Ringold E. The former tends to contain larger gravel clasts than the latter, but the Ringold E can locally contain significant amounts of gravel (SGW-40781; SGW-41213; and SGW-46279). The Ringold E unit in the vadose zone is described as silty sandy gravel in 100-N, the RUM was assumed to act as a lower bound (aquitard) for the aquifer (SGW-46279) and so was not directly included in the STOMP simulations.

100-NR-1 OU-specific values for several Mualem-van Genuchten hydraulic parameters were obtained for the Hanford formation from DOE/RL-96-11, *1301-N and 1325-N Liquid Waste Disposal Facilities Limited Field Investigation Report* and four additional raw data points obtained from HEIS. The RETC software (EPA/600/2-91/065, *The RETC Code for Quantifying the Hydraulic Functions of Unsaturated Soils*) was used to analyze the raw data to obtain the unsaturated hydraulic properties. These property values are all gravel corrected. The gravel correction was done using Equation 4 in WHC-EP-0883, *Variability and Scaling of Hydraulic Properties for 200 Area soils, Hanford Site*. There were other eight samples from the 100-N Area reported in DOE/RL-96-11. All the available vadose zone parameter values are listed in Table 3-4. The 100-N Area sediments are dominated by the gravel fraction (> 2-mm size), with gravel clasts accounting for 4 to 82% of the total sample mass (Table 3-4). 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.

Horizontal saturated hydraulic conductivity measurements from aquifer slug tests for the several areas presented therein were reviewed and geometric means were calculated for aquifer test measurements only (Table 3-5). These mean K_s values ranged from 2.6 to 9.4 m/day (Table 3-5). The geometric mean horizontal K_s values shown in Table 3-5 for the Ringold E in 100-N Area were compared against the range of preliminary calibration values currently in use for the 100 Area groundwater flow and transport model and found to be reasonably consistent. Vertical anisotropy value commonly assumed is 0.1 for Hanford Site sediments (SGW-40781; SGW-41213; and SGW-46279).

The Mualem-van Genuchten hydraulic properties for the Hanford formation were estimated for 100-N Area by averaging the individual parameter values for all samples (Table 3-6). An exception is the

saturated volumetric water content, given symbol θ_s in the van Genuchten (1980) moisture retention relation and equivalent to the diffusive porosity n_D in STOMP. The θ_s values in Table 3-4 were determined by applying a gravel correction factor to the values determined in the laboratory on the < 2mm fraction. The absence of the gravels may have resulted in underestimation of the void volume available for flow because of the difficultly in reconciling high K_s values with very low porosity values. Therefore, the Hanford site-wide estimate of 0.280 and Ringold site-wide estimates of 0.293 were adopted for the total porosity in these units.

Mualem-van Genuchten parameters for the Hanford formation in the 100-N Area were determined from the six samples taken from the Hanford formation in boreholes 199-N-108A and 199-N-109A. The arithmetic mean from all the available data was calculated for all the hydraulic parameters except for K_s. However, in the case of the K_s value, the geometric mean was calculated for sample identification codes BOGL72, BOGL74, BOGL98, BOGLB0 and BOGLB2. The horizontal aquifer saturated conductivity $K_{s,h}$ was estimated as ten times the vertical saturated hydraulic conductivity ($K_{s,h} = 10 \times K_{s,v}$).

Mualem-van Genuchten parameters for the Ringold Formation in 100-N were determined from the six samples taken from boreholes 199-N-108A and 199-N-109A. The arithmetic mean from all the available data was calculated for all the hydraulic parameters except for K_s. For K_s, the geometric mean was calculated from all the available samples and was used as model input. The horizontal aquifer K_s was also taken to be $10 \times K_{s,v}$.

Table 3-4. Mualem-van Genuchten Hydraulic Parameters for Sandy Gravels in the 100-N Area Vadose Zone

Sample	Hydro-stratigraphic Unit	Well Number	Depth (m)	% Gravel	θ_s *Saturated Volumetric Moisture Content* (cm^3/cm^3)	θ_r *Residual Volumetric Moisture Content* (cm^3/cm^3)	α van Genuchten (1980) Air Entry Head Fitting Parameter (1/cm)	n van Genuchten (1980) Exponential Fitting Parameter (-)	K_s Fitted Saturated Hydraulic Conductivity (cm/s)
2-3055 [a]	Hanford	199-N-108A	25-26	82	0.063	0	0.00512	1.31866	–
2-3056 [a]	Ringold	199-N-108A	46.5-47.5	60	0.129	0.0185	0.0375	1.6767	–
2-3057 [a]	Ringold	199-N-108A	53-54	60	0.152	0.0083	0.01805	1.8545	–
2-3058 [a]	Ringold	199-N-108A	93.5-94.5	60	0.139	0.0168	0.01388	1.788	–
BOGL72 [b]	Hanford	199-N-108A	15-15.5	69	0.1540	0.000	0.0018	1.6482	3.20E-04
BOGL74 [b]	Hanford	199-N-108A	24-24.5	4	0.4834	0.000	0.0081	1.4477	2.99E-05
BOGL80 [b]	Ringold	199-N-108A	43-43.5	60	0.1700	0.000	0.0032	1.5175	8.21E-04
BOGL85 [b]	Ringold	199-N-108A	62.8-63.3	51	0.2130	0.000	0.0024	1.6859	7.38E-04
BOGL98 [b]	Hanford	199-N-109A	10.5-11	76	0.0564	0.000	0.0148	1.3475	5.89E-02
BOGLB0 [b]	Hanford	199-N-109A	17.5-18	65	0.1070	0.000	0.0213	1.3184	5.80E-02
BOGLB2 [b]	Hanford	199-N-109A	24.5-25	72	0.0770	0.000	0.0084	1.3796	6.20E-03
BOGLB7 [b]	Ringold	199-N-109A	39.5-40	72	0.0628	0.000	0.0043	1.4565	5.29E-03

a. Source: Hanford Environmental Information System (HEIS), for the sample identification numbers shown.

b. Source: DOE/RL-96-11, *1301-N and 1325-N Liquid Waste Disposal Facilities Limited Field Investigation Report.*

Table 3-5. Aquifer Horizontal Saturated Hydraulic Conductivity Data Specific to 100-N Area

Source Area	Aquifer Formation	Number of Tests	Saturated Horizontal Hydraulic Conductivity $K_{s,h}$ [a]			
			Minimum (m/day)	Maximum (m/day)	Geometric Mean (m/day)	Geometric Mean (cm/s)
100-N	Ringold	8	2.6	9.4	5.0	5.78E-03

a. Source: ECF-100NR2-12-0031, *Analysis of Data Collected from Slug Tests Conducted in Remedial Investigation Boreholes Within the 100-NR-2 Groundwater Operable Unit.*

Table 3-6. Hydraulic Parameters Used for 100-N Source Areas

Source Operable Unit	Zone	Formation	n_T Total Porosity (cm^3/cm^3)	n_D Diffusive Porosity (cm^3/cm^3)	α van Genuchten (1980) Air Entry Head Fitting Parameter	n van Genuchten (1980) Exponential Fitting Parameter (-)	s_r Residual Saturation (-)	K_s Saturated Hydraulic Conductivity Horizontal (cm/s)	K_s Saturated Hydraulic Conductivity Vertical (cm/s)
100-N	Backfill	Backfill	0.276 [a]	0.262 [a]	0.0190 [a]	1.40 [a]	0.103 [a]	5.98E-04 [a]	5.98E-04 [a]
	Vadose	Hanford	0.280 [b]	0.247 [b]	0.00990 [c]	1.41 [c]	0.000 [c]	2.89E-02 [d]	2.89E-03 [e]
	Vadose	Ringold E	0.293 [f]	0.267 [f]	0.0132 [g]	1.66 [g]	0.0272 [g]	1.47E-02 [d]	1.47E-03 [h]
	Saturated	Ringold E	0.293 [f]	0.267 [f]	0.0132 [g]	1.66 [g]	0.0272 [g]	5.78E-03 [i]	5.78E-04 [d]

a. Source: arithmetic mean of hydraulic parameters for backfill calculated for six samples that were collected within the Hanford Site (hydraulic conductivity assumed isotropic for backfill) reported in PNNL-18564, Table A.12 (these are also the site-wide values for backfill listed in PNNL-14702 Rev. 1, Table 4.5).

b. Source: PNNL-18564, Tables 6.3 and 6.4, values for total and effective porosity for Hanford gravelly sand (Hgs), site-wide. Note the saturated volumetric moisture content values listed in Table 3-4 were determined by applying a gravel correction factor to the values determined in the laboratory on the < 2 mm fraction. However, these values appeared to be underestimated and were inconsistent with the high K_s values estimated, so a site-wide estimate was used.

c. Source: computed arithmetic mean of values for six Hanford formation samples (Table 3-4, samples 2-3055, BOGL72, BOGL74, BOGL98, and BOGLB0, and BOGLB2).

d. Source: calculated based on assumed vertical-to-horizontal anisotropy for Hanford Site sediments of 0.1.

e. Source: geometric mean calculated for five Hanford formation samples (Table 3-4, samples BOG72, BOGL74, BOGL98, BOGLB0, and BOGLB2).

f. Source: PNNL-18564, Tables 6.3 and 6.4, values for total and effective porosity for Ringold gravel (Rg), site-wide.

g. Source: computed arithmetic mean of values for six Ringold E Formation samples (Table 3-4, samples 2-3056, 2-3057, 2-3058, BOGL80, BOGL85, and BOGLB7).

h. Source: geometric mean calculated for three Ringold E Formation samples (Table 3-4, samples BOGL80, BOGL85, and BOGLB7).

i. Source: ECF-100NR2-12-0031, *Analysis of Data Collected from Slug Tests Conducted in Remedial Investigation Boreholes Within the 100-NR-2 Groundwater Operable Unit.*

The document and database review for this ECF did not yield operable-unit-specific or even 100 Area specific Mualem-van Genuchten property values for the backfill. In the absence of more site-specific data, Hanford site-wide mean parameter values for the backfill were taken from Table A.12 in PNNL-18564. Mean hydraulic parameters for six samples of backfill gravels that were collected within the Hanford Site (PNNL-18564) were selected to represent these units within the 100 Area. 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, such as 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 of each unit, dispersion coefficients, half-lives for each radiological COPC, and the distribution coefficient for each COPC.

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 gave 1.91 g/cm^3 for the Hanford formation and 1.90 g/cm^3 for the Ringold Formation. The bulk density estimate of 1.94 g/cm^3 for backfill was obtained from PNNL-18564.

Hydrodynamic dispersion was conservatively assumed negligible, so dispersivity values were all set to zero. Setting dispersivity values to zero yields higher peak groundwater concentrations than would be obtained using non-zero values. This, therefore, is a conservative assumption with respect to 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 COPCs were obtained from ECF-Hanford-12-0023 Rev. 2, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area.* These values are listed for each COPC in the tables of SSL values listed in Attachment B, and of PRG values listed in Attachment C, of this ECF. One COPC's K_d value requires elaboration here, that for hexavalent chromium. A site-specific, bounding value is selected in ECF-Hanford-12-0023 Rev. 2 for this COPC that 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 samples across the 100 Areas. 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 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.

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. These values are listed in those tables pertaining to radionuclides in Attachments B and C 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-N; 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.

Volatilization and gas phase transport is conservatively neglected in this calculation to maximize the peak groundwater concentration predicted by the model.

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 B and C of this ECF.

3.5 Simulation Duration

A 1000-year limit was established for purposes of 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 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 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 SSL or PRG (Section 2.5.1).

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).

STOMP has been shown through comparison to analytical solutions, benchmarking against other codes, and field validation to solve the governing equations it incorporates for flow and transport processes correctly, but that the representativeness of any given model implemented using STOMP is inherently limited by the accuracy of the conceptual representation and the representativeness of the parameterization.

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 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 was represented in the numerical model by uniform 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 PRGs uses bounding native vegetation rates based on numerous lysimeter and tracer recharge studies (PNNL-17841).

- The SSL values to be used for screening were 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.

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.

4 Software Applications

STOMP was the primary software used for this calculation; as approved software, the information required is provided in Section 4.1 below.

Microsoft Excel®[2] spreadsheets were used to calculate contaminant inventory values and approximate contaminant solute concentrations, back-calculate SSL and PRG values, and evaluate the results produced by STOMP. These calculations were performed on a desktop with ID INTERA-00466. The hardware is a HP Pavilion dv7 Notebook PC with a 2.53-GHz Intel® Core™ i5 CPU M460 processor and 6 GB of RAM loaded with the Windows 7 operating system. ProUCL comparison was performed on laptop computer with ID INTERA 00470. The hardware is a HP Pavilion dv7 Notebook PC with a 2.3-GHz AMD Turion™ II Dual-Core Mobile M520 processor and 4 GB of RAM loaded with the Windows 7.

4.1 Approved Software

The vadose zone fate and transport calculations are performed using CH2M HILL Plateau Remediation Company (CHPRC) Build 4 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 Document*; 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 Descriptions

The approved STOMP software package was used in the calculation, with required reporting details provided here:

- Software Title: STOMP
- Software Version: CHPRC Build 4
- HISI Identification Number: 2471 (Grade C)
- Workstation type and property number (from which software is run): STOMP was executed on the INTERA Richland GREEN Linux®[3] Cluster that is owned and managed by INTERA, Inc., a pre-selected subcontractor to CHPRC. The computer property tag for the frontend node is INTERA-00469, located at INTERA's Richland, Washington office. This node is a Dell®[4] PowerEdge® R510 with two six-core Intel®[5] Xeon® X5660 processors @ 2.80GHz and 48 GB of RAM. As given by the command "uname –a", the operating system details are:

  ```
  Linux green 3.2.0-54-generic #82-Ubuntu SMP Tue Sep 10 20:08:42 UTC
  2013 x86_64 GNU/Linux
  ```

- The RETC software was used to estimate water retention and conductivity parameters; this software is in the process of being qualified for use by CHPRC. The results of this calculation are contingent upon receiving approval for use of this software. The required information for this software is provided here:

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[2] Excel is a registered trademark of Microsoft Corporation in the United States and other countries.

[3] Linux is a registered trademark of Linux Torvalds in the United States and other countries.

[4] Dell and PowerEdge are registered trademarks of Dell Corporation in the United States and other countries.

[5] Intel and Xeon are registered trademarks of Dell Corporation in the United States and other countries.

- Software Title: RETC
- Software Version: CHPRC Build 1 (Grade D)
- HISI Identification Number: 3272

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 D of 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 software acceptance testing (CHPRC-00515) demonstrated 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 *STOMP 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. A description of the calculation of SSL and PRG values is described in Section 5.1. Site-specific modeling evaluations are described in 5.2.

5.1 Calculation of Soil Screening Levels and Preliminary Remediation Goals

The source-area-specific SSL values for the 100-NR-1 OU are presented in Attachment B of this ECF. The source-area-specific PRG values are presented for the 100-NR-1 OU in Attachment C of this ECF. Details of this calculation are provided below.

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 were scaled down unit horizontal grid length (1.0 m) by dividing the aqueous concentrations by 10.0 m (the representative site model width aligned to the direction of groundwater flow). 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, each for
  - → Four stratigraphic columns (Figure 3-1), each for
    - → All COPCs with their respective K_d values and decay half-lives (Attachments B and C of this ECF)

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.

5.1.3 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 dilution factor (dimensionless), 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}).

The effective dilution factors calculated using Equation 6 for recharge rates for each recharge phase in the predictive period (treated as steady-state values) are listed for each recharge scenario in Table 5-1. These factors are calculated using the recharge rates for each scenario and phase (Table 3-2; Table 3-3) median hydraulic gradients (Section 3.2.3), and aquifer saturated hydraulic conductivities (Table 3-6) along with dimensions of the STOMP model domain (Section 3.1). The dilution factors increase as recharge decreases, because recharge contributes a smaller fraction of the sum of fluxes (Equation 6). The 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 5-1 provide an indication of the magnitude of dilution calculated by STOMP. It is emphasized here, however, that these factors were not explicitly applied to 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 applied explicitly in a post-calculation step to model results.

Table 5-1. Effective Dilution Factors [a]

Area	Aquifer Formation	Effective Dilution Factors by Recharge Scenario Phase			
Native Vegetation Recharge Scenario		Bare Soil (2010-2015) 63 mm/yr	Cheatgrass (2015-2020) 31.5 mm/yr	Developing Shrub-Steppe (2020-2050) 8.0 mm/yr	Mature Shrub-Steppe (2050 >) 4.0 mm/yr
100-NR-1	Ringold	30.0	58.9	229	457
Irrigation Recharge Scenario		Bare Soil (2010-2015) 63 mm/yr	Irrigation I (2015-2045) 76.4 mm/yr		Irrigation II (2045 >) 72.4 mm/yr
100-NR-1	Ringold	30.0	24.9		26.2

a. Dilution factors calculated per Washington Administrative Code (WAC 173-340-747); calculation of dilution is for the steady-state recharge rate in each 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.

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.

The WAC requires the following with regard to the dilution factor where upgradient contamination is present for use of alternative fate and transport models:

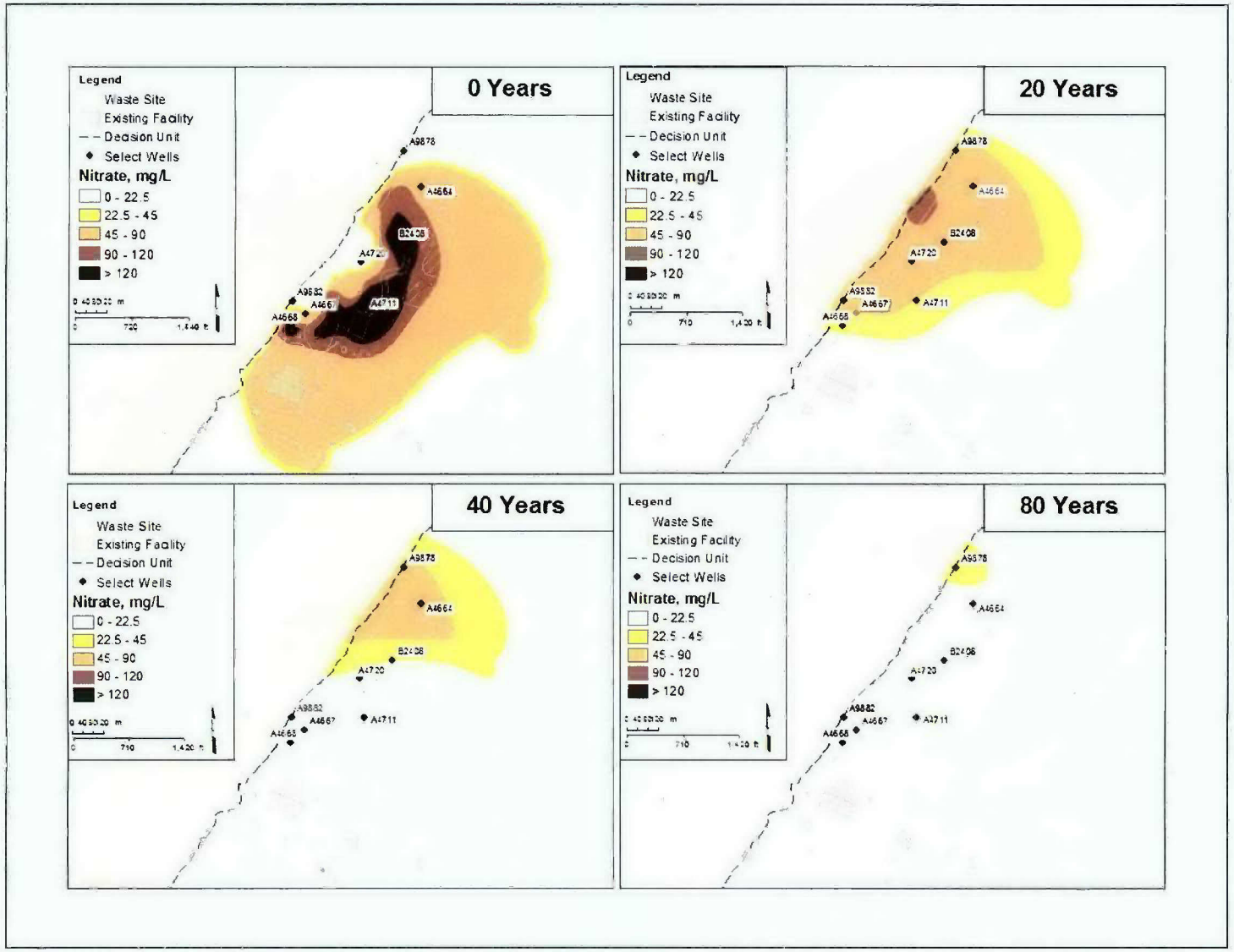
> **WAC 173-340-747 (8)(b)(vi)**: Dilution. Dilution shall be based on site-specific measurements or estimated using a model incorporating site-specific characteristics. If detectable concentrations of hazardous substances are present in upgradient groundwater, then the dilution factor may need to be adjusted downward in proportion to the background (upgradient) concentration.

SSLs and PRGs protective of groundwater and of surface water are calculated to establish soil contamination levels protective of groundwater and of surface water for the post-remedy period. The groundwater contaminants of concern (COCs) in 100-NR-2 Groundwater OU are strontium-90, nitrate, and TPH-diesel (ECF-100NR2-12-0053, *Saturated Zone Flow and Transport Modeling in Support of 100-N RI/FS Document*).

The TPH-diesel plume originates from a single location where existing (and anticipated future) remedial action addresses the contamination in both the vadose zone and groundwater; accordingly, there is no need to incorporate upgradient contamination of TPH-diesel in the calculation of SSLs or PRGs for other waste site locations.

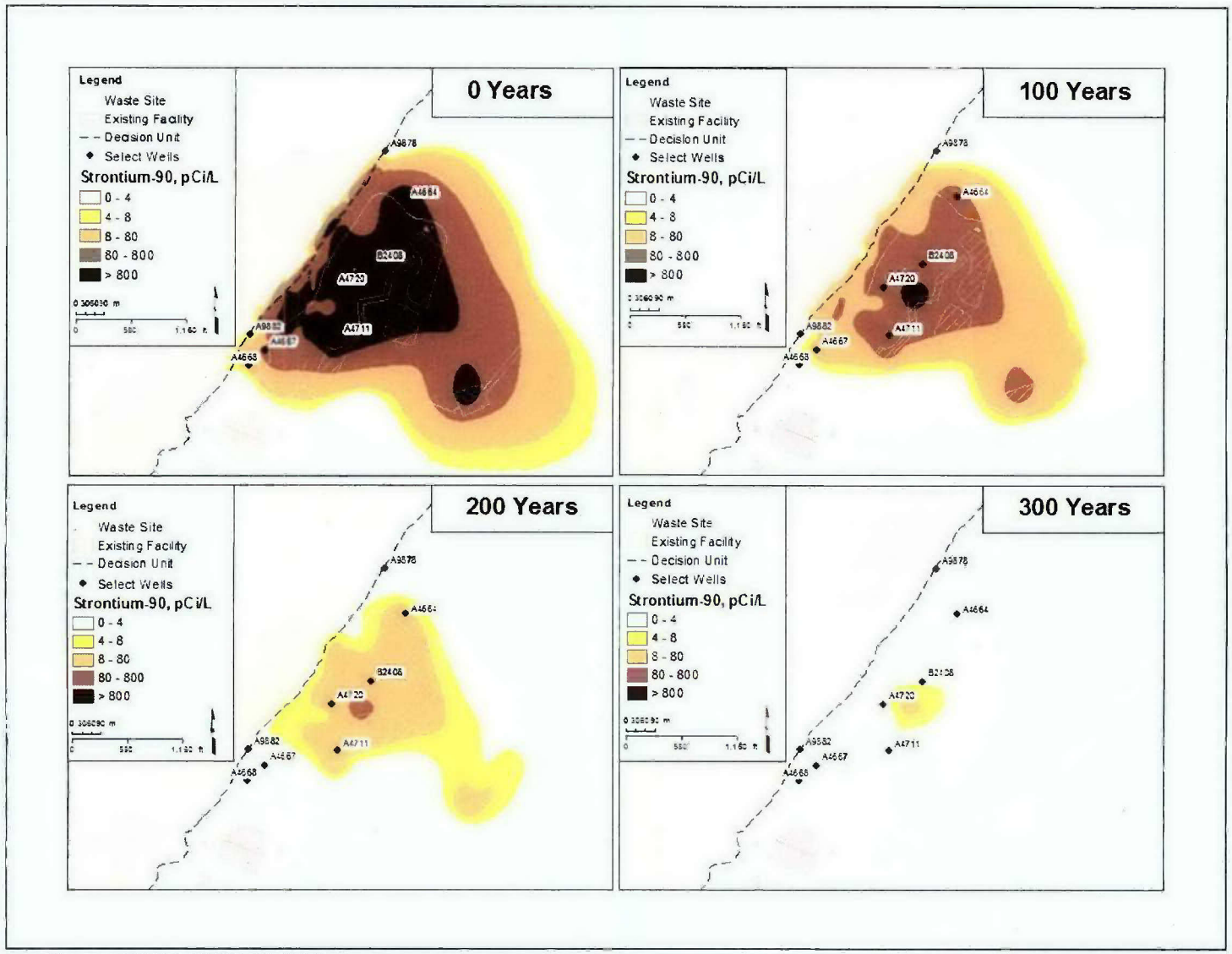
The nitrate plume is reasonably mobile, and already mostly downgradient from 100-N waste sites. Figure 5-1 is taken from groundwater modeling performed to evaluate fate and transport of the TPH-diesel plume (ECF-100NR2-12-0053, *Saturated Zone Flow and Transport Modeling in Support of 100-N RI/FS Document*). Even under no-action conditions, the plume evolution predicted by the groundwater modeling results and based on existing groundwater gradients and flux rates show the nitrate plume will be downgradient of the 100-N waste sites in a relatively short period. Therefore, adjustments to the dilution factor to account for upgradient concentration of nitrate are not necessary in calculation of SSL and PRG values to be protective of groundwater and surface water in the post-remedy period.

The current strontium-90 groundwater plume and its simulated future evolution (Figure 5-2) show that strontium-90 contamination in groundwater will persist for hundreds of years under no-further-action conditions (which retain those interim actions in place on January 1, 2011). Several remedial scenarios are also evaluated in ECF-100NR2-12-0053, but the common feature of these results is that a strontium-90 plume will persist under many waste sites for a long period (hundreds of years) under any of the alternatives evaluated. Incorporating upgradient contamination in the SSL and PRG calculation would be accomplished by applying the upgradient contamination as a solute boundary on the upgradient side of the aquifer nodes (Figure 3-2b). The resulting *CPK* value from STOMP used for back-calculation of the SSL and PRG values (Equation 1 and Equation 2, respectively) would include the impact of upgradient contamination. This approach is only meaningful if the upgradient contamination does not already exceed the protection level defined by the *WQS* value in Equation 1 and Equation 2. That is, where the upgradient concentration level in the aquifer is itself above the protection level, a soil-contamination level protective of groundwater cannot be defined. For this reason, in recognition of the long-term persistence of the strontium-90 plume above the MCL under many waste sites, the PRG value calculated using the site-specific model in ECF-100NR1-12-056 is applicable only to waste sites that are not located over the strontium-90 groundwater plume. No SSL or PRG value is provided for those sites that are located above the existing strontium-90 groundwater plume.



Source: ECF-100NR2-12-0053

Figure 5-1. Simulated Contours of Nitrate Plume over Time for No-Action Conditions



Source: ECF-100NR2-12-0053

Figure 5-2. Simulated Contours of Strontium-90 Plume over Time for No-Action Conditions

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, the maximum of the peak concentrations simulated for the representative stratigraphic columns for that source area (Figure 3-1) was selected as the basis for calculation of the SSL (if the irrigation recharge scenario) or 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 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 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 as well as the recharge scenario. Generally, for 70:30 initial source distributions, thicker vadose zone columns result in smaller K_d threshold values. The K_d threshold is denoted in Attachments B and C tabulations of SSL and PRG values that are presented in ascending K_d order (Tables B-1, B-2, and B-3; Tables C-1, C-2, and C-3), by a bold red line at the point where "NR" values result. Note the same SSL and PRG values are also tabulated in analyte-name ascending order for lookup convenience in Attachments B and C (Tables B-4, B-5 and B-6; Tables C-4, C-5 and C-6).

5.2 Site-Specific Modeling

DOE-RL/2011-50 provides a graded approach for calculation of 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. 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. As noted in Section 2.5.5, SSL and PRG values for strontium-90 were calculated using a second-level (site-specific, multi-dimensional) model that is documented separately in ECF-100NR1-12-0056. This was done because field data revealed that strontium-90 was found throughout the vadose zone at several 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. Given this consideration, the general conceptual site model used for first-level (1-D) modeling under the graded approach (DOE/RL-2011-50) was evaluated to be non-representative for this COPC. SSL and PRG values were instead calculated for strontium-90 using a multi-dimensional, site-specific model, consistent with elevated treatment under the graded approach (DOE/RL-2011-50).

6 Results/Conclusions

The results of this calculation include tabulated SSL and PRG values (described in Section 6.1).

6.1 Soil Screening Value and Preliminary Remediation Goal Results

As described in Section 5.1, the maximum of the peak groundwater concentrations calculated with STOMP for the range of representative stratigraphic columns using the irrigation recharge scenario was used in Equation 1 to compute the SSL value for each COPC. The resulting SSL values protective of surface water and of groundwater are reported for each COPC in Attachment B to this ECF.

Similarly, the maximum of the peak groundwater concentrations from the range of representative stratigraphic columns simulated using the native vegetation recharge scenario was used in Equation 2 to

compute the PRG value for each COPC. The resulting PRG values protective of surface water and groundwater are reported for each COPC in Attachment C to this ECF.

Note the following bounds were applied with regard to SSL and PRG values reported in Attachments B and C to this ECF, respectively:

- For COPCs for which applicable water quality standard are not available, the "NA" symbol was applied for SSL and PRG values (Section 2.5).
- Breakthrough was assumed not to occur if the simulated peak concentration in groundwater within 1000 years did not exceed 0.0001 μg/L for non-radionuclide COPCs or 0.0001 pCi/m^3 for radionuclide COPCs (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 1.78 mL/g for PRG values and 22 mL/g for 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 the results were below a level of numerical significance.
- If the calculated value for any SSL or PRG was less than the estimated quantitation limit (EQL) for soil concentration for a given COPC, then the SSL or PRG value was set equal to the EQL for that COPC (Section 2.5.2).
- If the calculated SSL or PRG value for any nonradionuclide COPC exceeded the physical upper bound of 389,000 mg/kg, then that SSL or PRG value was truncated at 389,000 mg/kg (Section 2.5.3).
- SSL and PRG values for hexavalent chromium were limited to a maximum value of 6.0 mg/kg (Section 2.5.4) because the K_d value used in the model was derived from experiments with soil concentration less than that value, so that there is no basis to infer greater PRGs for Cr(VI) based on these data (ECF-Hanford-11-0165).

The SSL and PRG values reported in this calculation are applicable only to sites and COPCs where the conditions and assumptions underpinning this calculation is representative. Some waste sites may require a more rigorous investigation of site-specific conditions than those underlying the SSL and PRG values listed in Attachments B and C to this ECF.

7 References

ANL/EAD-4, 2001, *User's Manual for RESRAD Version 6*, Argonne National Laboratory, Argonne, Illinois. Available at: http://web.ead.anl.gov/resrad/documents/resrad6.pdf.

CHPRC-00176, 2011, *STOMP Software Management Plan*, Rev. 2, CH2M HILL Plateau Remediation Company, Richland, Washington.

CHPRC-00211, 2011, *STOMP Software Test Plan*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington.

CHPRC-00222, 2011, *STOMP Functional Requirements Document*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington.

CHPRC-00269, 2011, *STOMP Requirements Traceability Matrix*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington.

CHPRC-00515, 2011, *STOMP Acceptance Test Report*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington.

DOE/RL-96-11, 1996, *1301-N and 1325-N Liquid Waste Disposal Facilities Limited Field Investigation Report*, Rev. 0 Draft A, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-96-17, 2009, *Remedial Design Report/Remedial Action Work Plan for the 100 Area*, Rev. 6 Draft A, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=0810240391.

DOE/RL-96-32, 2013, *Hanford Biological Resources Management Plan*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://www.hanford.gov/files.cfm/DOE-RL-96-32-01.pdf.

DOE/RL-2007-27, 2010, *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*, Draft C, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-2011-50, 2011, *Regulatory Basis and Implementation of a Graded Approach to Evaluation of Groundwater Protection*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=0093361.

DOE/RL-2009-42, 2010, *Sampling and Analysis Plan for the 100 NR-1 and 100-NR-2 Operable Units Remedial Investigation/Feasibility Study*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0084103.

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*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

ECF-Hanford-11-0165, *Evaluation of Hexavalent Chromium Leach Test Data Conducted on Vadose Zone Sediment Samples from the 100-Area*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington.

ECF-Hanford-12-0023, 2013, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*, Rev. 2, CH2M HILL Plateau Remediation Company, Richland, Washington.

ECF-Hanford-14-0028, 2014, *Median Hydraulic Gradient Calculation to Support Development of Soil Screening Levels and Preliminary Remediation Goals in the 100 Area*, Rev. 0, CH2M Hill Plateau Remediation Company, Richland, Washington.ECF-100NR2-12-0031, 2012, *Analysis of Data Collected from Slug Tests Conducted in Remedial Investigation Boreholes Within the 100-NR-2 Groundwater Operable Unit*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

EPA/540/1-89/002, 1989, *Risk Assessment Guidance for Superfund Volume I, Human Health Evaluation Manual (Part A)*, U.S. Environmental Protection Agency, Washington, D.C. Available at: http://rais.ornl.gov/documents/HHEMA.pdf.

EPA/540/F095/041, 1996, *Soil Screening Guidance: Fact Sheet*, U.S. Environmental Protection Agency, Washington, D.C. Available at: http://www.epa.gov/superfund/health/conmedia/soil/pdfs/fact_sht.pdf.

EPA/600/2-91/065, 1991, *The RETC Code for Quantifying the Hydraulic Functions of Unsaturated Soils*, U.S. Environmental Protection Agency, Ada, Oklahoma. Available at: http://afrsweb.usda.gov/SP2UserFiles/Place/53102000/pdf_pubs/P1228.pdf.

Huyakorn, P.S., and G.F. Pinder, 1983, Computational Methods in Subsurface Flow, Academic Press, San Diego, California, 473 pp.

Mualem, Y., 1976, "A New Model for Predicting the Hydraulic Conductivity of Unsaturated Porous Media," *Water Resources Research*, 12:513-522.

PNNL-11216, 1997, *STOMP Subsurface Transport Over Multiple Phases: Application Guide*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://stomp.pnl.gov/documentation/guides/application.pdf.

PNNL-12030, 2000, *STOMP Subsurface Transport Over Multiple Phases Version 2.0 Theory Guide*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://stomp.pnl.gov/documentation/guides/theory.pdf.

PNNL-14702, 2006, *Vadose Zone Hydrology Data Package for Hanford Assessments*, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14702rev1.pdf.

PNNL-15782, 2006, *STOMP Subsurface Transport Over Multiple Phases Version 4.0 User's Guide*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://stomp.pnl.gov/documentation/guides/userguide.pdf.

PNNL-17841, 2008, *Compendium of Data for the Hanford Site (Fiscal Years 2004 to 2008) Applicable to Estimation of Recharge Rates*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-17841.pdf.

PNNL-18564, 2009, *Selection and Traceability of Parameters to Support Hanford-Specific RESRAD Analyses*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-18564.pdf.

RPP-20621, 2004, *Far-Field Hydrology Data Package for the Integrated Disposal Facility Performance Assessment*, Rev.0, CH2M Hill Hanford Group, Richland, Washington.

SGW-40781, 2009, *100-HR-3 Remedial Process Optimization Modeling Data Package*, Rev.1 CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=0907010823.

SGW-41213, 2009, *100-KR-4 Remedial Process Optimization Modeling Data Package*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=0908311235.

SGW-46279, 2010, *Conceptual Framework and Numerical Implementation of 100 Areas Groundwater Flow and Transport Model,* CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-50776, 2011, *Model Package Report: Vadose Zone Model for the River Corridor*, Rev. 3, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-51818, 2012, *Conceptual Basis for Distribution of Highly Sorbed Contaminants in 100 Areas Vadose Zone*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

van Genuchten, M. T., 1980, "A Closed-Form Solution for Predicting the Conductivity of Unsaturated Soils," *Soil Science Society of America Journal*, 44:892-898.

WAC 173 340 747, "Deriving Soil Concentrations for Ground Water Protection," Washington Administrative Code, as amended, Washington State Department of Ecology, Olympia, Washington. Available at: http://apps.leg.wa.gov/wac/default.aspx?cite=173-340-747.

WCH-299, 2008, *River Corridor Closure Contractor Revegetation and Mitigation Monitoring Report*, Rev. 0, Washington Closure Hanford, Richland, Washington. Available at: http://www.osti.gov/scitech/biblio/973161.

WCH-362, 2009, *River Corridor Closure Contractor Revegetation and Mitigation Monitoring Report*, Rev. 0, Washington Closure Hanford, Richland, Washington. Available at: http://www.osti.gov/scitech/biblio/973170.

WCH-428, 2010, *River Corridor Closure Contractor Revegetation and Mitigation Monitoring Report*, Rev. 0, Washington Closure Hanford, Richland, Washington. Available at: http://www.osti.gov/scitech/biblio/1016157.

WCH-512, 2011, *River Corridor Closure Contractor Revegetation and Mitigation Monitoring Report*, Rev. 0, Washington Closure Hanford, Richland, Washington. Available at: http://www.osti.gov/scitech/biblio/1083995.

WCH-554, 2012, *River Corridor Closure Contractor Revegetation and Mitigation Monitoring Report*, Rev. 0, Washington Closure Hanford, Richland, Washington.

WDOH/320-015, 1997, *Hanford Guidance for Radiological Cleanup*, Washington State Department of Health, Olympia, Washington. Available at: http://www.doh.wa.gov/Portals/1/Documents/Pubs/320-015_cleanup_e.pdf.

WHC-EP-0883, 1995, *Variability and Scaling of Hydraulic Properties for 200 Area Soils, Hanford Site*, Westinghouse Hanford Company, Richland, Washington. Available at: http://www.osti.gov/bridge/servlets/purl/188564-WXbGAs/webviewable/188564.pdf.

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Attachment A

Crosswalk of WAC Requirements (WAC 173-340-747(8), 2007) for Use of Alternative Fate and Transport Modeling to Modeling Basis of Soil Screening Levels and Preliminary Remediation Goals for 100-N Remedial Investigation / Feasibility Study

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Crosswalk of WAC Requirements (WAC 173-340-747(8), 2007) for Use of Alternative Fate and Transport Modeling to Modeling Basis of Soil Screening Levels and Preliminary Remediation Goals for 100-N Remedial Investigation / Feasibility Study

This crosswalk demonstrates how the WAC 173-340-747(8) requirements for use of alternative fate and transport modeling are met in the use of STOMP modeling to derive soil screening level (SSL) and preliminary remediation goal (PRG) values for 100-N. Each requirement is listed in tabular form with a simple response, followed by an explanation, justification, and cross reference to where the information is found elsewhere in this RI/FS. Focus is on the parameterization of the alternative fate and transport model. Demonstration of the suitability of the STOMP code itself for use in alternative fate and transport modeling to meet WAC requirements is provided in DOE/RL-2011-50 Rev. 1.

Crosswalk of WAC Requirements (WAC 173-340-747(8), 2007) for Use of Alternative Fate and Transport Modeling to Modeling Basis of Soil Screening Levels and Preliminary Remediation Goals for 100-N Remedial Investigation / Feasibility Study

WAC	Requirement	Response
8(b)	**Assumptions.** When using alternative models, chemical partitioning and advective flow may be coupled with other processes to predict contaminant fate and transport, provided the following conditions are met:	
8(b)(i)	Sorption. Was approach (4)(c) or (5)(b) used? Go to correct entry and meet all requirements.	**Both**

Explanation:

- Both Approach (4)(c) and 5(b) were used, depending on the COPC evaluated, for the 201 non-radionuclide, and 32 radionuclide, COPCs evaluated using the alternative fate and transport model of the vadose zone.

Justification:

- For radionuclides, K_d values are selected from Appendix E of DOE/RL-96-17 Rev. 6, which provided a compilation of Hanford-Site-specific values derived from scientific literature, with the exception of one radionuclide, Silver-108m, which is a generic value from scientific literature.
- For organic analytes, K_d values are calculated using Equation 747-2. The K_d calculations assume a value of 0.001 g/g for the soil fraction of organic carbon (f_{oc}), as specified in Equation 747-2. Analyte-specific soil organic carbon-water partitioning coefficient (K_{oc}) values used in the K_d calculations are obtained from the following sources, in order of preference (i.e., if values available in higher preference source, those are used):
    1. Washington State Department of Ecology's "Cleanup Levels and Risk Calculations (CLARC)" online database application (Ecology, 2014) (https://fortress.wa.gov/ecy/clarc/CLARCOverview.aspx)
    2. EPA's "Regional Screening Levels for Chemical Contaminants at Superfund Sites" web site (EPA, 2012) (http://www.epa.gov/reg3hscd/risk/human/rb-concentration_table/)
    3. Oak Ridge National Laboratory's (ORNL) Risk Assessment Information System (RAIS) (ORNL, 2014) (http://rais.ornl.gov/cgi-bin/tools/TOX_search?select=chem_spef)
- For inorganic analytes, K_d values are obtained directly from tabulated sources in the same order of precedence shown above for organic analytes.
- Exception: for hexavalent chromium, the K_d value selected for use in modeling the residual fraction remaining in the vadose zone

Crosswalk of WAC Requirements (WAC 173-340-747(8), 2007) for Use of Alternative Fate and Transport Modeling to Modeling Basis of Soil Screening Levels and Preliminary Remediation Goals for 100-N Remedial Investigation / Feasibility Study

WAC	Requirement			Response
	following remediation is 0.8 mL/g. This value is obtained from ECF-HANFORD-11-0165. • Exception: for total petroleum hydrocarbons (TPH), the K_d value selected for use in modeling the residual fraction of TPH remaining in the vadose zone following remediation is 4 mL/g. This value is obtained from ECF-100NR2-12-0053. Documented: • Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area* (in its entirety) • DOE/RL-96-17, 2009, *Remedial Design Report/Remedial Action Work Plan for the 100 Area*, Rev. 6 (in its entirety). Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=0095436 • Appendix F, ECF-HANFORD-11-0165, *Evaluation of Hexavalent Chromium Leach Test Data Conducted on Vadose Zone Sediment Samples from the 100 Area* (in its entirety) • ECF-100NR2-12-0053, 2012, *Saturated Zone Flow and Transport Modeling in Support of 100-N RI/FS Document*, Rev. 2, Section 4.6.2.3 "K_d for TPH".			
3(b)(i)	4(c)	**4(c) Distribution coefficient (K_d).** The default K_d values for organics and metals used in Equation 747-1.		
3(b)(i)	(4c)	(i)	**(i) Organics.** For organic hazardous substances, was the K_d value derived using Equation 747-2? (required)	**Yes**
			Explanation: • K_d values were derived under Method (4)(c)(i), using Equation 747-2 from WAC 173-340-747 for the following organics using analyte-specific soil organic carbon-water partitioning coefficient (K_{oc}) values from the sources indicated: ○ K_d values derived using K_{oc} values from CLARC tables (Ecology 2014): 1,1,1-Trichloroethane, 1,1,2,2-Tetrachloroethane, 1,1,2-Trichloroethane, 1,1-Dichloroethane, 1,1-Dichloroethene, 1,2,4-Trichlorobenzene, 1,2-Dichlorobenzene, 1,2-Dichloroethane, 1,2-Dichloropropane, 1,4-Dichlorobenzene, 2,4,5-Trichlorophenol, 2,4,6-Trichlorophenol, 2,4-Dichlorophenol, 2,4-Dimethylphenol, 2,4-Dinitrophenol, 2,4-Dinitrotoluene, 2,6-Dinitrotoluene, 2-Chlorophenol, 2-Methylphenol (cresol, o-), 3,3'-Dichlorobenzidine, 4,4'-DDD (Dichlorodiphenyldichloroethane), 4,4'-DDE (Dichlorodiphenyldichloroethylene), 4,4'-DDT		

Crosswalk of WAC Requirements (WAC 173-340-747(8), 2007) for Use of Alternative Fate and Transport Modeling to Modeling Basis of Soil Screening Levels and Preliminary Remediation Goals for 100-N Remedial Investigation / Feasibility Study

WAC	Requirement	Response
	(Dichlorodiphenyltrichloroethane), 4-Chloroaniline, Acenaphthene, Acetone, Aldrin, Alpha-BHC, Alpha-Chlordane, Anthracene, Aroclor-1016, Aroclor-1260, Benzene, Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, beta-1,2,3,4,5,6-Hexachlorocyclohexane (beta-BHC), Bis(2-chloroethyl) ether, Bis(2-ethylhexyl) phthalate, Bromodichloromethane, Bromoform, Bromomethane, Butylbenzylphthalate, Carbazole, Carbon disulfide, Carbon tetrachloride, Chlordane, Chlorobenzene, Chloroform, Chloromethane, chrysene, cis-1,2-Dichloroethylene, cis-1,3-Dichloropropene, Dibenz[a,h]anthracene, Dibromochloromethane, Dieldrin, Diethylphthalate, Di-n-butylphthalate, Di-n-octylphthalate, Endosulfan I, Endosulfan II, Endrin, Ethylbenzene, Fluoranthene, Fluorene, Gamma-BHC (Lindane), Heptachlor, Heptachlor epoxide, Hexachlorobenzene, Hexachlorobutadiene, Hexachlorocyclopentadiene, Hexachloroethane, Indeno(1,2,3-cd)pyrene, Isophorone, Methoxychlor, Methylene chloride, m-Xylene, Naphthalene, Nitrobenzene, n-Nitrosodi-n-dipropylamine, n-Nitrosodiphenylamine, o-Xylene, Pentachlorophenol, Phenol, Pyrene, Styrene, Tetrachloroethene, Toluene, Toxaphene, trans-1,2-Dichloroethylene, trans-1,3-Dichloropropene, Trichloroethene, Vinyl chloride, Xylenes (total). ○ <u>K_d values derived using K_{oc} values from EPA (2012)</u>: 1,2-Dichloroethene (Total), 2-(2-methyl-4-chlorophenoxy) propionic acid, 2,4,5-T(2,4,5-Trichlorophenoxyacetic acid), 2,4,5-TP(2-(2,4,5-Trichlorophenoxy)propionic acid)Silvex, 2,4-DB(4-(2,4-Dichlorophenoxy)butanoic acid), 2,4-Dichlorophenoxyacetic acid, 2-Butanone, 2-Butoxyethanol, 2-Chloronaphthalene, 2-Hexanone, 2-Methylnaphthalene, 2-Nitroaniline, 4,6-Dinitro-2-methylphenol, 4-Amino-3,5,6-trichloropicolinic acid, 4-Chloro-3-methylphenol, 4-Methyl-2-pentanone, 4-Methylphenol (cresol, p-), 4-Nitroaniline, Acrylamide, Acrylonitrile, Aroclor-1221, Aroclor-1232, Aroclor-1242, Aroclor-1248, Aroclor-1254, Bis(2-chloro-1-methylethyl)ether, Bis(2-Chloroethoxy)methane, Chloride, Chloroethane, Co-elution of Aroclor 1242 and Aroclor 1016, Cyanide, Dalapon, Dibenzofuran, Dicamba, Diethyl ether, Dinoseb(2-secButyl-4,6-dinitrophenol), Ethyl acetate, Ethylene glycol, Isopropylbenzene, Methanol, Nitrate, Nitrite, Nitrogen in Nitrate, Nitrogen in Nitrite, Nitrogen in Nitrite and Nitrate, Tributyl phosphate, Trichloromonofluoromethane. ○ <u>K_d value derived using K_{oc} values from ORNL (2014)</u>: 1,3-Dichlorobenzene, 2-Nitrophenol, 3-Nitroaniline, 4-Bromophenylphenyl ether, 4-Chlorophenylphenyl ether, 4-Nitrophenol, Acenaphthylene, Benzo(ghi)perylene, Delta-BHC, Dichloroprop, Dimethyl phthalate, Endosulfan sulfate, Endrin aldehyde, Endrin ketone, Phenanthrene. ○ <u>K_d value derived from consideration of total petroleum hydrocarbon ranges (ECF- 100NR2-12-0053)</u>: Total petroleum hydrocarbons - diesel range, Total petroleum hydrocarbons - motor oil (high boiling)	

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WAC	Requirement				Response
			Justification: • Refer to responses by entry, below. Documented: • Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area* (in its entirety) • Appendix F, ECF-100NR2-12-0053, Rev. 2, *Saturated Zone Flow and Transport Modeling in Support of 100-N RI/FS Document*, Section 4.6.2.3 "K_d for TPH".		
8(b)(i)	(4c)	(i)	The K_{oc} (soil organic carbon-water partition coefficient) parameter specified in Equation 747-2 shall be derived as follows:		
8(b)(i)	(4c)	(i)	(A)	**(A) Nonionic organics.** Are there individual nonionic hydrophobic organic hazardous substances (e.g., benzene and naphthalene)?	**Yes**
				Explanation: • The COPC list includes nonionic organics, including naphthalene. Justification: • No justification is required for this response. Documented: • Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area* (in its entirety)	
8(b)(i)	(4c)	(i)	(A)	• If so, were K_{oc} values from Table 747-1 used? OR	**Yes**

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WAC				Requirement	Response
				Explanation: • Yes, K_{oc} values from Table 747-1 were used. Justification: • No justification is required for this response. Documented: • Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area* (in its entirety)	
8(b)(i)	(4c)	(i)	(A)	• For hazardous substances not listed in Table 747-1, were K_d values used from (5) (variable three-phase partitioning model)?	**N/A**
				Explanation: • No COPCs analyzed met this condition. Justification: • No justification is required for this response. Documented: • Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area* (in its entirety)	
8(b)(i)	(4c)	(i)	(B)	(B) **Ionizing organics.** For ionizing organic hazardous substances (e.g., pentachlorophenol and benzoic acid), were K_{oc} values used from Table 747-2? (required)	**Yes**
				Explanation:	

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WAC				Requirement	Response
				• The following ionizing organic hazardous substances are COPCs: 2,4,5-Trichlorophenol, 2,4,6-Trichlorophenol, 2,4-Dichlorophenol, 2,4-Dimethylphenol, 2,4-Dinitrophenol, 2-Chlorophenol, Pentachlorophenol. K_d values for these were derived under Method (4)(c)(i), using Equation 747-2 from WAC 173-340-747 for the following organics using analyte-specific soil organic carbon-water partitioning coefficient (K_{oc}) values from CLARC tables (Ecology 2009). Justification: • Compliant; no further justification is required for this response. Documented: • Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area* (in its entirety)	
8(b)(i)	(4c)	(i)	(B)	Was the soil pH measured? (required) and the K_{oc} value for the corresponding soil pH used?	**Yes**
				Explanation: • Soil pH was measured and the K_{oc} value for the corresponding soil pH was used. Justification: • Compliant; no further justification is required for this response. Documented: • Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area* (in its entirety)	
8(b)(i)	(4c)	(i)	(B)	If the soil pH fell between the pH values provided, were the values correctly interpolated?	**N/A**
				Explanation:	

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WAC	Requirement				Response
				• None detected, and hence not applicable. Justification: • No justification is required for this response. Documented: • Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area* (in its entirety)	
8(b)(i)	(4c)	(ii)	**(ii) Metals.**		
8(b)(i)	(4c)	(ii)	Were the K_d values from Table 747-3 used?		**Yes** **Except Cr(VI)**
			Explanation: • Yes: K_d values from Table 747-3 were used for the following metals: Antimony, Arsenic, Barium, Beryllium, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium, Silver, Thallium, Vanadium, Zinc. • No: K_d values were not available from Table 747-4 and were obtained from EPA (2012) for the following metals: Aluminum, Boron, Calcium, cobalt, Fluoride, Iron, Lithium, Magnesium, Manganese, Molybdenum, Potassium, Sodium, Strontium, Tin • No: a site-specific K_d value based on leach test results was used for Hexavalent Chromium. Justification: • No justification is required for the use of K_d values from Table 747-3. • Justification for using a site-specific K_d value derived from leach test results is provided below, in the response to 5(b)(iii). Documented:		

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WAC	Requirement			Response
			• Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area* (in its entirety)	
8(b)(i)	(4c)	(ii)	If metals were not listed in Table 747-3, was the subsection (5) (variable three-phase partitioning model) used?	**No**
			Explanation: • The variable three-phase partitioning model was not used. Justification: • No justification is required for this response. Documented: • Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area* (in its entirety)	
8(b)(i)	5(b)		**5(b) Methods for deriving a distribution coefficient (K_d).** To derive a site-specific distribution coefficient, which one of the following methods was used? Go to (i), (ii), (iii), or (iv).	**(iii) and (iv)**
			Explanation: • A site-specific K_d value for hexavalent chromium for the 100 Area was derived from batch leach test results under Method (iii). • Scientific literature was used to derive site-specific values for K_d for several constituents under Method (iv). Justification: • Justification is provided with explanation in responses to Methods (iii) and (iv), below. Documented:	

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WAC			Requirement	Response
		• Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area* (in its entirety)		
8(b)(i)	5(b)	(i)	**(i) Deriving K_d from soil fraction of organic carbon (foc) measurements.**	
			• Was Equation 747-2 used to derive distribution coefficients for nonionic hydrophobic organics for site-specific measurements of soil organic carbon?	**Yes**
			Explanation: • The COPC list includes nonionic organics, including naphthalene, and Equation 747-2 was used to derive distribution coefficients. Justification: • No justification is required for this response. Documented: • Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area* (in its entirety)	
8(b)(i)	5(b)	(i)	• Were soil organic carbon measurements based on uncontaminated soil below the root zone (i.e., soil greater than one meter in depth) that is representative of site conditions or in areas through which contaminants are likely to migrate?	**N/A**
8(b)(i)	5(b)	(i)	• Were laboratory protocols in the Puget Sound Estuary Program (March, 1986) used?	**N/A**
8(b)(i)	5(b)	(i)	• Were other methods used and approved by the department?	**N/A**

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WAC	Requirement			Response
8(b)(i)	5(b)	(i)	• Were all laboratory measurements of soil organic carbon based on methods that do not include inorganic carbon in the measurements?	**N/A**
8(b)(i)	5(b)	(ii)	**(ii) Deriving K_d from site data.**	
8(b)(i)	5(b)	(ii)	• Were site-specific measurements of hazardous concentrations in soil and soil pore water or ground water used to derive a K_d and was department approval obtained?	**No**
			Explanation: • This method was not used to derive a K_d value for any COPC evaluated. Justification: • No justification is required for this response. Documented: • Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area* (in its entirety)	
8(b)(i)	5(b)	(ii)	• Were K_ds derived from site data based on measurements of soil and ground water hazardous substance concentrations from the same depth and location?	**N/A**
8(b)(i)	5(b)	(ii)	• Were soil and ground water samples containing hazardous substances present as a nonaqueous phase liquid (NAPL) used to derive a K_d? (not allowed) and were measures taken to minimize biodegradation and volatilization during sampling, transport and analysis?	**N/A**
8(b)(i)	5(b)	(iii)	(iii) **Deriving K_d from batch tests.**	

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WAC			Requirement	Response
8(b)(i)	5(b)	(iii)	• Was a site-specific K_d derived by using batch equilibrium tests to measure hazardous substance adsorption and desorption and was department approval obtained?	**Yes**
			Explanation: • A site-specific value (specific to the 100 Area of the Hanford Site) of K_d for hexavalent chromium was derived using batch equilibrium tests. Justification: • Ecology approved the batch leach testing with the approval of the D/H SAP DOE/RL-2009-40 Rev 0. Page 2-127 describes the procedure. It was also modified by TPA-CN-368 signed by Ecology on 8/26/2010 to allow for removing the requirement for pH adjustment of demineralized water. Documented: • Chapter 5, Section 5.4.1.4 "Sorption" • Appendix F, ECF-HANFORD-11-0165 Rev. 1, *Evaluation of Hexavalent Chromium Leach Test Data Conducted on Vadose Zone Sediment Samples from the 100-Area* (in its entirety)	
8(b)(i)	5(b)	(iii)	• Were samples with hazardous substances present as a nonaqueous phase liquid (NAPL) used to derive a distribution coefficient (not allowed) and were measures shall be taken to minimize biodegradation and volatilization during testing?	**No**
			Explanation: • No samples with NAPLs present were used in the determination of K_d values. Justification: • No justification is required for this response. Documented:	

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WAC	Requirement			Response
			• Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area* (in its entirety)	
8(b)(i)	5(b)	(iv)	**(iv) Deriving K_d from the scientific literature.** Was scientific literature used to derive a site-specific distribution coefficient (K_d)? If so, were the requirements in WAC 173-340-702 (14), (15) and (16) met? (*see end of list under 8(c)*)	**Yes**
			Explanation: • Scientific literature values were applied to select COPCs as follows: General K_d values were derived from scientific literature for these COPCs: ○ Silver-108m – from ANL (1993) Hanford site-specific K_d values were derived from scientific literature for these COPCs: ○ Thorium-228, Thorium-230, Thorium-232 - Ames and Rai (1978) ○ Americium-241, Cesium-137, Cobalt-60, Europium-152, Europium-154, Europium-155, Nickel-63, Strontium-90 - Ames and Serne (1991) ○ Carbon-14 – from BHI (2002a) ○ Curium-243, Curium-244, Iodine-129, Neptunium-237, Niobium-94, Potassium-40, Sodium-22 – from Kincaid et al. (1998) ○ Plutonium-238, Plutonium-239/240, Plutonium-239, Plutonium-240, Plutonium-241, Radium-226, Radium-228, Technetium-99, Tritium (H-3), Uranium-233/234, Uranium-235, Uranium-238 – from Serne and Wood (1990), except all uranium values are replaced with "NVR" (no value required) for 100-N modeling purposes because uranium does not require modeling. No K_d values were available for these COPCs: ○ No value available: 3+4 Methylphenol (cresol, m+p), Bismuth, Bromide, Calcium, Co-elution of	

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WAC	Requirement	Response
	Aroclor 1242 and Aroclor 1016, Phosphate, Silicon. Justification: • Best-available scientific information applied in absence of higher-precedence values (CLARC 2014, EPA 2012, or ORNL 2014). Documented: • Appendix F, ECF-HANFORD-12-0023, Rev. 3, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area,* Table 3-5 "Final Nonradiological Analyte Distribution Coefficient (K_d) Selection" and Table 3-6 "Radiological Analyte Distribution Coefficients (K_d)" • DOE/RL-96-17, 2009, *Remedial Design Report/Remedial Action Work Plan for the 100 Area*, Rev. 6 (in its entirety). Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=0095436	
8(b)(ii)	**Vapor phase partitioning.** If Henry's law constant is used to establish vapor phase partitioning, then the constant shall be derived in accordance with subsection (4)(d) of this section.	**N/A**
	Explanation: • Volatilization was conservatively neglected in the calculation of SSL and PRG values. Justification: • This assumption is conservative, with respect to SSL and PRG values only, because modeling volatilization would reduce the mass transport to the groundwater pathway, with result of lower peak groundwater concentrations and hence higher SSL and PRG values. • This calculation is not the basis for direct exposure evaluations (presented in Chapter 6 of the RI/FS). Hence, this assumption does not apply to the inhalation pathway for direct exposure. Documented: • Appendix F, SGW-50776 Rev. 3, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 6.1 "Modeling Conservatisms" notes that volatile organic compounds were assumed to have negligible volatilization so that the resulting peak concentrations are larger than if volatilization had been included. • Appendix F, ECF-HANFORD-12-0017 Rev. 2, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-NR-1 Source Operable Unit*, Section 3.4 "Contaminant Transport Parameters" documents	

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WAC	Requirement			Response
	neglecting volatilization.			
8(b)(ii)	(4)(d)	**(4)(d) Henry's law constant.**		
8(b)(ii)	(4)(d)		For petroleum fractions, were the values for Henry's law constant in Table 747-4 used in Equation 747-1? (required)	**N/A**
8(b)(ii)	(4)(d)		For individual organic hazardous substances, was the value based on values in the scientific literature? (required)	**N/A**
8(b)(ii)	(4)(d)		For all metals present as inorganic compounds except mercury, was zero used? (required) For mercury, was either 0.47 or a value derived from the scientific literature used? (required)	**N/A**
8(b)(ii)	(4)(d)		Did the derivation of Henry's law constant from the scientific literature comply with WAC 173-340-702 (14), (15) and (16)? (required) (*see end of list under 8(c)*)	**N/A**
8(b)(iii)	**Natural biodegradation.** Were the rates of natural biodegradation derived from site-specific measurements? (required)			**No**
	Explanation: • Biodegradation is not incorporated into the calculation. Justification: • All COPCs are assumed not to be subject to natural biodegradation for purposes of calculating SSLs and PRG values. This is generally a conservative assumption (because of overstating COPC persistence by neglecting biodegradation). • This assumption may be non-conservative in some circumstances, e.g., 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. Groundwater protection levels are calculated based on meeting all applicable standards immediately under the waste site; including meeting ambient water quality standards with no credit for attenuation of organics as they			

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WAC	Requirement	Response
	travel from the waste site and interface with oxic water conditions. This additional conservatism covers the potential for biodegradation products to be generated while keeping the calculations as simple and transparent as possible. This is further supported by groundwater data collected from the OU which indicate that biodegradation products, such as 1,1-DCE and vinyl chloride, have not been detected in groundwater. Documented: • Appendix F, ECF-100NR1-12-0017 Rev. 2, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-NR-1 Source Operable Unit*, Section 3.4 "Contaminant Transport Parameters" documents that biodegradation is not incorporated into the calculation.	
8(b)(iv)	**Dispersion.** Were estimates of dispersion derived from either site-specific measurements or literature values? (required)	N/A
	Explanation: • Dispersion was conservatively minimized in the calculation by setting coefficients for hydrodynamic dispersion to zero. Additional considerations of the 1-D model construct follow: • The 1-D model construct does not address lateral transport, effectively assuming that contaminants in the vadose zone are continuously moving in one direction (downward) with no accounting for potential lateral migration. While lateral migration is highly likely under field conditions, this effect reduces and delays the peak groundwater concentration resulting from a given waste site. Hence, this 1-D modeling construct is conservative because it overstates the potential for groundwater impacts compared to a higher-dimensionality model construct that accounts for lateral migration. • The PRZ is not explicitly modeled (rise and fall of the water table is not assumed) to provide a bounding calculation. A fluctuating water table will provide additional attenuation distance between the source area and groundwater for six months every year. • Conditions from summer months (the period of highest river stage and groundwater heads in this locale) are used in the 1D STOMP models. This parameterization provides the simplest and most conservative evaluation of conditions under a waste site by providing the shortest travel distance from the contaminated source to groundwater, and by assuming that this short travel distance persists indefinitely. This, in turn, maximizes the predicted impact on groundwater by yielding a higher peak concentration is calculated than if water table is simulated as fluctuating. The effects of the PRZ are handled internally within STOMP. A three-dimensional treatment cannot result in greater impact on groundwater than the one-dimensional assumption because the one-dimensional treatment allows no lateral diffusion of contaminants; the only possible direction for contaminant movement is downward. Justification:	

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WAC	Requirement	Response
	• Simulating with no hydrodynamic dispersion is conservative, with respect to SSL and PRG values, because inclusion of greater hydrodynamic dispersion would result in lower peak groundwater concentrations, and therefore higher SSL and PRG values. Documented: • Chapter 5, Table 5-6, "Summary of Selected Primary Fate and Transport Simulation Input Parameters Used with 1D Model Implemented in STOMP Code for Screening Level and Preliminary Remediation Goal Calculations for the 100-NR-1 Operable Unit" • Appendix F, SGW-50776 Rev. 3, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 4.5.1 "Parameters and Ranges" notes that dispersion was conservatively assumed negligible, so dispersivity values were all set to zero. • Appendix F, ECF-100NR1-12-0017 Rev. 2, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-NR-1 Source Operable Unit*, Section 3.4 "Contaminant Transport Parameters" documents that hydrodynamic dispersion is set to zero in the calculation.	
8(b)(v)	**Decaying source.** Were fate and transport algorithms used that account for decay over time? Regulation states that Fate and Transport algorithms may be used that account for decay over time.	**Yes**
	Explanation: • Radioactive decay is accounted for in the STOMP code for radionuclides only. The STOMP simulator solves the Arrhenius-type kinetic reaction (PNNL-12030) according to the equation $$\frac{\partial c}{\partial t} = -\lambda^C c$$ where c is concentration of the COPC C in solute, t is time, and λ^C is the decay rate constant for COPC C. The decay rate is related to the radionuclide half-life according to the equation $$\lambda^C = \frac{\ln(2)}{t_{\frac{1}{2}}^C}$$ where $t_{1/2}^C$ is the half-life of COPC C. STOMP is capable of solving for chain decay, but this feature was not required or used for the SSL and PRG calculations. The only input parameter required is the half-lives $t_{1/2}^C$ for each radionuclide. All half-lives for this RI/FS were obtained from the Radiochemistry website in September 2011 (Radiochemistry Society, 2011). Justification:	

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WAC	Requirement	Response
	• Radioactive decay is an established physical process for radionuclides evaluated in this RI/FS and follow well established rate laws that are solved using analytical equations in the STOMP code. DOE/RL-96-17 Rev. 6 notes, with regard to radioactive daughter products, "The development of cleanup standards for the 100 Area will not be affected because the principal radionuclides of concern in the 100 Area (e.g., cobalt-60, cesium-137, europium-152, and europium-154) do not decay to daughter products that are more radioactive." • No radionuclide 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-N. The gamma emitters do not have decay products). • It is true that some volatiles are simulated with no biodegradation, which can have more toxic daughter products. While this could generate lower PRGs and SSLs for these volatiles, other conservatisms allow the calculated values to remain protective. The most notable conservatism for these volatiles is that their cleanup levels are based on the lowest applicable water quality standard. The groundwater protection levels are calculated based on meeting all applicable standards immediately under the waste site; including meeting ambient water quality standards with no credit for attenuation of organics as they travel from the waste site and interface with oxic water conditions. This additional conservatism covers the potential for biodegradation products to be generated while keeping the calculations as simple and transparent as possible. This is further supported by groundwater data collected from the OU which indicate that biodegradation products, such as 1,1-DCE and vinyl chloride, have not been detected in groundwater. Documented: • Chapter 5, Section 5.3.2, "Persistence of Radiological Constituents" describes the applicable radioactive decay processes. • Appendix F, ECF-100NR1-12-0017 Rev. 2, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-NR-1 Source Operable Unit*, Section 3.4 "Contaminant Transport Parameters" documents that STOMP is used to account for first-order decay in the solute mass conservation equation. The half-lives used for input to STOMP by radionuclide COPC are listed in Attachment B, Table B-3 and in Attachment C, Table C-3 list. Section 3.4 "Contaminant Transport Parameters" references PNNL-12030, *STOMP Subsurface Transport Over Multiple Phases Version 2.0 Theory Guide*, which describes the calculation of radioactive decay in the STOMP code. Section 3.4 "Contaminant Transport Parameters" also notes chain decay is not accounted for in this calculation. • DOE/RL-96-17 Rev. 6, *Remedial Design Report/Remedial Action Work Plan for the 100 Area*, Section 2.1.2.2 "Remedial Action Goals for Radionuclide Contaminants in Soil" dismisses the need to consider chain decay based on lack of daughter products for principal radionuclides of concern in the 100 Area. Available at: http://www5.hanford.gov/arpir/?content=findpage&AKey=0095436.	
8(b)(vi)	**Dilution.** Was dilution based on site-specific measurements or estimated using a model incorporating site-specific characteristics? (required)	**Estimated using a model incorporating site-specific**

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WAC	Requirement	Response
		characteristics

Explanation:

- Dilution is directly simulated in the STOMP model for SSL and PRG calculation through inclusion of the upper portion of the aquifer in the model, and using the mean hydraulic gradient for the OU to simulate for dilution directly. The dilution factor can be derived from the equation

$$Df = \frac{Q_{VZ} + Q_A}{Q_{VZ}}$$

where D_f is the dimensionless dilution factor, Q_{VZ} is the volumetric flux from the vadose zone into the aquifer, and Q_A is the volumetric flux through the upper 5 m of the aquifer. The value of Q_A is dependent upon the hydraulic gradient and hydraulic conductivity of the aquifer portion of the model. These input parameter values are input to the STOMP model constructed for SSL and PRG development. The recharge rate varies over time in the calculation according to the recharge scenario simulated; hence, the effective dilution factor also varies in time because the Q_{VZ} term in the dilution factor calculation represents the flux attributable to the recharge rate. The effective dilution factors were calculated and presented for all combinations of recharge scenarios, recharge phases, and hydraulic gradients used in the alternative fate and transport modeling. These dilution rates ranged from a low of 24.9 for the irrigation recharge rate under the irrigation recharge scenario to a high of 457 for the mature shrub-steppe recharge rate under the native vegetation recharge scenario. 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.

Justification:

- Where using an alternative fate and transport model (WAC 173-340-747(8)), it is required that dilution "be based on site-specific measurements or estimated using a model incorporating site-specific characteristics." The hydraulic gradient incorporates site-specific characteristics of the aquifer. The depth of the aquifer used for the dilution calculation follows WAC 173-340-747.

Documented:

- Chapter 5, Section 5.5 "Vadose Zone Modeling Methods and Results" describes the methodology for inclusion of the aquifer in the model domain and direct simulation of dilution as a function of aquifer depth, hydraulic gradient, domain size, and vadose zone leaching.
- Appendix F, SGW-50776 Rev. 3, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 5.4 "Calculating Dilution Factors" presents and discusses dilution factor calculation in the STOMP modeling.
- Appendix F, ECF-100NR1-12-0017 Rev. 2, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-NR-2 Source Operable Unit*, Section 5.1.3 "Dilution Factor"

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WAC	Requirement	Response
8(b)(vi)	If detectable concentrations of hazardous substances are present in upgradient ground water, then the dilution factor may need to be adjusted downward in proportion to the background (upgradient) concentration. Was an adjustment made?	No

Explanation:

- Adjustments were not made based on upgradient groundwater concentrations of hazardous substances.
- No SSL or PRG value is provided for strontium-90 in waste sites located over the current strontium-90 groundwater plume extent.

Justification:

- SSLs and PRGs protective of groundwater and of surface water are calculated to establish soil contamination levels protective of groundwater and of surface water for the post-remedy period. The groundwater contaminants of concern (COCs) in 100-NR-2 Groundwater OU are strontium-90, nitrate, and TPH-diesel:
  - The TPH-diesel plume originates from a single location where existing (and anticipated future) remedial action addresses the contamination in both the vadose zone and groundwater; accordingly, there is no need to incorporate upgradient contamination of TPH-diesel in the calculation of SSLs or PRGs for other waste site locations.
  - The nitrate plume is reasonably mobile, and already mostly downgradient from 100-N waste sites. Even under no-action conditions, and based on existing groundwater gradients and flux rates the plume evolution predicted by the groundwater modeling results show the nitrate plume will be downgradient of the 100-N waste sites in a relatively short period. Therefore, adjustments to the dilution factor to account for upgradient concentration of nitrate are not necessary in calculation of SSL and PRG values to be protective of groundwater and surface water in the post-remedy period.
  - The current strontium-90 groundwater plume and its simulated future evolution show that strontium-90 contamination in groundwater will persist for hundreds of years under no-further-action conditions (which retain those interim actions in place on January 1, 2011). Several remedial scenarios are also evaluated in ECF-100NR2-12-0053, but the common feature of these results is that a strontium-90 plume will persist under many waste sites for a long period (hundreds of years) under any of the alternatives evaluated. Incorporating upgradient contamination in the SSL and PRG calculation would be accomplished by applying the upgradient contamination as a solute boundary on the upgradient side of the aquifer nodes. The resulting peak concentration in groundwater simulated using STOMP and used for back-calculation of the SSL and PRG values would include the impact of upgradient contamination. This approach is only meaningful if the upgradient contamination does not already exceed the protection level used in the back-calculation step. That is, where the upgradient concentration level in the aquifer is itself above the protection level, a soil-contamination level protective of groundwater cannot be defined. For this reason, in recognition of the long-term persistence of the strontium-90 plume above the MCL under many waste sites, the PRG value calculated using the site-specific model in ECF-100NR1-12-056 is applicable only to waste sites that are not located over the

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WAC	Requirement	Response
	strontium-90 groundwater plume. No SSL or PRG value is provided for those sites that are located above the existing strontium-90 groundwater plume. Documented: • Appendix F, ECF-100NR1-12-0017, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-NR-2 Source Operable Unit*, Section 5.1.3 "Dilution Factor" • Appendix F, ECF-100NR2-12-0053, *Saturated Zone Flow and Transport Modeling in Support of 100-N RI/FS Document*, in its entirety.	
8(b)(vii)	**Infiltration.** Was infiltration derived in accordance with subsection (5)(f)(ii)(A) or (B) of this section? (required)	**Yes; (B)**

	Explanation:
	• (5)(f)(ii)(B); Infiltration was derived from site-specific measurements.
	Justification:
	• Use of site-specific values is permitted under (5)(f)(ii)(B).
	Documented:
	• Chapter 5, Section 5.4.1.1, "Surface Cover, Infiltration, and Recharge"
	• Chapter 5, Table 5-6, "Summary of Selected Primary Fate and Transport Simulation Input Parameters Used with 1D Model Implemented in STOMP Code for Screening Level and Preliminary Remediation Goal Calculations for the 100-NR-1 Operable Unit"
	• Appendix F, SGW-50776 Rev. 3, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 4.4.1 "Flow and Transport Boundary Conditions" presents the range of applicable site-specific recharge rates from
	  ○ PNNL-14702 Rev. 1, Table 4-15, available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14702rev1.pdf.
	• Appendix F, ECF-100NR1-12-0017 Rev. 2, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-NR-1 Source Operable Unit*, Section 3.2.1 "Upper Boundary Conditions" identifies the use of 100-Area-specific recharge rates for disturbed soils in the model (Tables 3 and 4 and Figures 3 and 4) obtained from
	  ○ PNNL-14702 Rev. 1, Table 4-15, available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14702rev1.pdf.	

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WAC	Requirement			Response
8(b)(vii)	(5)(f)(ii)	**(5)(f)(ii) Calculating or estimating infiltration.** Was equation 747-5 used to calculate the volume of water infiltrating (Q_p)?		**No**

		Explanation:
		• Equation 747-5 was not used. Site-specific measurements of infiltration were applied.
		Justification:
		• Use of site-specific values is permitted under (5)(f)(ii)(B).
		Documented:
		• Chapter 5, Section 5.4.1.1, "Surface Cover, Infiltration, and Recharge"
		• Chapter 5, Table 5-6, "Summary of Selected Primary Fate and Transport Simulation Input Parameters Used with 1D Model Implemented in STOMP Code for Screening Level and Preliminary Remediation Goal Calculations for the 100-NR-1 Operable Unit"
		• Appendix F, SGW-50776 Rev. 3, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 4.4.1 "Flow and Transport Boundary Conditions" presents the range of applicable site-specific recharge rates from
		  ○ PNNL-14702 Rev. 1, Table 4-15, available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14702rev1.pdf.
		• Appendix F, ECF-100NR1-12-0017 Rev. 2, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-NR-1 Source Operable Unit*, Section 3.2.1 "Upper Boundary Conditions" notes the use of 100-Area-specific recharge rates for disturbed soils from
		  ○ PNNL-14702 Rev. 1, Table 4-15, available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14702rev1.pdf.		

8(b)(vii)	(5)(f)(ii)	(A)	(A) If a default annual infiltration value (Inf) was used, the value shall meet the following: (required) • For sites west of the Cascade Mountains, was the default annual infiltration value = 70% of the average annual precipitation amount used? • For sites east of the Cascade Mountains, was the default annual	**N/A**

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WAC	Requirement			Response
			infiltration value = 25% of the average annual precipitation amount used?	

			Explanation:
			• Default infiltration values under (5)(f)(ii)(A) were not used.
			Justification:
			• Use of site-specific values is permitted under (5)(f)(ii)(B).
			Documented:
			• Chapter 5, Section 5.4.1.1, "Surface Cover, Infiltration, and Recharge"
			• Chapter 5, Table 5-6, "Summary of Selected Primary Fate and Transport Simulation Input Parameters Used with 1D Model Implemented in STOMP Code for Screening Level and Preliminary Remediation Goal Calculations for the 100-NR-1 Operable Unit"
			• Appendix F, SGW-50776 Rev. 3, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 4.4.1 "Flow and Transport Boundary Conditions" presents the range of applicable site-specific recharge rates from
			  ○ PNNL-14702 Rev. 1, Table 4-15, available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14702rev1.pdf.
			• Appendix F, ECF-100NR1-12-0017 Rev. 2, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-NR-1 Source Operable Unit*, Section 3.2.1 "Upper Boundary Conditions" notes the use of 100-Area-specific recharge rates for disturbed soils in the model (reference Tables 2 and 3 and Figures 3 and 4 in that section) from
			  ○ PNNL-14702 Rev. 1, Table 4-15, available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14702rev1.pdf.	

8(b)(vii)	(5)(f)(ii)	(B)	(B) If a site-specific measurement or estimate of infiltration (Inf) was made, was it based on	
8(b)(vii)	(5)(f)(ii)	(B)	• Site conditions without surface caps (e.g., pavement) or other structures that would control or impede infiltration?	**Yes**

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WAC			Requirement	Response

			Explanation:
			• Site-specific measurements of infiltration for site surface conditions without surface caps that would impede infiltration were used in the STOMP modeling to derive SSL and PRG values.
			Justification:
			• Reductions in infiltration due to surface caps are not considered; hence, no justification is necessary for this response.
			Documented:
			• Chapter 5, Section 5.4.1.1, "Surface Cover, Infiltration, and Recharge"
			• Chapter 5, Table 5-6, "Summary of Selected Primary Fate and Transport Simulation Input Parameters Used with 1D Model Implemented in STOMP Code for Screening Level and Preliminary Remediation Goal Calculations for the 100-NR-1 Operable Unit"
			• Appendix F, SGW-50776 Rev. 3, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 4.4.1 "Flow and Transport Boundary Conditions" presents the range of applicable site-specific recharge rates from
			  ○ PNNL-14702 Rev. 1, Table 4-15, available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14702rev1.pdf.
			• Appendix F, ECF-100NR1-12-0017 Rev. 2, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-NR-1 Source Operable Units*, Section 3.2.1 "Upper Boundary Conditions" notes the use of 100-Area-specific recharge rates for disturbed soils in the model (Tables 3 and 4 and Figures 3 and 4) from
			  ○ PNNL-14702 Rev. 1, Table 4-15, available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14702rev1.pdf	

8(b)(vii)	(5)(f)(ii)	(B)	• The presence of a cover or cap may be considered when evaluating the protectiveness of a remedy under WAC 173-340-350 through 173-340-360.	**Not Considered**
			Explanation:	

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WAC			Requirement	Response
			• Site-specific measurements of infiltration for site surface conditions without surface caps that would impede infiltration were used in the STOMP modeling to derive SSL and PRG values. Justification: • Reductions in infiltration due to surface caps are not considered; no justification is necessary for this response. Documented: • Appendix F, SGW-50776 Rev. 3, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 4.4.1 "Flow and Transport Boundary Conditions" presents the range of applicable site-specific recharge rates from ○ PNNL-14702 Rev. 1, Table 4-15, available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14702rev1.pdf. • Appendix F, ECF-100NR1-12-0017 Rev. 2, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-NR-1 Source Operable Unit*, Section 3.2.1 "Upper Boundary Conditions" notes the use of 100-Area-specific recharge rates for disturbed soils (Figures 3 and 4) from ○ PNNL-14702 Rev. 1, Table 4-15, available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14702rev1.pdf.	
8(b)(vii)	(5)(f)(ii)	(B)	• If a site-specific measurement or estimate of infiltration is made, did it comply with WAC 173-340-702 (14), (15) and (16)? required) (*requirements of 173-340-702 subsections follow*)	**Yes**
			Explanation: • Infiltration values used were temporally variable, reflecting changing surface conditions under two recharge scenarios. These were the native vegetation recharge scenario, representing the expected future land use (conservation with native shrub steppe vegetation developing over time following closure and revegetation) and the irrigation recharge scenario (representing an irrigated agriculture land use beginning very soon following closure). Justification: • Site-specific measurements of infiltration applicable to disturbed surface soil present in the 100 Areas are used to represent the variability of surface soil types on infiltration rates. Infiltration rates for these surface soil types	

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WAC			Requirement	Response
			under mature shrub steppe conditions that prevailed before Hanford operations commenced (that is, prior to 1944), and that would be prevalent again in the future following site closure with revegetation and a transition period to develop mature shrub steppe, are taken from values reported in PNNL-14702 Rev 1, *Vadose Zone Hydrogeology Data Package for Hanford Assessments*. Successful revegetation programs in the 100 Areas are well documented (WCH-288 Rev. 0; WCH-362 Rev. 0; WCH-428 Rev. 0; WCH-512 Rev. 0; WCH-554 Rev. 0), supporting the recharge scenarios that postulate plant succession for the native vegetation recharge scenario. The recharge rate estimates for natural recharge from PNNL-14702 Rev. 1 do not account for overland flow from roadways or roofs, waterline leaks, or any other anthropogenic recharge sources. The estimates were developed for natural and disturbed soils, and these are composited into the temporally variable recharge scenarios used to develop SSLs (irrigation scenario) and PRGs (native vegetation recharge scenario).DOE-RL/2011-50 Rev. 1 references PNNL-14702 Rev. 1 as a basis for recharge rates appropriate as initial parameter values for modeling of Central Plateau sites. The surface soil types and vegetation patterns present on the Central Plateau are prevalent in the River Corridor, so Hanford Site-specific recharge rates use the same documented basis that are listed above. The prevalence of the same surface soil types, precipitation patterns, and vegetation patterns that control recharge rates are the justification for use of recharge rate estimates derived from measurements collected at multiple sites across the Hanford Site. A range of surface soil types and temporally varying recharge reflecting changing surface conditions are used in the model to capture a range of expected response, with the most conservative result applied for determination of SSLs and PRGs. <u>Documented:</u> • Recharge scenarios and rates are discussed in: ○ Chapter 5, Section 5.4.1.1, "Surface Cover, Infiltration, and Recharge" ○ Chapter 5, Table 5-6, "Summary of Selected Primary Fate and Transport Simulation Input Parameters Used with 1D Model Implemented in STOMP Code for Screening Level and Preliminary Remediation Goal Calculations for the 100-NR-1 Operable Unit" ○ Appendix F, SGW-50776 Rev. 3, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 4.4.1 "Flow and Transport Boundary Conditions" presents the range of applicable site-specific recharge rates from PNNL-14702 Rev. 1. See Tables 4-1 and 4-2 in that report. ○ Appendix F, ECF-100NR1-12-0017 Rev. 2, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-NR-1 Source Operable Units*, Section 3.2.1 "Upper Boundary Conditions" notes the use of 100-Area-specific recharge rates for disturbed soils from PNNL-14702 Rev. 1 in the model. Reference Tables 2 and 3, and Figures 3 and 4, in that section.	

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WAC	Requirement	Response
		• Limitations and uncertainty associated with recharge scenarios and rates are discussed in: ○ Chapter 5, Section 5.9.4 "Uncertainties, Assumptions, and Limitations Specific to Vadose Zone Modeling" ○ Appendix F, SGW-50776 Rev. 3, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 6 "Model Sensitivity and Uncertainty" presents discussion of the modeling conservatism and the results of sensitivity and uncertainty analyses conducted to gain understanding of the important parameters that can affect soil screening level and preliminary remediation goal calculations, including recharge rate considerations. ○ Appendix F, ECF-100NR1-12-0017 Rev. 2, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-NR-1 Source Operable Unit*, Section 3.6 "Uncertainties, Assumptions, and Conservatism" • Revegetation is discussed in: ○ Appendix F, ECF-100NR1-12-0017 Rev. 2, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-NR-1 Source Operable Units*, Section 3.2.1.1 "Native Vegetation Recharge Scenario" discusses revegetation of waste sites in accordance with the DOE/RL-96-32, *Hanford Biological Resources Management Plan*. Documentation of successful revegetation conducted in the 100 Areas is provided in: ▪ WCH-288 Rev. 0, *2008 River Corridor Closure Contractor Revegetation and Mitigation Monitoring Report*. ▪ WCH-352 Rev. 0, 2009 *River Corridor Closure Contractor Revegetation and Mitigation Monitoring Report*. ▪ WCH-428 Rev. 0, *2010 River Corridor Closure Contractor Revegetation and Mitigation Monitoring Report*. ▪ WCH-512 Rev. 0, *2011 River Corridor Closure Contractor Revegetation and Mitigation Monitoring Report*. ▪ WCH-554 Rev. 0, *2012 River Corridor Closure Contractor Revegetation and Mitigation Monitoring Report*.
340-702	**Evaluation criteria.** Proposed fate and transport models, input parameters, and assumptions shall comply with WAC 173-340-702 (14), (15) and (16).	**Yes**

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WAC	Requirement			Response
	See responses to (14), (15), and (16) below.			
340-702	14	**WAC 173-340-702 (14) Burden of proof.** Any person responsible for undertaking a cleanup action under this chapter who proposes to:		
340-702	14	(a)	(a) Use a reasonable maximum exposure scenario other than the default provided for each medium;	**No**
			Explanation: • The default reasonable maximum exposure scenario (WAC 173-340-720-4) was used. Justification: • No justification is necessary for using the default maximum exposure scenario. Documented: • Section 6.3.2.2 "Identify Action Levels"	
340-702	14	(b)	(b) Use assumptions other than the default values provided for in this chapter;	**Yes**
			Explanation: • The following parameter values used in modeling were not default values: ○ Infiltration Rate: Assigned site-specific values for recharge rates (net infiltration). ○ Dilution Factor: The default dilution factor for the three-phase equation (WAC 173-340-747(3)(a)) was not used. Instead, of site-specific hydraulic properties and median site-specific hydraulic gradient were applied in the saturated portion of the model to effectively account for groundwater dilution in the calculation. Justification: • Infiltration Rate: Use of site-specific values is permitted under (5)(f)(ii)(B). • Dilution Factor: If using an alternative fate and transport model (WAC 173-340-747(8)), it is required that dilution "be based on site-specific measurements or estimated using a model incorporating site-specific characteristics."	

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WAC			Requirement	Response
			Documented: • Infiltration Rate ○ Chapter 5, Section 5.4.1.1, "Surface Cover, Infiltration, and Recharge" ○ Chapter 5, Table 5-6, "Summary of Selected Primary Fate and Transport Simulation Input Parameters Used with 1D Model Implemented in STOMP Code for Screening Level and Preliminary Remediation Goal Calculations for the 100-NR-1 Operable Unit" ○ Appendix F, SGW-50776 Rev. 3, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 4.4.1 "Flow and Transport Boundary Conditions" presents the range of applicable site-specific recharge rates from PNNL-14702 Rev. 1. See Tables 4-1 and 4-2 in that report. ○ Appendix F, ECF-100NR1-12-0017 Rev. 2, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-NR-1 Source Operable Units*, Section 3.2.1 "Upper Boundary Conditions" notes the use of 100-Area-specific recharge rates for disturbed soils from PNNL-14702 Rev. 1 in the model. Reference Tables 3 and 4 and Figures 3 and 4 in that section. • Dilution Factor ○ Chapter 5, Section 5.5, "Vadose Zone Modeling Methods and Results" describes the methodology for inclusion of the aquifer in the model domain and direct simulation of dilution as a function of aquifer depth, hydraulic gradient, domain size, and vadose zone leaching. ○ Appendix F, SGW-50776 Rev. 3, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 5.4 "Calculating Dilution Factors" presents and discusses dilution factor calculation in the STOMP modeling. ○ Appendix F, ECF-100NR1-12-0017 Rev. 2, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-NR-1 Source Operable Units*, Section 5.1.3 "Dilution Factor".	
340-702	(4)	(c)	(c) Establish a cleanup level under Method C; or	**No**
			Explanation:	

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WAC			Requirement	Response
			• A cleanup level was not established under Method C; the cleanup level used was beneficial use (drinking water). Justification: • For groundwater, The NCP at 40 C.F.R. § 300.430(a)(1)(iii)(F) states that EPA expects to return usable ground waters to their beneficial uses wherever practicable, within a timeframe that is reasonable given the particular circumstances of the site. The State of Washington defines groundwater as potable in WAC 173 340 720(2), unless the exclusion criteria in WAC 173 340 720(2)(a) through (c) can be demonstrated (insufficient yield, natural constituents that make it unsuitable as a drinking water source). The groundwater beneath the 100 Area does not meet the exclusion criteria; therefore, it is classified by the State as potable. The State of Washington has further determined that the highest beneficial use for potable groundwater, including the potable groundwater at the Hanford Site, is as a potential source of domestic drinking water (WAC 173 340 720(1)(a)). For surface water, the point of compliance is defined in the MTCA, "Surface Water Cleanup Standards" (WAC 173-340-730(7)(a)) as the point or points at which hazardous substances are released to surface waters of the state. MTCA, "Surface Water Cleanup Standards" (WAC 173-340-730(7)(b)) indicates that no mixing zone shall be allowed to demonstrate compliance with surface water cleanup levels. Documented: • Chapter 6, Section 6.3.2.2 "Identify Action Levels" • Appendix G, ECF-100NPL-10-0462, *Calculation of Standard Method B Groundwater Cleanup Levels for Potable Groundwater for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports*.	
340-702	14	(8)	d) Use a conditional point of compliance,	**No**
			Explanation: • The point of compliance is all soil per WAC-173-340-740(6)(b). Note here that the point of calculation referenced in the RI/FS and supporting documentation is the point where groundwater impacts of soil contamination is calculated to derive SSLs and PRGs; it is not the point of compliance itself. Justification: • No justification is necessary for using the prescribed point of compliance. Documented: • Chapter 5, Section 5.6.1 "Identification of Peak Groundwater Concentrations"	

Crosswalk of WAC Requirements (WAC 173-340-747(8), 2007) for Use of Alternative Fate and Transport Modeling to Modeling Basis of Soil Screening Levels and Preliminary Remediation Goals for 100-N Remedial Investigation / Feasibility Study

WAC		Requirement	Response
		• Appendix F, ECF-100NR1-12-0017 Rev. 2, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-NR-1 Source Operable Units*, Section 2.4 "Point of Calculation, Point of Compliance, and Protectiveness Criteria" identifies the point of compliance for SSL and PRG calculation as the WAC required point of compliance: all vadose zone soil.	
340-702	14	shall have the burden of demonstrating to the department that requirements in this chapter have been met to ensure protection of human health and the environment. The department shall only approve of such proposals when it determines that this burden of proof is met.	
340-702	15	**WAC 173-340-702 (15) New scientific information.** Did the proposal to use new scientific information meet the quality of information requirements in (16)? (required) Any proposal to use new scientific information should be introduced as early in the cleanup process as possible. Proposals to use new scientific information may be considered up to the time of issuance of the final cleanup action plan governing the cleanup action for a site unless triggered as part of a periodic review under WAC 173-340-420 or through a reopener under RCW 70.105D.040 (4)(c).	**Yes**
		Explanation: • New scientific information was introduced in the derivation of a site-specific value (specific to the 100 Area of the Hanford Site) of K_d for hexavalent chromium using batch equilibrium tests. Justification: • Ecology approved the batch leach testing with the approval of the D/H SAP DOE/RL-2009-40 Rev 0. Page 2-127 describes the procedure. It was also modified by TPA-CN-368 signed by Ecology on 8/26/2010 to allow for removing the requirement for pH adjustment of demineralized water. Documented: • Appendix F, ECF-HANFORD-11-0165 Rev. 1, *Evaluation of Hexavalent Chromium Leach Test Data Conducted on Vadose Zone Sediment Samples from the 100-Area.*	

Crosswalk of WAC Requirements (WAC 173-340-747(8), 2007) for Use of Alternative Fate and Transport Modeling to Modeling Basis of Soil Screening Levels and Preliminary Remediation Goals for 100-N Remedial Investigation / Feasibility Study

WAC	Requirement				Response
340-702	16	**WAC 173-340-702 (16) Criteria for quality of information.**			
340-702	16	(a)	(a) The intent of this subsection is to establish minimum criteria to be considered when evaluating information used by or submitted to the department proposing to modify the default methods or assumptions specified in this chapter or proposing methods or assumptions not specified in this chapter for calculating cleanup levels and remediation levels. This subsection does not establish a burden of proof or alter the burden of proof provided for elsewhere in this chapter.		
340-702	16	(b)	(b) When evaluating the quality of the information the department shall consider the following factors, as appropriate for the type of information submitted:		
340-702	16	(b)	(i)	(i) Is the information based on a theory or technique that has widespread acceptance within the relevant scientific community?	**Yes**
				Explanation: • The general modeling approach for using the STOMP code to calculate SSLs and PRGs under was proposed and accepted in DOE/RL-2011-50 Rev. 1. This document was noted to "provide justification for the uses of the STOMP code itself, but specific models implemented using the STOMP code require justification in application specific documents". Such information is provided in key supporting documents included in Appendix F of this RI/FS report. Justification: • Use of STOMP as a computational code to implement a numerical model for calculation of SSLs and PRGs under a general approach is justified in DOE/RL-2011-50 Rev. 1. (This justification is limited to STOMP as a computational tool, and does not cover the specific models implemented in STOMP, which must be documented and justified for specific applications.) • As noted by Ecology in their acceptance of DOE/RL-2011-50 Rev. 1, specific applications of this approach and use of STOMP require presentation and justification of model implementation (construction and parameterization) in application-specific documents. This RI/FS constitutes such an application-specific document. The specific conceptual model and parameterization to be implemented in STOMP are presented and justified in the RI/FS, specifically in the model package report SGW-50776 Rev. 3 and in the application of the model to calculate SSLs and PRGs in ECF-100NR1-12-0017 Rev. 2.		

Crosswalk of WAC Requirements (WAC 173-340-747(8), 2007) for Use of Alternative Fate and Transport Modeling to Modeling Basis of Soil Screening Levels and Preliminary Remediation Goals for 100-N Remedial Investigation / Feasibility Study

WAC				Requirement	Response
				Documented: • Chapter 5, Section 5.6, "Groundwater/Surface Water Protection Screening Level and Preliminary Remediation Goal Development" presents an overview of the SSL and PRG modeling approach. • DOE/RL-2011-50 Rev. 1, *Regulatory Basis and Implementation of a Graded Approach to Evaluation of Groundwater Protection*, justifies use of STOMP as a computational code for implementation of numerical models to calculate SSLs and PRGs. • PNNL-12030, *STOMP Subsurface Transport Over Multiple Phases Version 2.0 Theory Guide*, comprehensively documents the available governing and constitutive equations available in the STOMP code. • Appendix F, SGW-50776 Rev. 3, *Model Package Report: Vadose Zone Model for the River Corridor* (in its entirety) presents the basis for the modeling and parameterization of vadose zone models implemented in STOMP for the purpose of calculation of SSL and PRG values. This includes identification of the specific operational mode of STOMP used to implement the model, as well as identification of which STOMP equations are used in this model (in Section 4.1 "Governing Equations"). • Appendix F, ECF-100NR1-12-0017 Rev. 2 (in its entirety) presents details on the application of STOMP to calculate SSL and PRG values.	
340-702	16	(b)	(ii)	(ii) Is the information derived using standard testing methods or other widely accepted scientific methods?	**Yes**
				Explanation: • Batch leach test data used to derive a 100 Area specific K_d value for hexavalent chromium. Site-specific recharge rates were taken from scientific literature. Justification: • Batch leach test data were collected and submitted for leaching using ASTM D3987-06, *Standard Test Method for Shake Extraction of Solid Waste with Water*. Documented: • Soil Leaching Data: ○ Appendix F, ECF-HANFORD-11-0165 Rev. 1, *Evaluation of Hexavalent Chromium Leach Test*	

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WAC				Requirement	Response
				Data Conducted on Vadose Zone Sediment Samples from the 100-Area. • Recharge Rates: ○ Appendix F, SGW-50776 Rev. 3, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 3.2.2 "Recharge and Evapotranspiration", Section 4.4.1 "Flow and Transport Boundary Conditions", and Section 6.2.2 "Sensitivity to Long Term Recharge" ○ Appendix F, ECF-100NR1-12-0017, *STOMP 1-D Modeling for Determination of Preliminary Remediation Goals for 100-NR-1 Source Operable Unit*, Section 3.2.1 "Upper Boundary Conditions" which references these sources of site-specific recharge rates: ▪ PNNL-14702 Rev. 1, *Vadose Zone Hydrogeology Data Package for Hanford Assessments* (available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14702rev1.pdf) cites scientific data noted above in response to WAC requirement 8(b)(vii). ▪ PNNL-17841, *Compendium of Data for the Hanford Site (Fiscal Years 2004 to 2008) Applicable to Estimation of Recharge Rates* (available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-17841.pdf) provides additional scientific basis for recharge rate measurements.	
340-702	16	(b)	(iii)	(iii) Has a review of relevant available information, both in support of and not in support of the proposed modification, been provided along with the rationale explaining the reasons for the proposed modification?	**Yes**
				Explanation: • A conservative basis was selected for deriving a K_d value for hexavalent chromium through use of a 90 percent likelihood that actual values for residual hexavalent chromium contamination would exhibit a greater sorptive value. Justification: • This basis represents a conservative value for sorption of residual hexavalent chromium in the vadose zone. This assumption is not applicable to the mobile fraction of hexavalent chromium that has already migrated to groundwater.	

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WAC				Requirement	Response
				Documented: • Appendix F, ECF-HANFORD-11-0165 Rev. 1, *Evaluation of Hexavalent Chromium Leach Test Data Conducted on Vadose Zone Sediment Samples from the 100-Area* (in its entirety)	
				Explanation: • Batch leach test data used to derive a 100 Area specific K_d value for hexavalent chromium. Site-specific recharge rates were taken from scientific literature. Justification: • Batch leach test data were collected and submitted for leaching using ASTM D3987-06, *Standard Test Method for Shake Extraction of Solid Waste with Water*. Documented: • Soil Leaching Data: ○ Appendix F, ECF-HANFORD-11-0165 Rev. 1, *Evaluation of Hexavalent Chromium Leach Test Data Conducted on Vadose Zone Sediment Samples from the 100-Area.* • Recharge Rates: ○ Appendix F, SGW-50776 Rev. 3, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 3.2.2 "Recharge and Evapotranspiration", Section 4.4.1 "Flow and Transport Boundary Conditions", and Section 6.2.2 "Sensitivity to Long Term Recharge" ○ Appendix F, ECF-100NR1-12-0017, *STOMP 1-D Modeling for Determination of Preliminary Remediation Goals for 100-NR-1 Source Operable Unit*, Section 3.2.1 "Upper Boundary Conditions" which references these sources of site-specific recharge rates: ▪ PNNL-14702 Rev. 1, *Vadose Zone Hydrogeology Data Package for Hanford Assessments* (available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14702rev1.pdf) cites scientific data noted above in response to WAC requirement 8(b)(vii). ▪ PNNL-17841, *Compendium of Data for the Hanford Site (Fiscal Years 2004 to 2008) Applicable to Estimation of Recharge Rates* (available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-17841.pdf)	

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WAC				Requirement	Response
				provides additional scientific basis for recharge rate measurements.	
340-702	16	(b)	(iv)	(iv) Are the assumptions used in applying the information to the facility valid and would they ensure the proposed modification would err on behalf of human health and the environment?	**Yes**
				Explanation: • The modeling approach applied conservative assumptions, with respect to SSLs and PRGs, to structure and parameterization of the model, where uncertainty existed, to achieve this standard. Conservative assumptions include (not are not limited to): ○ The point of calculation is assumed to at the waste site boundary on the downstream side of the waste site, ○ Contaminant source is assumed to span a large portion of the vadose zone (100% of the vadose zone for mobile and somewhat immobile contaminants; upper 70% for less mobile contaminants except strontium-90), and ○ No credit is taken for natural degradation, air-phase partitioning, or hydrodynamic dispersion. Discussion of the limitations and uncertainty in the model and parameterization are provided. Other examples of conservatism include: ○ Application of irrigation for the irrigation recharge scenario starting less than five years after remedial action (when presumably institutional controls would delay this by decades; resulting in conservatism because higher recharge mobilizes and transports contaminants sooner and faster with higher peak groundwater concentrations and hence lower PRG values); ○ Derivation of stratigraphic profiles for the model at maximum water table (conservative because this minimizes transport distance in the vadose zone, resulting in earlier and higher peak concentrations); and ○ Assumption of uniform contamination in the vadose zone at the peak level (100:0 and 70:30 rules, depending on contaminant mobility) which is conservative because it brackets, and likely overestimates, the amount of contaminant mass present. These examples are not an exhaustive list of the conservatisms present in the alternative fate and transport model used for SSL and PRG development; full discussion is provided in model uncertainty and limitations discussions in Chapter 5 and the supporting environmental calculation files.	

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WAC				Requirement	Response
				Conservatism in the initial concentration distribution was validated to determine whether site-specific modeling was required. A more conservative approach was applied to simulate strontium-90 with a 100:0 distribution, despite its lower mobility under present day transport conditions, in recognition of its current distribution in the deep subsurface environment as a result of past discharge conditions for that constituent. • Dilution factors were treated with representative, site-specific parameter values rather than conservative assumptions. 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 [WAC 173-340-747(3)]. 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. • Only the upper 5 m of the aquifer is used to represent aquifer thickness; the actual saturated thickness is greater than 5 m in all 100-N waste site locations for this evaluation. Justification: • Uncertainty is consistently addressed through use of conservative assumptions and parameterization. Documented: • Point of Calculation: ○ Chapter 5, Section 5.9.4 "Uncertainties, Assumptions, and Limitations Specific to Vadose Modeling" ○ Appendix F, ECF-100NR1-12-0017 Rev. 2, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-NR-1 Source Operable Unit*, Section 2.4 "Point of Calculation, Point of Compliance, and Protectiveness Criteria" • Contaminant Initial Source Representation: ○ Chapter 5, Section 5.5.1 "Initial Contaminant Distribution" ○ For all COPCs except Strontium-90; Appendix F, ECF-100NR1-12-0017 Rev. 2, *STOMP 1-D*	

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WAC	Requirement				Response
				Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-NR-1 Source Operable Unit, Section 3.2.4 "Initial Conditions" ○ For Strontium-90; Appendix F, ECF-100NR1-12-0056 Rev. 1, *Vadose Zone Transport Modeling to Calculate Strontium-90 Flux to Groundwater and Preliminary Remediation Goal in Support of the 100-N Remedial Investigation/Feasibility Study*, Section 4.4, "Initial Conditions" • No credit taken for natural degradation, air-phase partitioning, or dispersion: ○ Appendix F, ECF-100NR1-12-0017 Rev. 2, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-NR-1 Source Operable Unit*, Section 3.4 "Contaminant Transport Parameters" • Model Uncertainties: ○ Appendix F, ECF-100NR1-12-0017 Rev. 2, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-NR-1 Source Operable Unit*, Section 3.6 "Uncertainties, Assumptions, and Conservatism" • Dilution Factor: ○ Appendix F, ECF-100NR1-12-0017 Rev. 2, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-NR-1 Source Operable Unit*, Section 5.3 "Dilution Factor" • Aquifer Thickness Representation: ○ Appendix F, ECF-100NR1-12-0017 Rev. 2, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-NR-1 Source Operable Unit*, Section 3.2.3 "Lateral Boundary Conditions"	
340-702	16	(b)	(v)	(v) Does the information adequately address populations that are more highly exposed than the population as a whole and are reasonably likely to be present at the site? And	**No**
				Explanation: • No cleanup levels are developed for sensitive subpopulations. However, Native American risk	

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WAC				Requirement	Response
				assessments are prepared and presented. Justification: • Reasonable maximum exposure assumptions are based on exposure scenarios used to derive regulatory standards, and therefore assumed protective of all populations and adequate to restore the resource to beneficial use. Documented: • Chapter 6, Sections 6.1.4 "Other Residential Land Use Scenarios in RCBRA" • Chapter 6, Section 6.3.8.5.1 "Uncertainties Associated with the Native American Risk Assessments" • Appendix G, ECF-100NR2-12-0024 Rev. 0, *Native American Risk Assessment for the 100-NR-2 Groundwater Operable Unit* (in its entirety)	
340-702	15	(b)	(vi)	(vi) • Has adequate quality assurance and quality control procedures been used? • Are any significant anomalies adequately explained? • Are the limitations of the information identified? and Is the known or potential rate of error is acceptable?	**Yes**
				Explanation: • Quality assurance for use of modeling to develop SSL and PRG values was performed following EPA guidance (EPA/240/R-02/007, EPA QA/G-5M, *Guidance for Quality Assurance Project Plans for Modeling*). Requirements addressed modeler training, software and model documentation and configuration control, model application checking, and controlled software use in the preparation of calculations using STOMP to derive SSL and PRG values. No significant anomalies were found during implementation of the STOMP model. The limitations of the alternative fate and transport modeling used to derive SSL and PRG values are identified. The STOMP code solves the numerical equations to a defined level of precision; hence, effectively any error would be associated with model uncertainties, scenario uncertainties, and parameter uncertainties. Judicious use of conservatism is made in the development of the model, scenarios, and parameterization to ensure that errors are biased in a conservative direction relative to protection of surface water and groundwater. That is, conservatism	

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WAC	Requirement	Response

	with regard to these areas where uncertainty in the model exists is used to cause calculated SSL and PRG values to be lower than would be calculated with reduced uncertainty and/or with less conservative bias in model development. Quality assurance for use of software used to implement the model was performed in accordance with the requirements of DOE Order 414.1, *Quality Assurance*, which imposes NQA-1 standards on software use. The STOMP software was tested and qualified before use for modeling under procedures that implement the requirements of DOE Order 414.1 and guidance of NQA-1.
	
	Justification:
	
	• Approved quality assurance plans and procedures written to meet the requirements of DOE and the guidance of the EPA were adhered to throughout the modeling process. All aspects required under this WAC requirement were included in the RI/FS documentation. Limitations of the model are discussed in the primary categories of (1) model uncertainties, (2) scenario uncertainties, and (3) parameter uncertainties.
	
	Documented:
	
	• Demonstration of quality assurance and quality control procedure use:
	  ○ Appendix F, ECF-100NR1-12-0017 Rev. 2, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-NR-1 Source Operable Unit* (in its entirety) and Appendix F, ECF-100NR1-12-0056 Rev. 1, *Vadose Zone Transport Modeling to Calculate Strontium-90 Flux to Groundwater and Preliminary Remediation Goal in Support of the 100-N Remedial Investigation/Feasibility Study* provide demonstration of documentation of model application in compliance with a plan that followed the guidance provided in
	  ○ EPA/240/R-02/007, EPA QA/G-5M, *Guidance for Quality Assurance Project Plans for Modeling*
	
	• Appendix F, ECF-100NR1-12-0017 Rev. 2, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-NR-1 Source Operable Unit*, Section 4 " Software Applications" and Appendix F, ECF-100NR1-12-0056 Rev. 1, *Vadose Zone Transport Modeling to Calculate Strontium-90 Flux to Groundwater and Preliminary Remediation Goal in Support of the 100-N Remedial Investigation/Feasibility Study*, Section 4 "Software Applications" demonstrate controlled software use under an approved quality assurance process in compliance with implementing procedures compliant with	

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WAC	Requirement				Response
				○ DOE O 414.1D, *Quality Assurance* • Signatures of the checker and senior reviewer on cover sheets of Appendix F, ECF-100NR1-12-0017 Rev. 2, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-NR-1 Source Operable Unit,* and Appendix F, ECF-100NR1-12-0056 Rev. 1, *Vadose Zone Transport Modeling to Calculate Strontium-90 Flux to Groundwater and Preliminary Remediation Goal in Support of the 100-N Remedial Investigation/Feasibility Study,* validate completion of independent review and checking of model application as required under an approved quality assurance procedure governing preparation of environmental calculations. Limitations of the information identified, and known or potential error rate: • Chapter 5, Section 5.9 "Uncertainties that Apply to Groundwater and Vadose Zone Modeling" • Appendix F, SGW-50776 Rev. 3, *Model Package Report: Vadose Zone Model for the River Corridor*, Section 6.1 "Modeling Conservatisms", Section 6.2 "Sensitivity Analyses", and Section 6.3 "Uncertainty Analyses" • Appendix F, ECF-100NR1-12-0017 Rev. 2, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-NR-1 Source Operable Unit*, Section 3.6 "Uncertainties, Assumptions, and Conservatism"	

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Attachment B

Soil Screening Levels Protective of Groundwater and Soil Screening Levels Protective of Surface Water for the 100-NR-1 Operable Unit

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Note

Tabulated soil screening level (SSL) values are presented in Tables B-1, B-2, and B-3 in ascending K_d order. This sorting order reveals the correlation between analyte K_d values and resulting SSL values. The threshold at which breakthrough does not occurs is denoted by a bold red borderline within these tables. Below this threshold, "NR" (non-representative result) values are reported (though shorter-lived radionuclides may result in "NR" values above the indicated threshold due to radiological decay). The "NR" code reflects that the model simulations did not predict breakthrough within 1000 years, defined here as a peak groundwater concentration exceeding 0.0001 µg/L for non-radionuclide analytes, or 0.0001 pCi/m^3 for radionuclide analytes), a value set as the lower limit of numerical significance for model groundwater concentration results.

The same SSL values are presented again in Tables B-4, B-5, and B-6, but in ascending analyte name order to enable lookup by the reader by analyte name.

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Table B-1. Soil Screening Levels Protective of Groundwater for Non-radionuclides in the 100-NR-1 Operable Unit (K_d order)

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)	Soil Screening Level Protective of Groundwater [c,d] (mg/kg·m)
16887-00-6	Chloride	chloride	0	250,000	2.00E+00	2.90E+03
14797-55-8	Nitrate	Nitrate	0	45,000	2.50E+00	5.22E+02
14797-65-0	Nitrite	Nitrite	0	3,300	2.50E+00	3.83E+01
NO3-N	Nitrogen in Nitrate	Nitrogen in Nitrate	0	10,000	7.50E-01	1.16E+02
NO2-N	Nitrogen in Nitrite	Nitrogen in Nitrite	0	1,000	7.50E-01	1.16E+01
NO2+NO3-N	Nitrogen in Nitrite and Nitrate	Nitrogen in Nitrite and Nitrate	0	10,000	---	1.16E+02
14808-79-8	Sulfate	sulfate	0	250,000	5.00E+00	2.90E+03
51-28-5	2,4-Dinitrophenol	dinitrophenol;2,4-	0.00001	0,032	8.25E-01	8.25E-01
67-64-1	Acetone	Acetone	0.0006	7200	2.00E-02	8.44E+01
111-76-2	2-Butoxyethanol	ethylene glycol monobutyl ether (EGBE)	0.0028	800	---	9.78E+00
75-99-0	Dalapon	Dalapon	0.0032	200	---	2.46E+00
78-93-3	2-Butanone	methyl ethyl ketone (MEK; 2-butanone)	0.0045	4800.0	1.00E-02	6.06E+01
74-87-3	Chloromethane	chloromethane	0.0060	--	1.00E-02	NA
74-83-9	Bromomethane	bromomethane	0.0090	11.2	1.00E-02	1.53E-01
75-09-2	Methylene chloride	methylene chloride	0.0100	5.00	5.00E-03	6.94E-02
108-10-1	4-Methyl-2-pentanone	methyl isobutyl ketone	0.0126	640.00	1.00E-02	9.32E+00
111-91-1	Bis(2-Chloroethoxy)methane	bis(2-chloroethoxyl)methane	0.0144	48	3.30E-01	7.10E-01
591-78-6	2-Hexanone	HEXANONE;2-[MBK, methyl butyl ketone]	0.0150	0,040	2.00E-02	6.01E-01
75-01-4	Vinyl chloride	vinyl chloride [chloroethene; 1-]	0.0186	0.060763889	5.00E-03	5.00E-03
75-00-3	Chloroethane	ethyl chloride	0.0217	--	1.00E-02	NA
621-64-7	n-Nitrosodi-n-dipropylamine	nitroso-di-n-propylamine;N-	0.0240	0.01	3.30E-01	3.30E-01
10061-01-5	cis-1,3-Dichloropropene	dichloropropene;1,2-,cis	0.0270	0	5.00E-03	7.80E-03
10061-02-6	trans-1,3-Dichloropropene	dichloropropene;1,3-,trans	0.0270	0	5.00E-03	7.80E-03
1918-00-9	Dicamba	Dicamba	0.0288	480	---	8.78E+00
108-95-2	Phenol	Phenol	0.0288	2,400	3.30E-01	4.39E+01
131-11-3	Dimethyl phthalate	dimethyl phthalate	0.0316	--	3.30E-01	NA
156-59-2	cis-1,2-Dichloroethylene	dichloroethylene;1,2-,cis	0.0355	16.0	5.00E-03	3.19E-01
107-06-2	1,2-Dichloroethane	dichloroethane;1,2-	0.0380	0.5	5.00E-03	9.81E-03
156-60-5	trans-1,2-Dichloroethylene	dichloroethylene;1,2-,trans	0.0380	100.0	5.00E-03	2.04E+00
1918-02-1	4-Amino-3,5,6-trichloropicolinic acid	picloram	0.0388	500.00	---	1.03E+01
540-59-0	1,2-Dichloroethene (Total)	dichloroethylene,1,2- (mixed isomers)	0.0396	72.00	5.00E-03	1.50E+00
75-69-4	Trichloromonofluoromethane	trichlorofluoromethane	0.0439	2400.00	---	5.23E+01
75-15-0	Carbon disulfide	carbon disulfide	0.0457	800.0	5.00E-03	1.78E+01
78-59-1	Isophorone	isophorone	0.0468	46.05	3.30E-01	1.04E+00
78-87-5	1,2-Dichloropropane	dichloropropane;1,2-	0.0470	1	5.00E-03	2.74E-02
93-65-2	2-(2-methyl-4-chlorophenoxy) propionic acid	Mecoprop (MCPP)	0.0485	16.000	2.10E+00	2.10E+00
75-34-3	1,1-Dichloroethane	dichloroethane;1,1-	0.0530	7.68	1.00E-02	1.84E-01
67-66-3	Chloroform	chloroform	0.0530	0,001	5.00E-03	3.38E-02
75-27-4	Bromodichloromethane	bromodichloromethane	0.0550	0.71	5.00E-03	1.72E-02
71-43-2	Benzene	Benzene	0.0620	1	5.00E-03	2.07E-02

Table B-1. Soil Screening Levels Protective of Groundwater for Non-radionuclides in the 100-NR-1 Operable Unit (K_d order)

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)	Soil Screening Level Protective of Groundwater [c,d] (mg/kg·m)
124-48-1	Dibromochloromethane	chlorodibromomethane [dibromochloromethane]	0.0631	0.52	5.00E-03	1.37E-02
75-35-4	1,1-Dichloroethene	Dichloroethene;1,1-	0.0650	7.00	1.00E-02	1.88E-01
106-47-8	4-Chloroaniline	chloroaniline;p-	0.0661	0.2	3.30E-01	3.30E-01
606-20-2	2,6-Dinitrotoluene	dinitrotoluene;2,6-	0.0692	16.0	3.30E-01	4.45E-01
79-00-5	1,1,2-Trichloroethane	trichloroethane;1,1,2-	0.0750	1	5.00E-03	2.24E-02
111-44-4	Bis(2-chloroethyl) ether	bis(2-chloroethyl)ether	0.0760	0	3.30E-01	3.30E-01
79-34-5	1,1,2,2-Tetrachloroethane	tetrachloroethane;1,1,2,2-	0.0790	0.2	5.00E-03	6.59E-03
84-66-2	Diethylphthalate	diethyl phthalate	0.0820	12800	3.30E-01	3.95E+02
108-60-1	Bis(2-chloro-1-methylethyl)ether	bis(2-chloro-1-methyl-ethyl)ether	0.0829	1	3.30E-01	3.30E-01
95-48-7	2-Methylphenol (cresol, o-)	cresol;o-	0.0912	400	3.30E-01	1.32E+01
79-01-6	Trichloroethene	trichloroethylene (TCE)	0.0940	0.95	5.00E-03	3.20E-02
121-14-2	2,4-Dinitrotoluene	dinitrotoluene;2,4-	0.0955	0,000	3.30E-01	3.30E-01
94-82-6	2,4-DB(4-(2,4-Dichlorophenoxy)butanoic acid)	Dichlorophenoxy)butyric Acid, 4-(2,4-	0.0984	128.0	1.30E-02	4.45E+00
99-09-2	3-Nitroaniline	nitroaniline, 3-	0.1090	4	3.30E-01	3.30E-01
100-01-6	4-Nitroaniline	nitroaniline, 4-	0.1091	0,004	3.30E-01	3.30E-01
88-74-4	2-Nitroaniline	nitroaniline, 2-	0.1113	0,160	3.30E-01	6.05E+00
98-95-3	Nitrobenzene	Nitrobenzene	0.1190	16.0	3.30E-01	6.34E-01
75-25-2	Bromoform	bromoform	0.1260	5.537974684	5.00E-03	2.29E-01
71-55-6	1,1,1-Trichloroethane	Trichloroethane;1,1,1-	0.1350	200	5.00E-03	8.69E+00
108-88-3	Toluene	Toluene	0.1400	640	5.00E-03	2.86E+01
120-83-2	2,4-Dichlorophenol	dichlorophenol;2,4-	0.1470	24	3.30E-01	1.11E+00
56-23-5	Carbon tetrachloride	carbon tetrachloride	0.1520	1	5.00E-03	2.97E-02
108-38-3	m-Xylene	Xylene, m-	0.1960	1600	---	9.35E+01
100-41-4	Ethylbenzene	ethylbenzene	0.2040	0,004	5.00E-03	2.41E-01
105-67-9	2,4-Dimethylphenol	dimethylphenol;2,4-	0.2090	160.00	3.30E-01	9.88E+00
108-90-7	Chlorobenzene	chlorobenzene	0.2240	100.0	5.00E-03	6.56E+00
1330-20-7	Xylenes (total)	Xylenes (total)	0.2330	1600.00	1.00E-02	1.09E+02
95-47-6	o-Xylene	xylene,o-	0.2410	1600.0	---	1.12E+02
127-18-4	Tetrachloroethene	tetrachloroethylene	0.2650	5	5.00E-03	3.81E-01
100-02-7	4-Nitrophenol	nitrophenol;4-	0.2910	--	6.60E-01	NA
88-75-5	2-Nitrophenol	nitrophenol;2-	0.30	--	6.60E-01	NA
106-44-5	4-Methylphenol (cresol, p-)	cresol;p-	0.30	800	---	6.82E+01
541-73-1	1,3-Dichlorobenzene	dichlorobenzene;1,3	0.38	--	3.30E-01	NA
95-50-1	1,2-Dichlorobenzene	dichlorobenzene;1,2- (ortho-Dichlorobenzene)	0.38	0,600	3.30E-01	6.33E+01
88-06-2	2,4,6-Trichlorophenol	Trichlorophenol2,4,6-	0.38	4	3.30E-01	4.22E-01
95-57-8	2-Chlorophenol	Chlorophenol;2-	0.39	40.0	3.30E-01	4.31E+00
59-50-7	4-Chloro-3-methylphenol	chloro-3-methylphenol;4-	0.49	1600.000	3.30E-01	2.16E+02
87-86-5	Pentachlorophenol	pentachlorophenol	0.59	0.2	3.30E-01	3.30E-01
106-46-7	1,4-Dichlorobenzene	dichlorobenzene;1,4- (para-Dichlorobenzene)	0.62	8	5.00E-03	1.35E+00
91-94-1	3,3'-Dichlorobenzidine	dichlorobenzidine;3,3'-	0.72	0.194	3.30E-01	3.30E-01

Table B-1. Soil Screening Levels Protective of Groundwater for Non-radionuclides in the 100-NR-1 Operable Unit (K_d order)

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)	Soil Screening Level Protective of Groundwater [c,d] (mg/kg·m)
534-52-1	4,6-Dinitro-2-methylphenol	dinitro-2-methylphenol;4,6-	0.75	1.3	3.30E-01	3.30E-01
18540-29-9	Hexavalent Chromium	chromium(VI)	0.80	48	---	6 [e]
100-42-5	Styrene	styrene	0.91	100	5.00E-03	2.42E+01
91-20-3	Naphthalene	naphthalene	1.19	160	1.00E-01	4.99E+01
86-30-6	n-Nitrosodiphenylamine	nitrosodiphenylamine;N-	1.29	0,018	3.30E-01	6.02E+00
58-89-9	Gamma-BHC (Lindane)	lindane [gamma-BHC] (see hexachlorocyclohexane)	1.35	0.079545455	1.65E-03	2.80E-02
84-74-2	Di-n-butylphthalate	di-butyl phthalate	1.57	1600	3.30E-01	6.53E+02
95-95-4	2,4,5-Trichlorophenol	Trichlorophenol;2,4,5-	1.60	800	3.30E-01	3.32E+02
120-82-1	1,2,4-Trichlorobenzene	trichlorobenzene;1,2,4-	1.66	1.5	3.30E-01	6.50E-01
319-84-6	Alpha-BHC	hexachlorocyclohexane;alpha (alpha-BHC, HCH)	1.76	0.013888889	1.65E-03	6.33E-03
67-72-1	Hexachloroethane	hexachloroethane	1.78	1.09375	3.30E-01	5.04E-01
959-98-8	Endosulfan I	Endosulfan I	2.04	96	1.65E-03	5.14E+01
33213-65-9	Endosulfan II	Endosulfan II	2.04	96	3.30E-03	5.14E+01
319-85-7	beta-1,2,3,4,5,6-Hexachlorocyclohexane (beta-BHC)	hexachlorocyclohexane;beta-	2.14	0.048611111	1.65E-03	2.73E-02
126-73-8	Tributyl phosphate	Tributyl phosphate	2.35	10	---	5.97E+00
91-58-7	2-Chloronaphthalene	beta-chloronaphthalene	2.48	640	3.30E-01	4.14E+02
91-57-6	2-Methylnaphthalene	methylnapthalene;2-	2.48	32	3.30E-01	2.07E+01
319-86-8	Delta-BHC	hexachlorocyclohexane;delta-	2.81	--	1.65E-03	NA
7440-42-8	Boron	Boron	3.00	3200.0	2.00E+00	2.50E+03
101-55-3	4-Bromophenylphenyl ether	bromodiphenyl ether;4-	3.08	--	3.30E-01	NA
7005-72-3	4-Chlorophenylphenyl ether	chlorodiphenyl ether;4-	3.08	--	3.30E-01	NA
7421-93-4	Endrin aldehyde	Endrin aldehyde	3.27	--	3.30E-03	NA
86-74-8	Carbazole	carbazole	3.39	4.375	3.30E-01	3.85E+00
7723-14-0	Phosphorus	phosphorus	3.50	--	5.00E+01	NA
PO4-P	Phosphorus in phosphate	Phosphorus in phosphate	3.50	--	---	NA
TPHDIESEL	Total petroleum hydrocarbons - diesel range	Total petroleum hydrocarbons - diesel range	4.00	500	---	5.18E+02
TPH/OILH	Total petroleum hydrocarbons - motor oil (high boiling)	Total petroleum hydrocarbons - motor oil (high boiling)	4.00	500.0	---	5.18E+02
88-85-7	Dinoseb(2-secButyl-4,6-dinitrophenol)	Dinoseb	4.29	7	1.50E-03	7.78E+00
7439-95-4	Magnesium	Magnesium (Not in CLARC database Tables)	4.50	--	7.50E+01	NA
83-32-9	Acenaphthene	acenaphthene	4.90	480	1.00E-01	6.16E+02
7782-49-2	Selenium	selenium and compounds	5.00	50	1.00E+00	6.57E+01
208-96-8	Acenaphthylene	acenaphthylene (Not in CLARC database tables; use acenaphthene as surrogate)	5.03	--	1.00E-01	NA
7440-09-7	Potassium	Potassium	5.50	--	4.00E+02	NA

Table B-1. Soil Screening Levels Protective of Groundwater for Non-radionuclides in the 100-NR-1 Operable Unit (K_d order)

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)	Soil Screening Level Protective of Groundwater [c,d] (mg/kg·m)
7440-43-9	Cadmium	cadmium	6.70	5.0000	2.00E-01	1.07E+01
86-73-7	Fluorene	fluorene	7.7	320.000	3.00E-02	1.07E+03
7440-22-4	Silver	silver	8.3	0,080	2.00E-01	3.64E+02
11104-28-2	Aroclor-1221	aroclor 1221 [PCB]	8.4	0,000	1.65E-02	1.05E-01
11141-16-5	Aroclor-1232	aroclor 1232 [PCB]	8.4	0.0	1.65E-02	1.05E-01
132-64-9	Dibenzofuran	dibenzofuran	9.2	8.0	3.30E-01	6.02E+01
76-44-8	Heptachlor	heptachlor	9.5	0.02	1.65E-03	1.84E-01
53494-70-5	Endrin ketone	Endrin ketone	9.7	--	3.30E-03	NA
1031-07-8	Endosulfan sulfate	Endosulfan sulfate	9.9	--	3.30E-03	NA
57-12-5	Cyanide	cyanide	9.9	4.80	---	5.78E+01
72-20-8	Endrin	endrin	10.8	2.00	3.30E-03	4.41E+01
85-68-7	Butylbenzylphthalate	butyl benzyl phthalate	13.8	46.1	3.30E-01	8.52E+03
85-01-8	Phenanthrene	Phenanthrene	16.7	--	5.00E-02	NA
7439-98-7	Molybdenum	molybdenum	20.0	0,080	2.00E+00	3.89E+05
7440-50-8	Copper	copper	22.0	640	1.00E+00	3.89E+05
120-12-7	Anthracene	anthracene	23.5	2400	5.00E-02	NR
7439-89-6	Iron	Iron	25.0	11200	5.00E+00	NR
60-57-1	Dieldrin	dieldrin	25.6	0.01	3.30E-03	NR
7440-38-2	Arsenic	arsenic, inorganic	29.0	0.058	1.00E+00	NR
7440-24-6	Strontium	strontium	35.0	9600.000	1.00E+00	NR
7440-39-3	Barium	Barium	41.0	2000.000	5.00E-01	NR
7440-36-0	Antimony	antimony	45.0	6	6.00E-01	NR
7440-48-4	cobalt	Cobalt	45.0	4.8000	2.00E+00	NR
72-54-8	4,4'-DDD (Dichlorodiphenyldichloroethane)	ddd	45.8	0.36	3.30E-03	NR
309-00-2	Aldrin	aldrin	48.7	0.003	1.65E-03	NR
206-44-0	Fluoranthene	fluoranthene	49	640	5.00E-02	NR
5103-71-9	Alpha-Chlordane	Alpha-Chlordane	51	0.25	1.65E-02	NR
57-74-9	Chlordane	chlordane	51	0.3	1.65E-02	NR
7439-97-6	Mercury	mercury (using mercruric chloride)	52	2.000	---	NR
87-68-3	Hexachlorobutadiene	hexachlorobutadiene	54	1	3.30E-01	NR
7440-66-6	Zinc	zinc	62	4800	1.00E+00	NR
7439-96-5	Manganese	manganese	65	0,384	5.00E+00	NR
7440-02-0	Nickel	nickel soluble salts	65	100	4.00E+00	NR
129-00-0	Pyrene	pyrene	68	240.00	5.00E-02	NR
7440-28-0	Thallium	Thallium, soluble salts	71	0.2	5.00E-01	NR
12672-29-6	Aroclor-1248	aroclor 1248 [PCB]	77	0	1.65E-02	NR
53469-21-9	Aroclor-1242	aroclor 1242 [PCB]	78	0.04	1.65E-02	NR
118-74-1	Hexachlorobenzene	hexachlorobenzene	80	0.1	3.30E-01	NR
72-43-5	Methoxychlor	methoxychlor	80	40.000	1.65E-02	NR
1024-57-3	Heptachlor epoxide	Heptachlor epoxide	83	0.005	1.65E-03	NR
72-55-9	4,4'-DDE (Dichlorodiphenyldichloroethylene)	dde	86	0	3.30E-03	NR
8001-35-2	Toxaphene	toxaphene	96	0	1.65E-01	NR
7440-23-5	Sodium	Sodium	100	--	5.00E+01	NA
12674-11-2	Aroclor-1016	aroclor 1016 (PCB)	107	0.50	1.65E-02	NR
117-81-7	Bis(2-ethylhexyl) phthalate	bis(2-ethylhexyl) phthalate	111	0,006	3.30E-01	NR
11097-69-1	Aroclor-1254	aroclor 1254 (PCB)	131	0.04	1.65E-02	NR

Table B-1. Soil Screening Levels Protective of Groundwater for Non-radionuclides in the 100-NR-1 Operable Unit (K_d order)

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)	Soil Screening Level Protective of Groundwater [c,d] (mg/kg·m)
16984-48-8	Fluoride	fluoride (using fluorine)	150	960	5.00E+00	NR
77-47-4	Hexachlorocyclopentadiene	hexachlorocyclopentadiene	200	48.00	3.30E-01	NR
7440-31-5	Tin	tin	250	9600	1.00E+01	NR
7439-93-2	Lithium	Lithium	300	32	2.50E+00	NR
56-55-3	Benzo(a)anthracene	Benzo(a)anthracene	358	0.119863014	1.50E-02	NR
218-01-9	chrysene	Chrysene	398	1.198630137	1.00E-01	NR
7440-61-1	Uranium	Uranium	NVR [f]	30	---	NVR [f]
50-29-3	4,4'-DDT (Dichlorodiphenyltrichloroethane)	ddt	678	0.257352941	3.30E-03	NR
7440-41-7	Beryllium	beryllium	790	4	2.00E-01	NR
11096-82-5	Aroclor-1260	aroclor 1260 (PCB)	822	0.04375	1.65E-02	NR
50-32-8	Benzo(a)pyrene	Benzo(a)pyrene	969	0.011986301	1.50E-02	NR
7440-47-3	Chromium	chromium (total)	1000	100	2.00E-01	NR
7440-62-2	Vanadium	vanadium	1000	80	2.50E+00	NR
205-99-2	Benzo(b)fluoranthene	Benzo(b)fluoranthene	1230	0.119863014	1.50E-02	NR
207-08-9	Benzo(k)fluoranthene	Benzo(k)fluoranthene	1230	0.119863014	1.50E-02	NR
7429-90-5	Aluminum	Aluminum (soluble)	1500	16000	5.00E+00	NR
53-70-3	Dibenz[a,h]anthracene	Dibenz[a,h]anthracene	1789	0.119863014	3.00E-02	NR
191-24-2	Benzo(ghi)perylene	BENZO(g,h,i)PERYLENE (using pyrene as a surrogate)	1950	--	3.00E-02	NA
193-39-5	Indeno(1,2,3-cd)pyrene	Indeno(1,2,3-cd)pyrene	3470	0.119863014	3.00E-02	NR
7439-92-1	Lead	lead	10000	15	5.00E-01	NR
117-84-0	Di-n-octylphthalate	di-n-octyl phthalate	83200	192	3.30E-01	NR
65794-96-9	3+4 Methylphenol (cresol, m+p)	methylphenol,3+4 (cresol, m+p)	--	--	3.30E-01	NA
7440-69-9	Bismuth	Bismuth	--	--	1.00E+01	NA
24959-67-9	Bromide	Bromide	--	--	2.50E+00	NA
7440-70-2	Calcium	Calcium	--	--	1.00E+02	NA
PCB1242/1016	Co-elution of Aroclor 1242 and Aroclor 1016	Co-elution of Aroclor 1242 and Aroclor 1017	--	--	---	NA
14265-44-2	Phosphate	Phosphate	--	--	5.00E+00	NA
7440-21-3	Silicon	Silicon	--	--	2.00E+00	NA

a. ECF-HANFORD-12-0023, 2013, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*, Rev. 3, CH2M-HILL Plateau Remediation Company, Richland, Washington.

b. DOE/RL-2009-42, 2010, *Sampling and Analysis Plan for the 100 NR-1 and 100-NR-2 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington (Appendix A).

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). The threshold for breakthrough occurs at K_d = 23.5 mL/g for soil screening levels, denoted in this table by a red threshold line.
- 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 389,000 mg/kg, based on the maximum pore space contaminant mass capacity.

d. Scale soil screening level value by waste site dimension (m) parallel to groundwater flow direction.

e. The soil screening level for hexavalent chromium was limited to a maximum value of 6.0 mg/kg because the K_d value used in the model for residual hexavalent chromium was derived from experiments with soil concentrations below than that value.

f. No Value Required. Uranium is not modeled because uranium was not identified in the groundwater risk assessment as a COC.

Note: this table is presented in order of ascending K_d to display the relationship between K_d and soil screening level values.

Table B-2. Soil Screening Levels Protective of Surface Water for Non-radionuclides in the 100-NR-1 Operable Unit (K_d order)

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)	Soil Screening Level Protective of Surface Water [c,d] (mg/kg·m)
16887-00-6	Chloride	chloride	0	230,000	2.00E+00	2.67E+03
14797-55-8	Nitrate	Nitrate	0	--	2.50E+00	NA
14797-65-0	Nitrite	Nitrite	0	--	2.50E+00	NA
NO3-N	Nitrogen in Nitrate	Nitrogen in Nitrate	0	--	7.50E-01	NA
NO2-N	Nitrogen in Nitrite	Nitrogen in Nitrite	0	--	7.50E-01	NA
NO2+NO3-N	Nitrogen in Nitrite and Nitrate	Nitrogen in Nitrite and Nitrate	0	--	---	NA
14808-79-8	Sulfate	sulfate	0	--	5.00E+00	NA
51-28-5	2,4-Dinitrophenol	dinitrophenol;2,4-	0.00001	--	8.25E-01	NA
67-64-1	Acetone	Acetone	0.0006	--	2.00E-02	NA
111-76-2	2-Butoxyethanol	ethylene glycol monobutyl ether (EGBE)	0.0028	--	---	NA
75-99-0	Dalapon	Dalapon	0.0032	--	---	NA
78-93-3	2-Butanone	methyl ethyl ketone (MEK; 2-butanone)	0.0045	--	1.00E-02	NA
74-87-3	Chloromethane	chloromethane	0.0060	--	1.00E-02	NA
74-83-9	Bromomethane	bromomethane	0.0090	--	1.00E-02	NA
75-09-2	Methylene chloride	methylene chloride	0.0100	--	5.00E-03	NA
108-10-1	4-Methyl-2-pentanone	methyl isobutyl ketone	0.0126	--	1.00E-02	NA
111-91-1	Bis(2-Chloroethoxy)methane	bis(2-chloroethoxyl)methane	0.0144	--	3.30E-01	NA
591-78-6	2-Hexanone	HEXANONE;2-[MBK, methyl butyl ketone]	0.0150	--	2.00E-02	NA
75-01-4	Vinyl chloride	vinyl chloride [chloroethene; 1-]	0.0186	--	5.00E-03	NA
75-00-3	Chloroethane	ethyl chloride	0.0217	--	1.00E-02	NA
621-64-7	n-Nitrosodi-n-dipropylamine	nitroso-di-n-propylamine;N-	0.0240	--	3.30E-01	NA
10061-01-5	cis-1,3-Dichloropropene	dichloropropene;1,2-,cis	0.0270	--	5.00E-03	NA
10061-02-6	trans-1,3-Dichloropropene	dichloropropene;1,3-,trans	0.0270	--	5.00E-03	NA
1918-00-9	Dicamba	Dicamba	0.0288	--	---	NA
108-95-2	Phenol	Phenol	0.0288	--	3.30E-01	NA
131-11-3	Dimethyl phthalate	dimethyl phthalate	0.0316	--	3.30E-01	NA
156-59-2	cis-1,2-Dichloroethylene	dichloroethylene;1,2-,cis	0.0355	--	5.00E-03	NA
107-06-2	1,2-Dichloroethane	dichloroethane;1,2-	0.0380	--	5.00E-03	NA
156-60-5	trans-1,2-Dichloroethylene	dichloroethylene;1,2-,trans	0.0380	--	5.00E-03	NA
1918-02-1	4-Amino-3,5,6-trichloropicolinic acid	picloram	0.0388	--	---	NA
540-59-0	1,2-Dichloroethene (Total)	dichloroethylene,1,2- (mixed isomers)	0.0396	--	5.00E-03	NA
75-69-4	Trichloromonofluoromethane	trichlorofluoromethane	0.0439	--	---	NA
75-15-0	Carbon disulfide	carbon disulfide	0.0457	--	5.00E-03	NA
78-59-1	Isophorone	isophorone	0.0468	--	3.30E-01	NA
78-87-5	1,2-Dichloropropane	dichloropropane;1,2-	0.0470	--	5.00E-03	NA
93-65-2	2-(2-methyl-4-chlorophenoxy) propionic acid	Mecoprop (MCPP)	0.0485	--	2.10E+00	NA
75-34-3	1,1-Dichloroethane	dichloroethane;1,1-	0.0530	--	1.00E-02	NA
67-66-3	Chloroform	chloroform	0.0530	--	5.00E-03	NA
75-27-4	Bromodichloromethane	bromodichloromethane	0.0550	--	5.00E-03	NA

Table B-2. Soil Screening Levels Protective of Surface Water for Non-radionuclides in the 100-NR-1 Operable Unit (K_d order)

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)	Soil Screening Level Protective of Surface Water [c,d] (mg/kg·m)
71-43-2	Benzene	Benzene	0.0620	--	5.00E-03	NA
124-48-1	Dibromochloromethane	chlorodibromomethane [dibromochloromethane]	0.0631	--	5.00E-03	NA
75-35-4	1,1-Dichloroethene	Dichloroethene;1,1-	0.0650	--	1.00E-02	NA
106-47-8	4-Chloroaniline	chloroaniline;p-	0.0661	--	3.30E-01	NA
606-20-2	2,6-Dinitrotoluene	dinitrotoluene;2,6-	0.0692	--	3.30E-01	NA
79-00-5	1,1,2-Trichloroethane	trichloroethane;1,1,2-	0.0750	--	5.00E-03	NA
111-44-4	Bis(2-chloroethyl) ether	bis(2-chloroethyl)ether	0.0760	--	3.30E-01	NA
79-34-5	1,1,2,2-Tetrachloroethane	tetrachloroethane;1,1,2,2-	0.0790	--	5.00E-03	NA
84-66-2	Diethylphthalate	diethyl phthalate	0.0820	--	3.30E-01	NA
108-60-1	Bis(2-chloro-1-methylethyl)ether	bis(2-chloro-1-methyl-ethyl)ether	0.0829	--	3.30E-01	NA
95-48-7	2-Methylphenol (cresol, o-)	cresol;o-	0.0912	--	3.30E-01	NA
79-01-6	Trichloroethene	trichloroethylene (TCE)	0.0940	--	5.00E-03	NA
121-14-2	2,4-Dinitrotoluene	dinitrotoluene;2,4-	0.0955	--	3.30E-01	NA
94-82-6	2,4-DB(4-(2,4-Dichlorophenoxy)butanoic acid)	Dichlorophenoxy)butyric Acid, 4-(2,4-	0.0984	--	1.30E-02	NA
99-09-2	3-Nitroaniline	nitroaniline, 3-	0.1090	--	3.30E-01	NA
100-01-6	4-Nitroaniline	nitroaniline, 4-	0.1091	--	3.30E-01	NA
88-74-4	2-Nitroaniline	nitroaniline, 2-	0.1113	--	3.30E-01	NA
98-95-3	Nitrobenzene	Nitrobenzene	0.1190	--	3.30E-01	NA
75-25-2	Bromoform	bromoform	0.1260	--	5.00E-03	NA
71-55-6	1,1,1-Trichloroethane	Trichloroethane;1,1,1-	0.1350	--	5.00E-03	NA
108-88-3	Toluene	Toluene	0.1400	--	5.00E-03	NA
120-83-2	2,4-Dichlorophenol	dichlorophenol;2,4-	0.1470	--	3.30E-01	NA
56-23-5	Carbon tetrachloride	carbon tetrachloride	0.1520	--	5.00E-03	NA
108-38-3	m-Xylene	Xylene, m-	0.1960	--	---	NA
100-41-4	Ethylbenzene	ethylbenzene	0.2040	--	5.00E-03	NA
105-67-9	2,4-Dimethylphenol	dimethylphenol;2,4-	0.2090	--	3.30E-01	NA
108-90-7	Chlorobenzene	chlorobenzene	0.2240	--	5.00E-03	NA
1330-20-7	Xylenes (total)	Xylenes (total)	0.2330	--	1.00E-02	NA
95-47-6	o-Xylene	xylene,o-	0.2410	--	---	NA
127-18-4	Tetrachloroethene	tetrachloroethylene	0.2650	--	5.00E-03	NA
100-02-7	4-Nitrophenol	nitrophenol;4-	0.2910	--	6.60E-01	NA
88-75-5	2-Nitrophenol	nitrophenol;2-	0.30	--	6.60E-01	NA
106-44-5	4-Methylphenol (cresol, p-)	cresol;p-	0.30	--	---	NA
541-73-1	1,3-Dichlorobenzene	dichlorobenzene;1,3	0.38	--	3.30E-01	NA
95-50-1	1,2-Dichlorobenzene	dichlorobenzene;1,2- (ortho-Dichlorobenzene)	0.38	--	3.30E-01	NA
88-06-2	2,4,6-Trichlorophenol	Trichlorophenol2,4,6-	0.38	--	3.30E-01	NA
95-57-8	2-Chlorophenol	Chlorophenol;2-	0.39	--	3.30E-01	NA
59-50-7	4-Chloro-3-methylphenol	chloro-3-methylphenol;4-	0.49	--	3.30E-01	NA
87-86-5	Pentachlorophenol	pentachlorophenol	0.59	13	3.30E-01	2.09E+00
106-46-7	1,4-Dichlorobenzene	dichlorobenzene;1,4- (para-Dichlorobenzene)	0.62	--	5.00E-03	NA

Table B-2. Soil Screening Levels Protective of Surface Water for Non-radionuclides in the 100-NR-1 Operable Unit (K_d order)

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)	Soil Screening Level Protective of Surface Water [c,d] (mg/kg·m)
91-94-1	3,3'-Dichlorobenzidine	dichlorobenzidine;3,3'-	0.72	--	3.30E-01	NA
534-52-1	4,6-Dinitro-2-methylphenol	dinitro-2-methylphenol;4,6-	0.75	--	3.30E-01	NA
18540-29-9	Hexavalent Chromium	chromium(VI)	0.80	10	---	2.14E+00 [e]
100-42-5	Styrene	styrene	0.91	--	5.00E-03	NA
91-20-3	Naphthalene	naphthalene	1.19	--	1.00E-01	NA
86-30-6	n-Nitrosodiphenylamine	nitrosodiphenylamine;N-	1.29	--	3.30E-01	NA
58-89-9	Gamma-BHC (Lindane)	lindane [gamma-BHC] (see hexachlorocyclohexane)	1.35	0.080	1.65E-03	2.82E-02
84-74-2	Di-n-butylphthalate	di-butyl phthalate	1.57	--	3.30E-01	NA
95-95-4	2,4,5-Trichlorophenol	Trichlorophenol;2,4,5-	1.60	--	3.30E-01	NA
120-82-1	1,2,4-Trichlorobenzene	trichlorobenzene;1,2,4-	1.66	--	3.30E-01	NA
319-84-6	Alpha-BHC	hexachlorocyclohexane;alpha (alpha-BHC, HCH)	1.76	--	1.65E-03	NA
67-72-1	Hexachloroethane	hexachloroethane	1.78	--	3.30E-01	NA
959-98-8	Endosulfan I	Endosulfan I	2.04	0.056	1.65E-03	3.00E-02
33213-65-9	Endosulfan II	Endosulfan II	2.04	0.056	3.30E-03	3.00E-02
319-85-7	beta-1,2,3,4,5,6-Hexachlorocyclohexane (beta-BHC)	hexachlorocyclohexane;beta-	2.14	--	1.65E-03	NA
126-73-8	Tributyl phosphate	Tributyl phosphate	2.35	--	---	NA
91-58-7	2-Chloronaphthalene	beta-chloronaphthalene	2.48	--	3.30E-01	NA
91-57-6	2-Methylnaphthalene	methylnapthalene;2-	2.48	--	3.30E-01	NA
319-86-8	Delta-BHC	hexachlorocyclohexane;delta-	2.81	--	1.65E-03	NA
7440-42-8	Boron	Boron	3.00	--	2.00E+00	NA
101-55-3	4-Bromophenylphenyl ether	bromodiphenyl ether;4-	3.08	--	3.30E-01	NA
7005-72-3	4-Chlorophenylphenyl ether	chlorodiphenyl ether;4-	3.08	--	3.30E-01	NA
7421-93-4	Endrin aldehyde	Endrin aldehyde	3.27	--	3.30E-03	NA
86-74-8	Carbazole	carbazole	3.39	--	3.30E-01	NA
7723-14-0	Phosphorus	phosphorus	3.50	--	5.00E+01	NA
PO4-P	Phosphorus in phosphate	Phosphorus in phosphate	3.50	--	---	NA
TPHDIESEL	Total petroleum hydrocarbons - diesel range	Total petroleum hydrocarbons - diesel range	4.00	--	---	NA
TPH/OILH	Total petroleum hydrocarbons - motor oil (high boiling)	Total petroleum hydrocarbons - motor oil (high boiling)	4.00	--	---	NA
88-85-7	Dinoseb(2-secButyl-4,6-dinitrophenol)	Dinoseb	4.29	--	1.50E-03	NA
7439-95-4	Magnesium	Magnesium (Not in CLARC database Tables)	4.50	--	7.50E+01	NA
83-32-9	Acenaphthene	acenaphthene	4.90	--	1.00E-01	NA
7782-49-2	Selenium	selenium and compounds	5.00	5.0	1.00E+00	6.57E+00

Table B-2. Soil Screening Levels Protective of Surface Water for Non-radionuclides in the 100-NR-1 Operable Unit (K_d order)

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)	Soil Screening Level Protective of Surface Water [c,d] (mg/kg·m)
208-96-8	Acenaphthylene	acenaphthylene (Not in CLARC database tables; use acenaphthene as surrogate)	5.03	--	1.00E-01	NA
7440-09-7	Potassium	Potassium	5.50	--	4.00E+02	NA
7440-43-9	Cadmium	cadmium	6.70	0.25	2.00E-01	5.37E-01
86-73-7	Fluorene	fluorene	7.7	--	3.00E-02	NA
7440-22-4	Silver	silver	8.3	2.6	2.00E-01	1.19E+01
11104-28-2	Aroclor-1221	aroclor 1221 [PCB]	8.4	0.014	1.65E-02	6.72E-02
11141-16-5	Aroclor-1232	aroclor 1232 [PCB]	8.4	0.014	1.65E-02	6.72E-02
132-64-9	Dibenzofuran	dibenzofuran	9.2	--	3.30E-01	NA
76-44-8	Heptachlor	heptachlor	9.5	0.0038	1.65E-03	3.60E-02
53494-70-5	Endrin ketone	Endrin ketone	9.7	--	3.30E-03	NA
1031-07-8	Endosulfan sulfate	Endosulfan sulfate	9.9	--	3.30E-03	NA
57-12-5	Cyanide	cyanide	9.9	5.2	---	6.26E+01
72-20-8	Endrin	endrin	10.8	0.0023	3.30E-03	5.08E-02
85-68-7	Butylbenzylphthalate	butyl benzyl phthalate	13.8	--	3.30E-01	NA
85-01-8	Phenanthrene	Phenanthrene	16.7	--	5.00E-02	NA
7439-98-7	Molybdenum	molybdenum	20.0	--	2.00E+00	NA
7440-50-8	Copper	copper	22.0	9.0	1.00E+00	3.89E+05
120-12-7	Anthracene	anthracene	23.5	--	5.00E-02	NA
7439-89-6	Iron	Iron	25.0	1,000	5.00E+00	NR
60-57-1	Dieldrin	dieldrin	25.6	0.0019	3.30E-03	NR
7440-38-2	Arsenic	arsenic, inorganic	29.0	150	1.00E+00	NR
7440-24-6	Strontium	strontium	35.0	--	1.00E+00	NA
7440-39-3	Barium	Barium	41.0	--	5.00E-01	NA
7440-36-0	Antimony	antimony	45.0	--	6.00E-01	NA
7440-48-4	cobalt	Cobalt	45.0	--	2.00E+00	NA
72-54-8	4,4'-DDD (Dichlorodiphenyldichloroethane)	ddd	45.8	--	3.30E-03	NA
309-00-2	Aldrin	aldrin	48.7	0.0019	1.65E-03	NR
206-44-0	Fluoranthene	fluoranthene	49	--	5.00E-02	NA
5103-71-9	Alpha-Chlordane	Alpha-Chlordane	51	0.0043	1.65E-02	NR
57-74-9	Chlordane	chlordane	51	0.0043	1.65E-02	NR
7439-97-6	Mercury	mercury (using mercruric chloride)	52	0.012	---	NR
87-68-3	Hexachlorobutadiene	hexachlorobutadiene	54	--	3.30E-01	NA
7440-66-6	Zinc	zinc	62	91	1.00E+00	NR
7439-96-5	Manganese	manganese	65	--	5.00E+00	NA
7440-02-0	Nickel	nickel soluble salts	65	52	4.00E+00	NR
129-00-0	Pyrene	pyrene	68	--	5.00E-02	NA
7440-28-0	Thallium	Thallium, soluble salts	71	--	5.00E-01	NA
12672-29-6	Aroclor-1248	aroclor 1248 [PCB]	77	0.014	1.65E-02	NR
53469-21-9	Aroclor-1242	aroclor 1242 [PCB]	78	0.014	1.65E-02	NR
118-74-1	Hexachlorobenzene	hexachlorobenzene	80	--	3.30E-01	NA
72-43-5	Methoxychlor	methoxychlor	80	0.030	1.65E-02	NR
1024-57-3	Heptachlor epoxide	Heptachlor epoxide	83	0.0038	1.65E-03	NR
72-55-9	4,4'-DDE (Dichlorodiphenyldichloroethylene)	dde	86	--	3.30E-03	NA
8001-35-2	Toxaphene	toxaphene	96	2.00E-04	1.65E-01	NR

Table B-2. Soil Screening Levels Protective of Surface Water for Non-radionuclides in the 100-NR-1 Operable Unit (K_d order)

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)	Soil Screening Level Protective of Surface Water [c,d] (mg/kg·m)
7440-23-5	Sodium	Sodium	100	--	5.00E+01	NA
12674-11-2	Aroclor-1016	aroclor 1016 (PCB)	107	0.014	1.65E-02	NR
117-81-7	Bis(2-ethylhexyl) phthalate	bis(2-ethylhexyl) phthalate	111	--	3.30E-01	NA
11097-69-1	Aroclor-1254	aroclor 1254 (PCB)	131	0.014	1.65E-02	NR
16984-48-8	Fluoride	fluoride (using fluorine)	150	--	5.00E+00	NA
77-47-4	Hexachlorocyclopentadiene	hexachlorocyclopentadiene	200	--	3.30E-01	NA
7440-31-5	Tin	tin	250	--	1.00E+01	NA
7439-93-2	Lithium	Lithium	300	--	2.50E+00	NA
56-55-3	Benzo(a)anthracene	Benzo(a)anthracene	358	--	1.50E-02	NA
218-01-9	chrysene	Chrysene	398	--	1.00E-01	NA
7440-61-1	Uranium	Uranium	NVR [f]	--	---	NVR [f]
50-29-3	4,4'-DDT (Dichlorodiphenyltrichloroethane)	ddt	678	0.0010	3.30E-03	NR
7440-41-7	Beryllium	beryllium	790	--	2.00E-01	NA
11096-82-5	Aroclor-1260	aroclor 1260 (PCB)	822	0.014	1.65E-02	NR
50-32-8	Benzo(a)pyrene	Benzo(a)pyrene	969	--	1.50E-02	NA
7440-47-3	Chromium	chromium (total)	1000	65	2.00E-01	NR
7440-62-2	Vanadium	vanadium	1000	--	2.50E+00	NA
205-99-2	Benzo(b)fluoranthene	Benzo(b)fluoranthene	1230	--	1.50E-02	NA
207-08-9	Benzo(k)fluoranthene	Benzo(k)fluoranthene	1230	--	1.50E-02	NA
7429-90-5	Aluminum	Aluminum (soluble)	1500	87	5.00E+00	NR
53-70-3	Dibenz[a,h]anthracene	Dibenz[a,h]anthracene	1789	--	3.00E-02	NA
191-24-2	Benzo(ghi)perylene	BENZO(g,h,i)PERYLENE (using pyrene as a surrogate)	1950	--	3.00E-02	NA
193-39-5	Indeno(1,2,3-cd)pyrene	Indeno(1,2,3-cd)pyrene	3470	--	3.00E-02	NA
7439-92-1	Lead	lead	10000	2.1	5.00E-01	NR
117-84-0	Di-n-octylphthalate	di-n-octyl phthalate	83200	--	3.30E-01	NA
65794-96-9	3+4 Methylphenol (cresol, m+p)	methylphenol,3+4 (cresol, m+p)	--	--	3.30E-01	NA
7440-69-9	Bismuth	Bismuth	--	--	1.00E+01	NA
24959-67-9	Bromide	Bromide	--	--	2.50E+00	NA
7440-70-2	Calcium	Calcium	--	--	1.00E+02	NA
PCB1242/1016	Co-elution of Aroclor 1242 and Aroclor 1016	Co-elution of Aroclor 1242 and Aroclor 1017	--	--	---	NA
14265-44-2	Phosphate	Phosphate	--	--	5.00E+00	NA
7440-21-3	Silicon	Silicon	--	--	2.00E+00	NA

a. ECF-HANFORD-12-0023, 2013, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*, Rev. 3, CH2M-HILL Plateau Remediation Company, Richland, Washington.

b. DOE/RL-2009-42, 2010, *Sampling and Analysis Plan for the 100 NR-1 and 100-NR-2 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington (Appendix A).

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). The threshold for breakthrough occurs at K_d = 25 mL/g for soil screening levels, denoted in this table by a red threshold line.
- 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 389,000 mg/kg, based on the maximum pore space contaminant mass capacity.

d. Scale soil screening level value by waste site dimension (m) parallel to groundwater flow direction.

e. The soil screening level for hexavalent chromium was limited to a maximum value of 6.0 mg/kg because the K_d value used in the model for residual hexavalent chromium was derived from experiments with soil concentrations below than that value.

f. No Value Required. Uranium is not modeled because uranium was not identified in the groundwater risk assessment as a COC.

Note: this table is presented in order of ascending K_d to display the relationship between K_d and soil screening level values.

Table B-3. Soil Screening Levels Protective of Groundwater for Radionuclides in the 100-NR-1 Operable Unit (K_d order)

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)	Soil Screening Levels Protective of Groundwater [d,e] (pCi/g·m)
Carbon-14 [f]	0	2000	5.7300E+03	---	2.35E+01
Technetium-99	0	900	2.1300E+05	---	1.06E+01
Tritium	0	20000	1.2350E+01	---	4.43E+02
Iodine-129	1	1	1.5700E+07	---	2.94E-01
Neptunium-237	15	15	2.1400E+06	---	NR
Strontium-90 [g]	25	8	2.9120E+01	---	NR
Nickel-63	30	50	9.6000E+01	---	NR
Cesium-137	50	200	3.0000E+01	1.00E-01	NR
Cobalt-60	50	100	5.7210E+00	5.00E-02	NR
Americium-241	200	15	4.32E+02	1.00E+00	NR
Carbon-14 [h]	200	2,000	5.73E+03	---	NR
Curium-243	200	15	2.85E+01	---	NR
Europium-152	200	200	1.33E+01	1.00E-01	NR
Europium-154	200	60	8.80E+00	1.00E-01	NR
Europium-155	200	600	4.96E+00	1.00E-01	NR
Niobium-94	200	--	2.03E+04	---	NA
Plutonium-238	200	15	8.77E+01	1.00E+00	NR
Plutonium-239	200	15	2.41E+04	1.00E+00	NR
Plutonium-240	200	15	6.54E+03	1.00E+00	NR
Plutonium-241	200	300	1.40E+01	---	NR
Radium-226	200	5	1.60E+03	---	NR
Radium-228	200	5	5.75E+00	2.00E-01	NR
Thorium-228	200	15	1.91E+00	---	NR
Thorium-230	200	15	7.70E+04	---	NR
Thorium-232	200	15	1.41E+10	---	NR

a. ECF-HANFORD-12-0023, 2013, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*, Rev. 3, CH2M-HILL Plateau Remediation Company, Richland, Washington.

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

c. DOE/RL-2009-42, 2010, *Sampling and Analysis Plan for the 100 NR-1 and 100-NR-2 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington (Appendix A).

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/m^3 (a value set as the lower limit of numerical significance). The threshold for breakthrough occurs at K_d = 15 mL/g for soil screening levels, denoted in this table by a red threshold line.
- Value defaults to the estimated quantitation limit for any analyte where the calculated value is less than the estimated quantitation limit.

e. Scale soil screening level value by waste site dimension (m) parallel to groundwater flow direction.

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

g. The soil screening level for strontium-90 reported here is superseded by site-specific modeling results reported in ECF-100NR1-12-0056 Rev. 1, *Vadose Zone Transport Modeling to Calculate Strontium-90 Flux to Groundwater and Preliminary Remediation Goal in Support of the 100-N Remedial Investigation/Feasibility Study*. This value is only applicable to waste sites not located over the strontium-90 plume because a soil screening level protective of groundwater cannot be defined where the groundwater is already above the pertinent water quality standard.

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

Note: this table is presented in order of ascending K_d to display the relationship between K_d and soil screening level values.

Table B-4. Soil Screening Levels Protective of Groundwater for Non-radionuclides in the 100-NR-1 Operable Unit (analyte order)

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)	Soil Screening Level Protective of Groundwater [c,d] (mg/kg·m)
50-29-3	4,4'-DDT (Dichlorodiphenyltrichloroethane)	ddt	678	0.257352941	3.30E-03	NR
534-52-1	4,6-Dinitro-2-methylphenol	dinitro-2-methylphenol;4,6-	0.75	1.3	3.30E-01	3.30E-01
1918-02-1	4-Amino-3,5,6-trichloropicolinic acid	picloram	0.0388	500.00	---	1.03E+01
101-55-3	4-Bromophenylphenyl ether	bromodiphenyl ether;4-	3.08	--	3.30E-01	NA
59-50-7	4-Chloro-3-methylphenol	chloro-3-methylphenol;4-	0.49	1600.000	3.30E-01	2.16E+02
106-47-8	4-Chloroaniline	chloroaniline;p-	0.0661	0.2	3.30E-01	3.30E-01
7005-72-3	4-Chlorophenylphenyl ether	chlorodiphenyl ether;4-	3.08	--	3.30E-01	NA
108-10-1	4-Methyl-2-pentanone	methyl isobutyl ketone	0.0126	640.00	1.00E-02	9.32E+00
106-44-5	4-Methylphenol (cresol, p-)	cresol;p-	0.30	800	---	6.82E+01
100-01-6	4-Nitroaniline	nitroaniline, 4-	0.1091	0,004	3.30E-01	3.30E-01
100-02-7	4-Nitrophenol	nitrophenol;4-	0.2910	--	6.60E-01	NA
83-32-9	Acenaphthene	acenaphthene	4.90	480	1.00E-01	6.16E+02
208-96-8	Acenaphthylene	acenaphthylene (Not in CLARC database tables; use acenaphthene as surrogate)	5.03	--	1.00E-01	NA
67-64-1	Acetone	Acetone	0.0006	7200	2.00E-02	8.44E+01
309-00-2	Aldrin	aldrin	48.7	0.003	1.65E-03	NR
319-84-6	Alpha-BHC	hexachlorocyclohexane;alpha (alpha-BHC, HCH)	1.76	0.013888889	1.65E-03	6.33E-03
5103-71-9	Alpha-Chlordane	Alpha-Chlordane	51	0.25	1.65E-02	NR
7429-90-5	Aluminum	Aluminum (soluble)	1500	16000	5.00E+00	NR
120-12-7	Anthracene	anthracene	23.5	2400	5.00E-02	NR
7440-36-0	Antimony	antimony	45.0	6	6.00E-01	NR
12674-11-2	Aroclor-1016	aroclor 1016 (PCB)	107	0.50	1.65E-02	NR
11104-28-2	Aroclor-1221	aroclor 1221 [PCB]	8.4	0,000	1.65E-02	1.05E-01
11141-16-5	Aroclor-1232	aroclor 1232 [PCB]	8.4	0.0	1.65E-02	1.05E-01
53469-21-9	Aroclor-1242	aroclor 1242 [PCB]	78	0.04	1.65E-02	NR
12672-29-6	Aroclor-1248	aroclor 1248 [PCB]	77	0	1.65E-02	NR
11097-69-1	Aroclor-1254	aroclor 1254 (PCB)	131	0.04	1.65E-02	NR
11096-82-5	Aroclor-1260	aroclor 1260 (PCB)	822	0.04375	1.65E-02	NR
7440-38-2	Arsenic	arsenic, inorganic	29.0	0.058	1.00E+00	NR
7440-39-3	Barium	Barium	41.0	2000.000	5.00E-01	NR
71-43-2	Benzene	Benzene	0.0620	1	5.00E-03	2.07E-02
56-55-3	Benzo(a)anthracene	Benzo(a)anthracene	358	0.119863014	1.50E-02	NR
50-32-8	Benzo(a)pyrene	Benzo(a)pyrene	969	0.011986301	1.50E-02	NR
205-99-2	Benzo(b)fluoranthene	Benzo(b)fluoranthene	1230	0.119863014	1.50E-02	NR
191-24-2	Benzo(ghi)perylene	BENZO(g,h,i)PERYLENE (using pyrene as a surrogate)	1950	--	3.00E-02	NA
207-08-9	Benzo(k)fluoranthene	Benzo(k)fluoranthene	1230	0.119863014	1.50E-02	NR
7440-41-7	Beryllium	beryllium	790	4	2.00E-01	NR
319-85-7	beta-1,2,3,4,5,6-Hexachlorocyclohexane (beta-BHC)	hexachlorocyclohexane;beta-	2.14	0.048611111	1.65E-03	2.73E-02
108-60-1	Bis(2-chloro-1-methylethyl)ether	bis(2-chloro-1-methyl-ethyl)ether	0.0829	1	3.30E-01	3.30E-01

Table B-4. Soil Screening Levels Protective of Groundwater for Non-radionuclides in the 100-NR-1 Operable Unit (analyte order)

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)	Soil Screening Level Protective of Groundwater [c,d] (mg/kg·m)
111-91-1	Bis(2-Chloroethoxy)methane	bis(2-chloroethoxyl)methane	0.0144	48	3.30E-01	7.10E-01
111-44-4	Bis(2-chloroethyl) ether	bis(2-chloroethyl)ether	0.0760	0	3.30E-01	3.30E-01
117-81-7	Bis(2-ethylhexyl) phthalate	bis(2-ethylhexyl) phthalate	111	0,006	3.30E-01	NR
7440-69-9	Bismuth	Bismuth	--	--	1.00E+01	NA
7440-42-8	Boron	Boron	3.00	3200.0	2.00E+00	2.50E+03
24959-67-9	Bromide	Bromide	--	--	2.50E+00	NA
75-27-4	Bromodichloromethane	bromodichloromethane	0.0550	0.71	5.00E-03	1.72E-02
75-25-2	Bromoform	bromoform	0.1260	5.537974684	5.00E-03	2.29E-01
74-83-9	Bromomethane	bromomethane	0.0090	11.2	1.00E-02	1.53E-01
85-68-7	Butylbenzylphthalate	butyl benzyl phthalate	13.8	46.1	3.30E-01	8.52E+03
7440-43-9	Cadmium	cadmium	6.70	5.0000	2.00E-01	1.07E+01
7440-70-2	Calcium	Calcium	--	--	1.00E+02	NA
86-74-8	Carbazole	carbazole	3.39	4.375	3.30E-01	3.85E+00
75-15-0	Carbon disulfide	carbon disulfide	0.0457	800.0	5.00E-03	1.78E+01
56-23-5	Carbon tetrachloride	carbon tetrachloride	0.1520	1	5.00E-03	2.97E-02
57-74-9	Chlordane	chlordane	51	0.3	1.65E-02	NR
16887-00-6	Chloride	chloride	0	250,000	2.00E+00	2.90E+03
108-90-7	Chlorobenzene	chlorobenzene	0.2240	100.0	5.00E-03	6.56E+00
75-00-3	Chloroethane	ethyl chloride	0.0217	--	1.00E-02	NA
67-66-3	Chloroform	chloroform	0.0530	0,001	5.00E-03	3.38E-02
74-87-3	Chloromethane	chloromethane	0.0060	--	1.00E-02	NA
7440-47-3	Chromium	chromium (total)	1000	100	2.00E-01	NR
218-01-9	chrysene	Chrysene	398	1.198630137	1.00E-01	NR
156-59-2	cis-1,2-Dichloroethylene	dichloroethylene;1,2-,cis	0.0355	16.0	5.00E-03	3.19E-01
10061-01-5	cis-1,3-Dichloropropene	dichloropropene;1,2-,cis	0.0270	0	5.00E-03	7.80E-03
7440-48-4	cobalt	Cobalt	45.0	4.8000	2.00E+00	NR
PCB1242/1016	Co-elution of Aroclor 1242 and Aroclor 1016	Co-elution of Aroclor 1242 and Aroclor 1017	--	--	---	NA
7440-50-8	Copper	copper	22.0	640	1.00E+00	3.89E+05
57-12-5	Cyanide	cyanide	9.9	4.80	---	5.78E+01
75-99-0	Dalapon	Dalapon	0.0032	200	---	2.46E+00
319-86-8	Delta-BHC	hexachlorocyclohexane;delta-	2.81	--	1.65E-03	NA
53-70-3	Dibenz[a,h]anthracene	Dibenz[a,h]anthracene	1789	0.119863014	3.00E-02	NR
132-64-9	Dibenzofuran	dibenzofuran	9.2	8.0	3.30E-01	6.02E+01
124-48-1	Dibromochloromethane	chlorodibromomethane [dibromochloromethane]	0.0631	0.52	5.00E-03	1.37E-02
1918-00-9	Dicamba	Dicamba	0.0288	480	---	8.78E+00
60-57-1	Dieldrin	dieldrin	25.6	0.01	3.30E-03	NR
84-66-2	Diethylphthalate	diethyl phthalate	0.0820	12800	3.30E-01	3.95E+02
131-11-3	Dimethyl phthalate	dimethyl phthalate	0.0316	--	3.30E-01	NA
84-74-2	Di-n-butylphthalate	di-butyl phthalate	1.57	1600	3.30E-01	6.53E+02
117-84-0	Di-n-octylphthalate	di-n-octyl phthalate	83200	192	3.30E-01	NR
88-85-7	Dinoseb(2-secButyl-4,6-dinitrophenol)	Dinoseb	4.29	7	1.50E-03	7.78E+00
959-98-8	Endosulfan I	Endosulfan I	2.04	96	1.65E-03	5.14E+01
33213-65-9	Endosulfan II	Endosulfan II	2.04	96	3.30E-03	5.14E+01

Table B-4. Soil Screening Levels Protective of Groundwater for Non-radionuclides in the 100-NR-1 Operable Unit (analyte order)

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)	Soil Screening Level Protective of Groundwater [c,d] (mg/kg·m)
1031-07-8	Endosulfan sulfate	Endosulfan sulfate	9.9	--	3.30E-03	NA
72-20-8	Endrin	endrin	10.8	2.00	3.30E-03	4.41E+01
7421-93-4	Endrin aldehyde	Endrin aldehyde	3.27	--	3.30E-03	NA
53494-70-5	Endrin ketone	Endrin ketone	9.7	--	3.30E-03	NA
100-41-4	Ethylbenzene	ethylbenzene	0.2040	0,004	5.00E-03	2.41E-01
206-44-0	Fluoranthene	fluoranthene	49	640	5.00E-02	NR
86-73-7	Fluorene	fluorene	7.7	320.000	3.00E-02	1.07E+03
16984-48-8	Fluoride	fluoride (using fluorine)	150	960	5.00E+00	NR
58-89-9	Gamma-BHC (Lindane)	lindane [gamma-BHC] (see hexachlorocyclohexane)	1.35	0.079545455	1.65E-03	2.80E-02
76-44-8	Heptachlor	heptachlor	9.5	0.02	1.65E-03	1.84E-01
1024-57-3	Heptachlor epoxide	Heptachlor epoxide	83	0.005	1.65E-03	NR
118-74-1	Hexachlorobenzene	hexachlorobenzene	80	0.1	3.30E-01	NR
87-68-3	Hexachlorobutadiene	hexachlorobutadiene	54	1	3.30E-01	NR
77-47-4	Hexachlorocyclopentadiene	hexachlorocyclopentadiene	200	48.00	3.30E-01	NR
67-72-1	Hexachloroethane	hexachloroethane	1.78	1.09375	3.30E-01	5.04E-01
18540-29-9	Hexavalent Chromium	chromium(VI)	0.80	48	---	6 [e]
193-39-5	Indeno(1,2,3-cd)pyrene	Indeno(1,2,3-cd)pyrene	3470	0.119863014	3.00E-02	NR
7439-89-6	Iron	Iron	25.0	11200	5.00E+00	NR
78-59-1	Isophorone	isophorone	0.0468	46.05	3.30E-01	1.04E+00
7439-92-1	Lead	lead	10000	15	5.00E-01	NR
7439-93-2	Lithium	Lithium	300	32	2.50E+00	NR
7439-95-4	Magnesium	Magnesium (Not in CLARC database Tables)	4.50	--	7.50E+01	NA
7439-96-5	Manganese	manganese	65	0,384	5.00E+00	NR
7439-97-6	Mercury	mercury (using mercruric chloride)	52	2.000	---	NR
72-43-5	Methoxychlor	methoxychlor	80	40.000	1.65E-02	NR
75-09-2	Methylene chloride	methylene chloride	0.0100	5.00	5.00E-03	6.94E-02
7439-98-7	Molybdenum	molybdenum	20.0	0,080	2.00E+00	3.89E+05
108-38-3	m-Xylene	Xylene, m-	0.1960	1600	---	9.35E+01
91-20-3	Naphthalene	naphthalene	1.19	160	1.00E-01	4.99E+01
7440-02-0	Nickel	nickel soluble salts	65	100	4.00E+00	NR
14797-55-8	Nitrate	Nitrate	0	45,000	2.50E+00	5.22E+02
14797-65-0	Nitrite	Nitrite	0	3,300	2.50E+00	3.83E+01
98-95-3	Nitrobenzene	Nitrobenzene	0.1190	16.0	3.30E-01	6.34E-01
NO3-N	Nitrogen in Nitrate	Nitrogen in Nitrate	0	10,000	7.50E-01	1.16E+02
NO2-N	Nitrogen in Nitrite	Nitrogen in Nitrite	0	1,000	7.50E-01	1.16E+01
NO2+NO3-N	Nitrogen in Nitrite and Nitrate	Nitrogen in Nitrite and Nitrate	0	10,000	---	1.16E+02
621-64-7	n-Nitrosodi-n-dipropylamine	nitroso-di-n-propylamine;N-	0.0240	0.01	3.30E-01	3.30E-01
86-30-6	n-Nitrosodiphenylamine	nitrosodiphenylamine;N-	1.29	0,018	3.30E-01	6.02E+00
95-47-6	o-Xylene	xylene,o-	0.2410	1600.0	---	1.12E+02
87-86-5	Pentachlorophenol	pentachlorophenol	0.59	0.2	3.30E-01	3.30E-01
85-01-8	Phenanthrene	Phenanthrene	16.7	--	5.00E-02	NA
108-95-2	Phenol	Phenol	0.0288	2,400	3.30E-01	4.39E+01
14265-44-2	Phosphate	Phosphate	--	--	5.00E+00	NA
7723-14-0	Phosphorus	phosphorus	3.50	--	5.00E+01	NA

Table B-4. Soil Screening Levels Protective of Groundwater for Non-radionuclides in the 100-NR-1 Operable Unit (analyte order)

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)	Soil Screening Level Protective of Groundwater [c,d] (mg/kg·m)
PO4-P	Phosphorus in phosphate	Phosphorus in phosphate	3.50	--	---	NA
7440-09-7	Potassium	Potassium	5.50	--	4.00E+02	NA
129-00-0	Pyrene	pyrene	68	240.00	5.00E-02	NR
7782-49-2	Selenium	selenium and compounds	5.00	50	1.00E+00	6.57E+01
7440-21-3	Silicon	Silicon	--	--	2.00E+00	NA
7440-22-4	Silver	silver	8.3	0,080	2.00E-01	3.64E+02
7440-23-5	Sodium	Sodium	100	--	5.00E+01	NA
7440-24-6	Strontium	strontium	35.0	9600.000	1.00E+00	NR
100-42-5	Styrene	styrene	0.91	100	5.00E-03	2.42E+01
14808-79-8	Sulfate	sulfate	0	250,000	5.00E+00	2.90E+03
127-18-4	Tetrachloroethene	tetrachloroethylene	0.2650	5	5.00E-03	3.81E-01
7440-28-0	Thallium	Thallium, soluble salts	71	0.2	5.00E-01	NR
7440-31-5	Tin	tin	250	9600	1.00E+01	NR
108-88-3	Toluene	Toluene	0.1400	640	5.00E-03	2.86E+01
TPHDIESEL	Total petroleum hydrocarbons - diesel range	Total petroleum hydrocarbons - diesel range	4.00	500	---	5.18E+02
TPH/OILH	Total petroleum hydrocarbons - motor oil (high boiling)	Total petroleum hydrocarbons - motor oil (high boiling)	4.00	500.0	---	5.18E+02
8001-35-2	Toxaphene	toxaphene	96	0	1.65E-01	NR
156-60-5	trans-1,2-Dichloroethylene	dichloroethylene;1,2-,trans	0.0380	100.0	5.00E-03	2.04E+00
10061-02-6	trans-1,3-Dichloropropene	dichloropropene;1,3-,trans	0.0270	0	5.00E-03	7.80E-03
126-73-8	Tributyl phosphate	Tributyl phosphate	2.35	10	---	5.97E+00
79-01-6	Trichloroethene	trichloroethylene (TCE)	0.0940	0.95	5.00E-03	3.20E-02
75-69-4	Trichloromonofluoromethane	trichlorofluoromethane	0.0439	2400.00	---	5.23E+01
7440-61-1	Uranium	Uranium	NVR [f]	30	---	NVR [f]
7440-62-2	Vanadium	vanadium	1000	80	2.50E+00	NR
75-01-4	Vinyl chloride	vinyl chloride [chloroethene; 1-]	0.0186	0.060763889	5.00E-03	5.00E-03
1330-20-7	Xylenes (total)	Xylenes (total)	0.2330	1600.00	1.00E-02	1.09E+02
7440-66-6	Zinc	zinc	62	4800	1.00E+00	NR

g. ECF-HANFORD-12-0023, 2013, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*, Rev. 3, CH2M-HILL Plateau Remediation Company, Richland, Washington.

h. DOE/RL-2009-42, 2010, *Sampling and Analysis Plan for the 100 NR-1 and 100-NR-2 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington (Appendix A).

i. 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). The threshold for breakthrough occurs at K_d = 23.5 mL/g for soil screening levels, denoted in this table by a red threshold line.
- 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 389,000 mg/kg, based on the maximum pore space contaminant mass capacity.

j. Scale soil screening level value by waste site dimension (m) parallel to groundwater flow direction.

k. The soil screening level for hexavalent chromium was limited to a maximum value of 6.0 mg/kg because the K_d value used in the model for residual hexavalent chromium was derived from experiments with soil concentrations below than that value.

l. No Value Required. Uranium is not modeled because uranium was not identified in the groundwater risk assessment as a COC.

Note: this table is presented in order of ascending analyte name for convenient lookup.

Table B-5. Soil Screening Levels Protective of Surface Water for Non-radionuclides in the 100-NR-1 Operable Unit (analyte order)

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)	Soil Screening Level Protective of Surface Water [c,d] (mg/kg·m)
71-55-6	1,1,1-Trichloroethane	Trichloroethane;1,1,1-	0.1350	--	5.00E-03	NA
79-34-5	1,1,2,2-Tetrachloroethane	tetrachloroethane;1,1,2,2-	0.0790	--	5.00E-03	NA
79-00-5	1,1,2-Trichloroethane	trichloroethane;1,1,2-	0.0750	--	5.00E-03	NA
75-34-3	1,1-Dichloroethane	dichloroethane;1,1-	0.0530	--	1.00E-02	NA
75-35-4	1,1-Dichloroethene	Dichloroethene;1,1-	0.0650	--	1.00E-02	NA
120-82-1	1,2,4-Trichlorobenzene	trichlorobenzene;1,2,4-	1.66	--	3.30E-01	NA
95-50-1	1,2-Dichlorobenzene	dichlorobenzene;1,2- (ortho-Dichlorobenzene)	0.38	--	3.30E-01	NA
107-06-2	1,2-Dichloroethane	dichloroethane;1,2-	0.0380	--	5.00E-03	NA
540-59-0	1,2-Dichloroethene (Total)	dichloroethylene,1,2- (mixed isomers)	0.0396	--	5.00E-03	NA
78-87-5	1,2-Dichloropropane	dichloropropane;1,2-	0.0470	--	5.00E-03	NA
541-73-1	1,3-Dichlorobenzene	dichlorobenzene;1,3	0.38	--	3.30E-01	NA
106-46-7	1,4-Dichlorobenzene	dichlorobenzene;1,4- (para-Dichlorobenzene)	0.62	--	5.00E-03	NA
93-65-2	2-(2-methyl-4-chlorophenoxy) propionic acid	Mecoprop (MCPP)	0.0485	--	2.10E+00	NA
95-95-4	2,4,5-Trichlorophenol	Trichlorophenol;2,4,5-	1.60	--	3.30E-01	NA
88-06-2	2,4,6-Trichlorophenol	Trichlorophenol2,4,6-	0.38	--	3.30E-01	NA
94-82-6	2,4-DB(4-(2,4-Dichlorophenoxy)butanoic acid)	Dichlorophenoxy)butyric Acid, 4-(2,4-	0.0984	--	1.30E-02	NA
120-83-2	2,4-Dichlorophenol	dichlorophenol;2,4-	0.1470	--	3.30E-01	NA
105-67-9	2,4-Dimethylphenol	dimethylphenol;2,4-	0.2090	--	3.30E-01	NA
51-28-5	2,4-Dinitrophenol	dinitrophenol;2,4-	0.00001	--	8.25E-01	NA
121-14-2	2,4-Dinitrotoluene	dinitrotoluene;2,4-	0.0955	--	3.30E-01	NA
606-20-2	2,6-Dinitrotoluene	dinitrotoluene;2,6-	0.0692	--	3.30E-01	NA
78-93-3	2-Butanone	methyl ethyl ketone (MEK; 2-butanone)	0.0045	--	1.00E-02	NA
111-76-2	2-Butoxyethanol	ethylene glycol monobutyl ether (EGBE)	0.0028	--	---	NA
91-58-7	2-Chloronaphthalene	beta-chloronaphthalene	2.48	--	3.30E-01	NA
95-57-8	2-Chlorophenol	Chlorophenol;2-	0.39	--	3.30E-01	NA
591-78-6	2-Hexanone	HEXANONE;2- [MBK, methyl butyl ketone]	0.0150	--	2.00E-02	NA
91-57-6	2-Methylnaphthalene	methylnapthalene;2-	2.48	--	3.30E-01	NA
95-48-7	2-Methylphenol (cresol, o-)	cresol;o-	0.0912	--	3.30E-01	NA
88-74-4	2-Nitroaniline	nitroaniline, 2-	0.1113	--	3.30E-01	NA
88-75-5	2-Nitrophenol	nitrophenol;2-	0.30	--	6.60E-01	NA
91-94-1	3,3'-Dichlorobenzidine	dichlorobenzidine;3,3'-	0.72	--	3.30E-01	NA
65794-96-9	3+4 Methylphenol (cresol, m+p)	methylphenol,3+4 (cresol, m+p)	--	--	3.30E-01	NA
99-09-2	3-Nitroaniline	nitroaniline, 3-	0.1090	--	3.30E-01	NA
72-54-8	4,4'-DDD (Dichlorodiphenyldichloroethane)	ddd	45.8	--	3.30E-03	NA
72-55-9	4,4'-DDE (Dichlorodiphenyldichloroethylene)	dde	86	--	3.30E-03	NA

Table B-5. Soil Screening Levels Protective of Surface Water for Non-radionuclides in the 100-NR-1 Operable Unit (analyte order)

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)	Soil Screening Level Protective of Surface Water [c,d] (mg/kg·m)
50-29-3	4,4'-DDT (Dichlorodiphenyltrichloroethane)	ddt	678	0.0010	3.30E-03	NR
534-52-1	4,6-Dinitro-2-methylphenol	dinitro-2-methylphenol;4,6-	0.75	--	3.30E-01	NA
1918-02-1	4-Amino-3,5,6-trichloropicolinic acid	picloram	0.0388	--	---	NA
101-55-3	4-Bromophenylphenyl ether	bromodiphenyl ether;4-	3.08	--	3.30E-01	NA
59-50-7	4-Chloro-3-methylphenol	chloro-3-methylphenol;4-	0.49	--	3.30E-01	NA
106-47-8	4-Chloroaniline	chloroaniline;p-	0.0661	--	3.30E-01	NA
7005-72-3	4-Chlorophenylphenyl ether	chlorodiphenyl ether;4-	3.08	--	3.30E-01	NA
108-10-1	4-Methyl-2-pentanone	methyl isobutyl ketone	0.0126	--	1.00E-02	NA
106-44-5	4-Methylphenol (cresol, p-)	cresol;p-	0.30	--	---	NA
100-01-6	4-Nitroaniline	nitroaniline, 4-	0.1091	--	3.30E-01	NA
100-02-7	4-Nitrophenol	nitrophenol;4-	0.2910	--	6.60E-01	NA
83-32-9	Acenaphthene	acenaphthene	4.90	--	1.00E-01	NA
208-96-8	Acenaphthylene	acenaphthylene (Not in CLARC database tables; use acenaphthene as surrogate)	5.03	--	1.00E-01	NA
67-64-1	Acetone	Acetone	0.0006	--	2.00E-02	NA
309-00-2	Aldrin	aldrin	48.7	0.0019	1.65E-03	NR
319-84-6	Alpha-BHC	hexachlorocyclohexane;alpha (alpha-BHC, HCH)	1.76	--	1.65E-03	NA
5103-71-9	Alpha-Chlordane	Alpha-Chlordane	51	0.0043	1.65E-02	NR
7429-90-5	Aluminum	Aluminum (soluble)	1500	87	5.00E+00	NR
120-12-7	Anthracene	anthracene	23.5	--	5.00E-02	NA
7440-36-0	Antimony	antimony	45.0	--	6.00E-01	NA
12674-11-2	Aroclor-1016	aroclor 1016 (PCB)	107	0.014	1.65E-02	NR
11104-28-2	Aroclor-1221	aroclor 1221 [PCB]	8.4	0.014	1.65E-02	6.72E-02
11141-16-5	Aroclor-1232	aroclor 1232 [PCB]	8.4	0.014	1.65E-02	6.72E-02
53469-21-9	Aroclor-1242	aroclor 1242 [PCB]	78	0.014	1.65E-02	NR
12672-29-6	Aroclor-1248	aroclor 1248 [PCB]	77	0.014	1.65E-02	NR
11097-69-1	Aroclor-1254	aroclor 1254 (PCB)	131	0.014	1.65E-02	NR
11096-82-5	Aroclor-1260	aroclor 1260 (PCB)	822	0.014	1.65E-02	NR
7440-38-2	Arsenic	arsenic, inorganic	29.0	150	1.00E+00	NR
7440-39-3	Barium	Barium	41.0	--	5.00E-01	NA
71-43-2	Benzene	Benzene	0.0620	--	5.00E-03	NA
56-55-3	Benzo(a)anthracene	Benzo(a)anthracene	358	--	1.50E-02	NA
50-32-8	Benzo(a)pyrene	Benzo(a)pyrene	969	--	1.50E-02	NA
205-99-2	Benzo(b)fluoranthene	Benzo(b)fluoranthene	1230	--	1.50E-02	NA
191-24-2	Benzo(ghi)perylene	BENZO(g,h,i)PERYLENE (using pyrene as a surrogate)	1950	--	3.00E-02	NA
207-08-9	Benzo(k)fluoranthene	Benzo(k)fluoranthene	1230	--	1.50E-02	NA
7440-41-7	Beryllium	beryllium	790	--	2.00E-01	NA
319-85-7	beta-1,2,3,4,5,6-Hexachlorocyclohexane (beta-BHC)	hexachlorocyclohexane;beta-	2.14	--	1.65E-03	NA
108-60-1	Bis(2-chloro-1-methylethyl)ether	bis(2-chloro-1-methyl-ethyl)ether	0.0829	--	3.30E-01	NA

Table B-5. Soil Screening Levels Protective of Surface Water for Non-radionuclides in the 100-NR-1 Operable Unit (analyte order)

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)	Soil Screening Level Protective of Surface Water [c,d] (mg/kg·m)
111-91-1	Bis(2-Chloroethoxy)methane	bis(2-chloroethoxyl)methane	0.0144	--	3.30E-01	NA
111-44-4	Bis(2-chloroethyl) ether	bis(2-chloroethyl)ether	0.0760	--	3.30E-01	NA
117-81-7	Bis(2-ethylhexyl) phthalate	bis(2-ethylhexyl) phthalate	111	--	3.30E-01	NA
7440-69-9	Bismuth	Bismuth	--	--	1.00E+01	NA
7440-42-8	Boron	Boron	3.00	--	2.00E+00	NA
24959-67-9	Bromide	Bromide	--	--	2.50E+00	NA
75-27-4	Bromodichloromethane	bromodichloromethane	0.0550	--	5.00E-03	NA
75-25-2	Bromoform	bromoform	0.1260	--	5.00E-03	NA
74-83-9	Bromomethane	bromomethane	0.0090	--	1.00E-02	NA
85-68-7	Butylbenzylphthalate	butyl benzyl phthalate	13.8	--	3.30E-01	NA
7440-43-9	Cadmium	cadmium	6.70	0.25	2.00E-01	5.37E-01
7440-70-2	Calcium	Calcium	--	--	1.00E+02	NA
86-74-8	Carbazole	carbazole	3.39	--	3.30E-01	NA
75-15-0	Carbon disulfide	carbon disulfide	0.0457	--	5.00E-03	NA
56-23-5	Carbon tetrachloride	carbon tetrachloride	0.1520	--	5.00E-03	NA
57-74-9	Chlordane	chlordane	51	0.0043	1.65E-02	NR
16887-00-6	Chloride	chloride	0	230,000	2.00E+00	2.67E+03
108-90-7	Chlorobenzene	chlorobenzene	0.2240	--	5.00E-03	NA
75-00-3	Chloroethane	ethyl chloride	0.0217	--	1.00E-02	NA
67-66-3	Chloroform	chloroform	0.0530	--	5.00E-03	NA
74-87-3	Chloromethane	chloromethane	0.0060	--	1.00E-02	NA
7440-47-3	Chromium	chromium (total)	1000	65	2.00E-01	NR
218-01-9	chrysene	Chrysene	398	--	1.00E-01	NA
156-59-2	cis-1,2-Dichloroethylene	dichloroethylene;1,2-,cis	0.0355	--	5.00E-03	NA
10061-01-5	cis-1,3-Dichloropropene	dichloropropene;1,2-,cis	0.0270	--	5.00E-03	NA
7440-48-4	cobalt	Cobalt	45.0	--	2.00E+00	NA
PCB1242/1016	Co-elution of Aroclor 1242 and Aroclor 1016	Co-elution of Aroclor 1242 and Aroclor 1017	--	--	---	NA
7440-50-8	Copper	copper	22.0	9.0	1.00E+00	3.89E+05
57-12-5	Cyanide	cyanide	9.9	5.2	---	6.26E+01
75-99-0	Dalapon	Dalapon	0.0032	--	---	NA
319-86-8	Delta-BHC	hexachlorocyclohexane;delta-	2.81	--	1.65E-03	NA
53-70-3	Dibenz[a,h]anthracene	Dibenz[a,h]anthracene	1789	--	3.00E-02	NA
132-64-9	Dibenzofuran	dibenzofuran	9.2	--	3.30E-01	NA
124-48-1	Dibromochloromethane	chlorodibromomethane [dibromochloromethane]	0.0631	--	5.00E-03	NA
1918-00-9	Dicamba	Dicamba	0.0288	--	---	NA
60-57-1	Dieldrin	dieldrin	25.6	0.0019	3.30E-03	NR
84-66-2	Diethylphthalate	diethyl phthalate	0.0820	--	3.30E-01	NA
131-11-3	Dimethyl phthalate	dimethyl phthalate	0.0316	--	3.30E-01	NA
84-74-2	Di-n-butylphthalate	di-butyl phthalate	1.57	--	3.30E-01	NA
117-84-0	Di-n-octylphthalate	di-n-octyl phthalate	83200	--	3.30E-01	NA
88-85-7	Dinoseb(2-secButyl-4,6-dinitrophenol)	Dinoseb	4.29	--	1.50E-03	NA
959-98-8	Endosulfan I	Endosulfan I	2.04	0.056	1.65E-03	3.00E-02

Table B-5. Soil Screening Levels Protective of Surface Water for Non-radionuclides in the 100-NR-1 Operable Unit (analyte order)

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)	Soil Screening Level Protective of Surface Water [c,d] (mg/kg·m)
33213-65-9	Endosulfan II	Endosulfan II	2.04	0.056	3.30E-03	3.00E-02
1031-07-8	Endosulfan sulfate	Endosulfan sulfate	9.9	--	3.30E-03	NA
72-20-8	Endrin	endrin	10.8	0.0023	3.30E-03	5.08E-02
7421-93-4	Endrin aldehyde	Endrin aldehyde	3.27	--	3.30E-03	NA
53494-70-5	Endrin ketone	Endrin ketone	9.7	--	3.30E-03	NA
100-41-4	Ethylbenzene	ethylbenzene	0.2040	--	5.00E-03	NA
206-44-0	Fluoranthene	fluoranthene	49	--	5.00E-02	NA
86-73-7	Fluorene	fluorene	7.7	--	3.00E-02	NA
16984-48-8	Fluoride	fluoride (using fluorine)	150	--	5.00E+00	NA
58-89-9	Gamma-BHC (Lindane)	lindane [gamma-BHC] (see hexachlorocyclohexane)	1.35	0.080	1.65E-03	2.82E-02
76-44-8	Heptachlor	heptachlor	9.5	0.0038	1.65E-03	3.60E-02
1024-57-3	Heptachlor epoxide	Heptachlor epoxide	83	0.0038	1.65E-03	NR
118-74-1	Hexachlorobenzene	hexachlorobenzene	80	--	3.30E-01	NA
87-68-3	Hexachlorobutadiene	hexachlorobutadiene	54	--	3.30E-01	NA
77-47-4	Hexachlorocyclopentadiene	hexachlorocyclopentadiene	200	--	3.30E-01	NA
67-72-1	Hexachloroethane	hexachloroethane	1.78	--	3.30E-01	NA
18540-29-9	Hexavalent Chromium	chromium(VI)	0.80	10	---	2.14E+00 [e]
193-39-5	Indeno(1,2,3-cd)pyrene	Indeno(1,2,3-cd)pyrene	3470	--	3.00E-02	NA
7439-89-6	Iron	Iron	25.0	1,000	5.00E+00	NR
78-59-1	Isophorone	isophorone	0.0468	--	3.30E-01	NA
7439-92-1	Lead	lead	10000	2.1	5.00E-01	NR
7439-93-2	Lithium	Lithium	300	--	2.50E+00	NA
7439-95-4	Magnesium	Magnesium (Not in CLARC database Tables)	4.50	--	7.50E+01	NA
7439-96-5	Manganese	manganese	65	--	5.00E+00	NA
7439-97-6	Mercury	mercury (using mercruric chloride)	52	0.012	---	NR
72-43-5	Methoxychlor	methoxychlor	80	0.030	1.65E-02	NR
75-09-2	Methylene chloride	methylene chloride	0.0100	--	5.00E-03	NA
7439-98-7	Molybdenum	molybdenum	20.0	--	2.00E+00	NA
108-38-3	m-Xylene	Xylene, m-	0.1960	--	---	NA
91-20-3	Naphthalene	naphthalene	1.19	--	1.00E-01	NA
7440-02-0	Nickel	nickel soluble salts	65	52	4.00E+00	NR
14797-55-8	Nitrate	Nitrate	0	--	2.50E+00	NA
14797-65-0	Nitrite	Nitrite	0	--	2.50E+00	NA
98-95-3	Nitrobenzene	Nitrobenzene	0.1190	--	3.30E-01	NA
NO3-N	Nitrogen in Nitrate	Nitrogen in Nitrate	0	--	7.50E-01	NA
NO2-N	Nitrogen in Nitrite	Nitrogen in Nitrite	0	--	7.50E-01	NA
NO2+NO3-N	Nitrogen in Nitrite and Nitrate	Nitrogen in Nitrite and Nitrate	0	--	---	NA
621-64-7	n-Nitrosodi-n-dipropylamine	nitroso-di-n-propylamine;N-	0.0240	--	3.30E-01	NA
86-30-6	n-Nitrosodiphenylamine	nitrosodiphenylamine;N-	1.29	--	3.30E-01	NA
95-47-6	o-Xylene	xylene,o-	0.2410	--	---	NA
87-86-5	Pentachlorophenol	pentachlorophenol	0.59	13	3.30E-01	2.09E+00
85-01-8	Phenanthrene	Phenanthrene	16.7	--	5.00E-02	NA
108-95-2	Phenol	Phenol	0.0288	--	3.30E-01	NA

Table B-5. Soil Screening Levels Protective of Surface Water for Non-radionuclides in the 100-NR-1 Operable Unit (analyte order)

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)	Soil Screening Level Protective of Surface Water [c,d] (mg/kg·m)
14265-44-2	Phosphate	Phosphate	--	--	5.00E+00	NA
7723-14-0	Phosphorus	phosphorus	3.50	--	5.00E+01	NA
PO4-P	Phosphorus in phosphate	Phosphorus in phosphate	3.50	--	---	NA
7440-09-7	Potassium	Potassium	5.50	--	4.00E+02	NA
129-00-0	Pyrene	pyrene	68	--	5.00E-02	NA
7782-49-2	Selenium	selenium and compounds	5.00	5.0	1.00E+00	6.57E+00
7440-21-3	Silicon	Silicon	--	--	2.00E+00	NA
7440-22-4	Silver	silver	8.3	2.6	2.00E-01	1.19E+01
7440-23-5	Sodium	Sodium	100	--	5.00E+01	NA
7440-24-6	Strontium	strontium	35.0	--	1.00E+00	NA
100-42-5	Styrene	styrene	0.91	--	5.00E-03	NA
14808-79-8	Sulfate	sulfate	0	--	5.00E+00	NA
127-18-4	Tetrachloroethene	tetrachloroethylene	0.2650	--	5.00E-03	NA
7440-28-0	Thallium	Thallium, soluble salts	71	--	5.00E-01	NA
7440-31-5	Tin	tin	250	--	1.00E+01	NA
108-88-3	Toluene	Toluene	0.1400	--	5.00E-03	NA
TPHDIESEL	Total petroleum hydrocarbons - diesel range	Total petroleum hydrocarbons - diesel range	4.00	--	---	NA
TPH/OILH	Total petroleum hydrocarbons - motor oil (high boiling)	Total petroleum hydrocarbons - motor oil (high boiling)	4.00	--	---	NA
8001-35-2	Toxaphene	toxaphene	96	2.00E-04	1.65E-01	NR
156-60-5	trans-1,2-Dichloroethylene	dichloroethylene;1,2-,trans	0.0380	--	5.00E-03	NA
10061-02-6	trans-1,3-Dichloropropene	dichloropropene;1,3-,trans	0.0270	--	5.00E-03	NA
126-73-8	Tributyl phosphate	Tributyl phosphate	2.35	--	---	NA
79-01-6	Trichloroethene	trichloroethylene (TCE)	0.0940	--	5.00E-03	NA
75-69-4	Trichloromonofluoromethane	trichlorofluoromethane	0.0439	--	---	NA
7440-61-1	Uranium	Uranium	NVR [f]	--	---	NVR [f]
7440-62-2	Vanadium	vanadium	1000	--	2.50E+00	NA
75-01-4	Vinyl chloride	vinyl chloride [chloroethene; 1-]	0.0186	--	5.00E-03	NA
1330-20-7	Xylenes (total)	Xylenes (total)	0.2330	--	1.00E-02	NA
7440-66-6	Zinc	zinc	62	91	1.00E+00	NR

a. ECF-HANFORD-12-0023, 2013, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*, Rev. 3, CH2M-HILL Plateau Remediation Company, Richland, Washington.

b. DOE/RL-2009-42, 2010, *Sampling and Analysis Plan for the 100 NR-1 and 100-NR-2 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington (Appendix A).

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 389,000 mg/kg, based on the maximum pore space contaminant mass capacity.

d. Scale soil screening level value by waste site dimension (m) parallel to groundwater flow direction.

e. The soil screening level for hexavalent chromium was limited to a maximum value of 6.0 mg/kg because the K_d value used in the model for residual hexavalent chromium was derived from experiments with soil concentrations below than that value.

f. No Value Required. Uranium is not modeled because uranium was not identified in the groundwater risk assessment as a COC.

Note: this table is presented in order of ascending analyte name for convenient lookup.

Table B-6. Soil Screening Levels Protective of Groundwater for Radionuclides in the 100-NR-1 Operable Unit (analyte order)

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)	Soil Screening Levels Protective of Groundwater [d,e] (pCi/g·m)
Americium-241	200	15	4.32E+02	1.00E+00	NR
Carbon-14 [f]	0	2000	5.7300E+03	---	2.35E+01
Carbon-14 [g]	200	2,000	5.73E+03	---	NR
Cesium-137	50	200	3.0000E+01	1.00E-01	NR
Cobalt-60	50	100	5.7210E+00	5.00E-02	NR
Curium-243	200	15	2.85E+01	---	NR
Europium-152	200	200	1.33E+01	1.00E-01	NR
Europium-154	200	60	8.80E+00	1.00E-01	NR
Europium-155	200	600	4.96E+00	1.00E-01	NR
Iodine-129	1	1	1.5700E+07	---	2.94E-01
Neptunium-237	15	15	2.1400E+06	---	NR
Nickel-63	30	50	9.6000E+01	---	NR
Niobium-94	200	--	2.03E+04	---	NA
Plutonium-238	200	15	8.77E+01	1.00E+00	NR
Plutonium-239	200	15	2.41E+04	1.00E+00	NR
Plutonium-240	200	15	6.54E+03	1.00E+00	NR
Plutonium-241	200	300	1.40E+01	---	NR
Radium-226	200	5	1.60E+03	---	NR
Radium-228	200	5	5.75E+00	2.00E-01	NR
Strontium-90 [h]	25	8	2.9120E+01	---	NR
Technetium-99	0	900	2.1300E+05	---	1.06E+01
Thorium-228	200	15	1.91E+00	---	NR
Thorium-230	200	15	7.70E+04	---	NR
Thorium-232	200	15	1.41E+10	---	NR
Tritium	0	20000	1.2350E+01	---	4.43E+02

a. ECF-HANFORD-12-0023, 2013, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*, Rev. 3, CH2M-HILL Plateau Remediation Company, Richland, Washington.

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

c. DOE/RL-2009-42, 2010, *Sampling and Analysis Plan for the 100 NR-1 and 100-NR-2 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington (Appendix A).

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/m^3 (a value set as the lower limit of numerical significance).

a. Value defaults to the estimated quantitation limit for any analyte where the calculated value is less than the estimated quantitation limit.

e. Scale soil screening level value by waste site dimension (m) parallel to groundwater flow direction.

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

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

h. The soil screening level for strontium-90 reported here is superseded by site-specific modeling results reported in ECF-100NR1-12-0056 Rev. 1, *Vadose Zone Transport Modeling to Calculate Strontium-90 Flux to Groundwater and Preliminary Remediation Goal in Support of the 100-N Remedial Investigation/Feasibility Study*. This value is only applicable to waste sites not located over the strontium-90 plume because a soil screening level protective of groundwater cannot be defined where the groundwater is already above the pertinent water quality standard.

Note: this table is presented in order of ascending analyte name for convenient lookup.

Attachment C

Preliminary Remediation Goals Protective of Groundwater and Preliminary Remediation Goals Protective of Surface Water for the 100-NR-1 Operable Unit

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Note

Tabulated preliminary remediation goal (PRG) values are presented in Tables C-1, C-2, and C-3 in ascending K_d order. This sorting order reveals the correlation between analyte K_d values and resulting PRG values. The threshold at which breakthrough does not occurs is denoted by a bold red borderline within these tables. Below this threshold, "NR" (non-representative result) values are reported (though shorter-lived radionuclides may result in "NR" values above the indicated threshold due to radiological decay). The "NR" code reflects that the model simulations did not predict breakthrough within 1000 years, defined here as a peak groundwater concentration exceeding 0.0001 μg/L for non-radionuclide analytes, or 0.0001 pCi/m^3 for radionuclide analytes), a value set as the lower limit of numerical significance for model groundwater concentration results.

The same PRG values are presented again in Tables C-4, C-5, and C-6, but in ascending analyte name order to enable lookup by the reader by analyte name.

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Table C-1. Preliminary Remediation Goals Protective of Groundwater for Non-radionuclides in the 100-NR-1 Operable Unit (K_d order)

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)	Preliminary Remediation Goal Protective of Groundwater [c,d] (mg/kg·m)
16887-00-6	Chloride	chloride	0	250,000	2.00E+00	5.10E+03
14797-55-8	Nitrate	Nitrate	0	45,000	2.50E+00	9.18E+02
14797-65-0	Nitrite	Nitrite	0	3,300	2.50E+00	6.73E+01
NO3-N	Nitrogen in Nitrate	Nitrogen in Nitrate	0	10,000	7.50E-01	2.04E+02
NO2-N	Nitrogen in Nitrite	Nitrogen in Nitrite	0	1,000	7.50E-01	2.04E+01
NO2+NO3-N	Nitrogen in Nitrite and Nitrate	Nitrogen in Nitrite and Nitrate	0	10,000	---	2.04E+02
14808-79-8	Sulfate	sulfate	0	250,000	5.00E+00	5.10E+03
51-28-5	2,4-Dinitrophenol	dinitrophenol;2,4-	0.00001	0,032	8.25E-01	8.25E-01
67-64-1	Acetone	Acetone	0.0006	7200	2.00E-02	1.49E+02
111-76-2	2-Butoxyethanol	ethylene glycol monobutyl ether (EGBE)	0.0028	800	---	1.74E+01
75-99-0	Dalapon	Dalapon	0.0032	200	---	4.37E+00
78-93-3	2-Butanone	methyl ethyl ketone (MEK; 2-butanone)	0.0045	4800.0	1.00E-02	1.08E+02
74-87-3	Chloromethane	chloromethane	0.0060	--	1.00E-02	NA
74-83-9	Bromomethane	bromomethane	0.0090	11.2	1.00E-02	2.75E-01
75-09-2	Methylene chloride	methylene chloride	0.0100	5.00	5.00E-03	1.25E-01
108-10-1	4-Methyl-2-pentanone	methyl isobutyl ketone	0.0126	640.00	1.00E-02	1.69E+01
111-91-1	Bis(2-Chloroethoxy)methane	bis(2-chloroethoxyl)methane	0.0144	48	3.30E-01	1.29E+00
591-78-6	2-Hexanone	HEXANONE;2-[MBK, methyl butyl ketone]	0.0150	0,040	2.00E-02	1.09E+00
75-01-4	Vinyl chloride	vinyl chloride [chloroethene; 1-]	0.0186	0.060763889	5.00E-03	5.00E-03
75-00-3	Chloroethane	ethyl chloride	0.0217	--	1.00E-02	NA
621-64-7	n-Nitrosodi-n-dipropylamine	nitroso-di-n-propylamine;N-	0.0240	0.01	3.30E-01	3.30E-01
10061-01-5	cis-1,3-Dichloropropene	dichloropropene;1,2-,cis	0.0270	0	5.00E-03	1.43E-02
10061-02-6	trans-1,3-Dichloropropene	dichloropropene;1,3-,trans	0.0270	0	5.00E-03	1.43E-02
1918-00-9	Dicamba	Dicamba	0.0288	480	---	1.61E+01
108-95-2	Phenol	Phenol	0.0288	2,400	3.30E-01	8.07E+01
131-11-3	Dimethyl phthalate	dimethyl phthalate	0.0316	--	3.30E-01	NA
156-59-2	cis-1,2-Dichloroethylene	dichloroethylene;1,2-,cis	0.0355	16.0	5.00E-03	5.89E-01
107-06-2	1,2-Dichloroethane	dichloroethane;1,2-	0.0380	0.5	5.00E-03	1.81E-02
156-60-5	trans-1,2-Dichloroethylene	dichloroethylene;1,2-,trans	0.0380	100.0	5.00E-03	3.77E+00
1918-02-1	4-Amino-3,5,6-trichloropicolinic acid	picloram	0.0388	500.00	---	1.90E+01
540-59-0	1,2-Dichloroethene (Total)	dichloroethylene,1,2- (mixed isomers)	0.0396	72.00	5.00E-03	2.77E+00
75-69-4	Trichloromonofluoromethane	trichlorofluoromethane	0.0439	2400.00	---	9.71E+01
75-15-0	Carbon disulfide	carbon disulfide	0.0457	800.0	5.00E-03	3.30E+01
78-59-1	Isophorone	isophorone	0.0468	46.05	3.30E-01	1.93E+00
78-87-5	1,2-Dichloropropane	dichloropropane;1,2-	0.0470	1	5.00E-03	5.09E-02
93-65-2	2-(2-methyl-4-chlorophenoxy) propionic acid	Mecoprop (MCPP)	0.0485	16.000	2.10E+00	2.10E+00
75-34-3	1,1-Dichloroethane	dichloroethane;1,1-	0.0530	7.68	1.00E-02	3.43E-01
67-66-3	Chloroform	chloroform	0.0530	0,001	5.00E-03	6.31E-02
75-27-4	Bromodichloromethane	bromodichloromethane	0.0550	0.71	5.00E-03	3.22E-02
71-43-2	Benzene	Benzene	0.0620	1	5.00E-03	3.90E-02

Table C-1. Preliminary Remediation Goals Protective of Groundwater for Non-radionuclides in the 100-NR-1 Operable Unit (K_d order)

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)	Preliminary Remediation Goal Protective of Groundwater [c,d] (mg/kg·m)
124-48-1	Dibromochloromethane	chlorodibromomethane [dibromochloromethane]	0.0631	0.52	5.00E-03	2.58E-02
75-35-4	1,1-Dichloroethene	Dichloroethene;1,1-	0.0650	7.00	1.00E-02	3.54E-01
106-47-8	4-Chloroaniline	chloroaniline;p-	0.0661	0.2	3.30E-01	3.30E-01
606-20-2	2,6-Dinitrotoluene	dinitrotoluene;2,6-	0.0692	16.0	3.30E-01	8.42E-01
79-00-5	1,1,2-Trichloroethane	trichloroethane;1,1,2-	0.0750	1	5.00E-03	4.26E-02
111-44-4	Bis(2-chloroethyl) ether	bis(2-chloroethyl)ether	0.0760	0	3.30E-01	3.30E-01
79-34-5	1,1,2,2-Tetrachloroethane	tetrachloroethane;1,1,2,2-	0.0790	0.2	5.00E-03	1.26E-02
84-66-2	Diethylphthalate	diethyl phthalate	0.0820	12800	3.30E-01	7.57E+02
108-60-1	Bis(2-chloro-1-methylethyl)ether	bis(2-chloro-1-methyl-ethyl)ether	0.0829	1	3.30E-01	3.30E-01
95-48-7	2-Methylphenol (cresol, o-)	cresol;o-	0.0912	400	3.30E-01	2.56E+01
79-01-6	Trichloroethene	trichloroethylene (TCE)	0.0940	0.95	5.00E-03	6.23E-02
121-14-2	2,4-Dinitrotoluene	dinitrotoluene;2,4-	0.0955	0,000	3.30E-01	3.30E-01
94-82-6	2,4-DB(4-(2,4-Dichlorophenoxy)butanoic acid)	Dichlorophenoxy)butyric Acid, 4-(2,4-	0.0984	128.0	1.30E-02	8.70E+00
99-09-2	3-Nitroaniline	nitroaniline, 3-	0.1090	4	3.30E-01	3.30E-01
100-01-6	4-Nitroaniline	nitroaniline, 4-	0.1091	0,004	3.30E-01	3.30E-01
88-74-4	2-Nitroaniline	nitroaniline, 2-	0.1113	0,160	3.30E-01	1.20E+01
98-95-3	Nitrobenzene	Nitrobenzene	0.1190	16.0	3.30E-01	1.28E+00
75-25-2	Bromoform	bromoform	0.1260	5.537974684	5.00E-03	4.66E-01
71-55-6	1,1,1-Trichloroethane	Trichloroethane;1,1,1-	0.1350	200	5.00E-03	1.80E+01
108-88-3	Toluene	Toluene	0.1400	640	5.00E-03	5.95E+01
120-83-2	2,4-Dichlorophenol	dichlorophenol;2,4-	0.1470	24	3.30E-01	2.34E+00
56-23-5	Carbon tetrachloride	carbon tetrachloride	0.1520	1	5.00E-03	6.31E-02
108-38-3	m-Xylene	Xylene, m-	0.1960	1600	---	2.14E+02
100-41-4	Ethylbenzene	ethylbenzene	0.2040	0,004	5.00E-03	5.59E-01
105-67-9	2,4-Dimethylphenol	dimethylphenol;2,4-	0.2090	160.00	3.30E-01	2.32E+01
108-90-7	Chlorobenzene	chlorobenzene	0.2240	100.0	5.00E-03	1.58E+01
1330-20-7	Xylenes (total)	Xylenes (total)	0.2330	1600.00	1.00E-02	2.66E+02
95-47-6	o-Xylene	xylene,o-	0.2410	1600.0	---	2.78E+02
127-18-4	Tetrachloroethene	tetrachloroethylene	0.2650	5	5.00E-03	9.87E-01
100-02-7	4-Nitrophenol	nitrophenol;4-	0.2910	--	6.60E-01	NA
88-75-5	2-Nitrophenol	nitrophenol;2-	0.30	--	6.60E-01	NA
106-44-5	4-Methylphenol (cresol, p-)	cresol;p-	0.30	800	---	1.89E+02
541-73-1	1,3-Dichlorobenzene	dichlorobenzene;1,3	0.38	--	3.30E-01	NA
95-50-1	1,2-Dichlorobenzene	dichlorobenzene;1,2- (ortho-Dichlorobenzene)	0.38	0,600	3.30E-01	2.02E+02
88-06-2	2,4,6-Trichlorophenol	Trichlorophenol2,4,6-	0.38	4	3.30E-01	1.35E+00
95-57-8	2-Chlorophenol	Chlorophenol;2-	0.39	40.0	3.30E-01	1.40E+01
59-50-7	4-Chloro-3-methylphenol	chloro-3-methylphenol;4-	0.49	1600.000	3.30E-01	8.25E+02
87-86-5	Pentachlorophenol	pentachlorophenol	0.59	0.2	3.30E-01	3.30E-01
106-46-7	1,4-Dichlorobenzene	dichlorobenzene;1,4- (para-Dichlorobenzene)	0.62	8	5.00E-03	6.31E+00
91-94-1	3,3'-Dichlorobenzidine	dichlorobenzidine;3,3'-	0.72	0.194	3.30E-01	3.30E-01

Table C-1. Preliminary Remediation Goals Protective of Groundwater for Non-radionuclides in the 100-NR-1 Operable Unit (K_d order)

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)	Preliminary Remediation Goal Protective of Groundwater [c,d] (mg/kg·m)
534-52-1	4,6-Dinitro-2-methylphenol	dinitro-2-methylphenol;4,6-	0.75	1.3	3.30E-01	1.51E+00
18540-29-9	Hexavalent Chromium	chromium(VI)	0.80	48	---	6 [e]
100-42-5	Styrene	styrene	0.91	100	5.00E-03	1.79E+02
91-20-3	Naphthalene	naphthalene	1.19	160	1.00E-01	5.46E+02
86-30-6	n-Nitrosodiphenylamine	nitrosodiphenylamine;N-	1.29	0,018	3.30E-01	7.50E+01
58-89-9	Gamma-BHC (Lindane)	lindane [gamma-BHC] (see hexachlorocyclohexane)	1.35	0.079545455	1.65E-03	3.76E-01
84-74-2	Di-n-butylphthalate	di-butyl phthalate	1.57	1600	3.30E-01	1.13E+04
95-95-4	2,4,5-Trichlorophenol	Trichlorophenol;2,4,5-	1.60	800	3.30E-01	5.98E+03
120-82-1	1,2,4-Trichlorobenzene	trichlorobenzene;1,2,4-	1.66	1.5	3.30E-01	1.21E+01
319-84-6	Alpha-BHC	hexachlorocyclohexane;alpha (alpha-BHC, HCH)	1.76	0.013888889	1.65E-03	1.18E-01
67-72-1	Hexachloroethane	hexachloroethane	1.78	1.09375	3.30E-01	9.43E+00
959-98-8	Endosulfan I	Endosulfan I	2.04	96	1.65E-03	NR
33213-65-9	Endosulfan II	Endosulfan II	2.04	96	3.30E-03	NR
319-85-7	beta-1,2,3,4,5,6-Hexachlorocyclohexane (beta-BHC)	hexachlorocyclohexane;beta-	2.14	0.048611111	1.65E-03	NR
126-73-8	Tributyl phosphate	Tributyl phosphate	2.35	10	---	NR
91-58-7	2-Chloronaphthalene	beta-chloronaphthalene	2.48	640	3.30E-01	NR
91-57-6	2-Methylnaphthalene	methylnapthalene;2-	2.48	32	3.30E-01	NR
319-86-8	Delta-BHC	hexachlorocyclohexane;delta-	2.81	--	1.65E-03	NA
7440-42-8	Boron	Boron	3.00	3200.0	2.00E+00	NR
101-55-3	4-Bromophenylphenyl ether	bromodiphenyl ether;4-	3.08	--	3.30E-01	NA
7005-72-3	4-Chlorophenylphenyl ether	chlorodiphenyl ether;4-	3.08	--	3.30E-01	NA
7421-93-4	Endrin aldehyde	Endrin aldehyde	3.27	--	3.30E-03	NA
86-74-8	Carbazole	carbazole	3.39	4.375	3.30E-01	NR
7723-14-0	Phosphorus	phosphorus	3.50	--	5.00E+01	NA
PO4-P	Phosphorus in phosphate	Phosphorus in phosphate	3.50	--	---	NA
TPHDIESEL	Total petroleum hydrocarbons - diesel range	Total petroleum hydrocarbons - diesel range	4.00	500	---	NR
TPH/OILH	Total petroleum hydrocarbons - motor oil (high boiling)	Total petroleum hydrocarbons - motor oil (high boiling)	4.00	500.0	---	NR
88-85-7	Dinoseb(2-secButyl-4,6-dinitrophenol)	Dinoseb	4.29	7	1.50E-03	NR
7439-95-4	Magnesium	Magnesium (Not in CLARC database Tables)	4.50	--	7.50E+01	NA
83-32-9	Acenaphthene	acenaphthene	4.90	480	1.00E-01	NR
7782-49-2	Selenium	selenium and compounds	5.00	50	1.00E+00	NR
208-96-8	Acenaphthylene	acenaphthylene (Not in CLARC database tables; use acenaphthene as surrogate)	5.03	--	1.00E-01	NA
7440-09-7	Potassium	Potassium	5.50	--	4.00E+02	NA

Table C-1. Preliminary Remediation Goals Protective of Groundwater for Non-radionuclides in the 100-NR-1 Operable Unit (K_d order)

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)	Preliminary Remediation Goal Protective of Groundwater [c,d] (mg/kg·m)
7440-43-9	Cadmium	cadmium	6.70	5.0000	2.00E-01	NR
86-73-7	Fluorene	fluorene	7.7	320.000	3.00E-02	NR
7440-22-4	Silver	silver	8.3	0,080	2.00E-01	NR
11104-28-2	Aroclor-1221	aroclor 1221 [PCB]	8.4	0,000	1.65E-02	NR
11141-16-5	Aroclor-1232	aroclor 1232 [PCB]	8.4	0.0	1.65E-02	NR
132-64-9	Dibenzofuran	dibenzofuran	9.2	8.0	3.30E-01	NR
76-44-8	Heptachlor	heptachlor	9.5	0.02	1.65E-03	NR
53494-70-5	Endrin ketone	Endrin ketone	9.7	--	3.30E-03	NA
1031-07-8	Endosulfan sulfate	Endosulfan sulfate	9.9	--	3.30E-03	NA
57-12-5	Cyanide	cyanide	9.9	4.80	---	NR
72-20-8	Endrin	endrin	10.8	2.00	3.30E-03	NR
85-68-7	Butylbenzylphthalate	butyl benzyl phthalate	13.8	46.1	3.30E-01	NR
85-01-8	Phenanthrene	Phenanthrene	16.7	--	5.00E-02	NA
7439-98-7	Molybdenum	molybdenum	20.0	0,080	2.00E+00	NR
7440-50-8	Copper	copper	22.0	640	1.00E+00	NR
120-12-7	Anthracene	anthracene	23.5	2400	5.00E-02	NR
7439-89-6	Iron	Iron	25.0	11200	5.00E+00	NR
60-57-1	Dieldrin	dieldrin	25.6	0.01	3.30E-03	NR
7440-38-2	Arsenic	arsenic, inorganic	29.0	0.058	1.00E+00	NR
7440-24-6	Strontium	strontium	35.0	9600.000	1.00E+00	NR
7440-39-3	Barium	Barium	41.0	2000.000	5.00E-01	NR
7440-36-0	Antimony	antimony	45.0	6	6.00E-01	NR
7440-48-4	cobalt	Cobalt	45.0	4.8000	2.00E+00	NR
72-54-8	4,4'-DDD (Dichlorodiphenyldichloroethane)	ddd	45.8	0.36	3.30E-03	NR
309-00-2	Aldrin	aldrin	48.7	0.003	1.65E-03	NR
206-44-0	Fluoranthene	fluoranthene	49	640	5.00E-02	NR
5103-71-9	Alpha-Chlordane	Alpha-Chlordane	51	0.25	1.65E-02	NR
57-74-9	Chlordane	chlordane	51	0.3	1.65E-02	NR
7439-97-6	Mercury	mercury (using mercruric chloride)	52	2.000	---	NR
87-68-3	Hexachlorobutadiene	hexachlorobutadiene	54	1	3.30E-01	NR
7440-66-6	Zinc	zinc	62	4800	1.00E+00	NR
7439-96-5	Manganese	manganese	65	0,384	5.00E+00	NR
7440-02-0	Nickel	nickel soluble salts	65	100	4.00E+00	NR
129-00-0	Pyrene	pyrene	68	240.00	5.00E-02	NR
7440-28-0	Thallium	Thallium, soluble salts	71	0.2	5.00E-01	NR
12672-29-6	Aroclor-1248	aroclor 1248 [PCB]	77	0	1.65E-02	NR
53469-21-9	Aroclor-1242	aroclor 1242 [PCB]	78	0.04	1.65E-02	NR
118-74-1	Hexachlorobenzene	hexachlorobenzene	80	0.1	3.30E-01	NR
72-43-5	Methoxychlor	methoxychlor	80	40.000	1.65E-02	NR
1024-57-3	Heptachlor epoxide	Heptachlor epoxide	83	0.005	1.65E-03	NR
72-55-9	4,4'-DDE (Dichlorodiphenyldichloroethylene)	dde	86	0	3.30E-03	NR
8001-35-2	Toxaphene	toxaphene	96	0	1.65E-01	NR
7440-23-5	Sodium	Sodium	100	--	5.00E+01	NA
12674-11-2	Aroclor-1016	aroclor 1016 (PCB)	107	0.50	1.65E-02	NR
117-81-7	Bis(2-ethylhexyl) phthalate	bis(2-ethylhexyl) phthalate	111	0,006	3.30E-01	NR
11097-69-1	Aroclor-1254	aroclor 1254 (PCB)	131	0.04	1.65E-02	NR

Table C-1. Preliminary Remediation Goals Protective of Groundwater for Non-radionuclides in the 100-NR-1 Operable Unit (K_d order)

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)	Preliminary Remediation Goal Protective of Groundwater [c,d] (mg/kg·m)
16984-48-8	Fluoride	fluoride (using fluorine)	150	960	5.00E+00	NR
77-47-4	Hexachlorocyclopentadiene	hexachlorocyclopentadiene	200	48.00	3.30E-01	NR
7440-31-5	Tin	tin	250	9600	1.00E+01	NR
7439-93-2	Lithium	Lithium	300	32	2.50E+00	NR
56-55-3	Benzo(a)anthracene	Benzo(a)anthracene	358	0.119863014	1.50E-02	NR
218-01-9	chrysene	Chrysene	398	1.198630137	1.00E-01	NR
7440-61-1	Uranium	Uranium	NVR [f]	30	---	NVR [f]
50-29-3	4,4'-DDT (Dichlorodiphenyltrichloroethane)	ddt	678	0.257352941	3.30E-03	NR
7440-41-7	Beryllium	beryllium	790	4	2.00E-01	NR
11096-82-5	Aroclor-1260	aroclor 1260 (PCB)	822	0.04375	1.65E-02	NR
50-32-8	Benzo(a)pyrene	Benzo(a)pyrene	969	0.011986301	1.50E-02	NR
7440-47-3	Chromium	chromium (total)	1000	100	2.00E-01	NR
7440-62-2	Vanadium	vanadium	1000	80	2.50E+00	NR
205-99-2	Benzo(b)fluoranthene	Benzo(b)fluoranthene	1230	0.119863014	1.50E-02	NR
207-08-9	Benzo(k)fluoranthene	Benzo(k)fluoranthene	1230	0.119863014	1.50E-02	NR
7429-90-5	Aluminum	Aluminum (soluble)	1500	16000	5.00E+00	NR
53-70-3	Dibenz[a,h]anthracene	Dibenz[a,h]anthracene	1789	0.119863014	3.00E-02	NR
191-24-2	Benzo(ghi)perylene	BENZO(g,h,i)PERYLENE (using pyrene as a surrogate)	1950	--	3.00E-02	NA
193-39-5	Indeno(1,2,3-cd)pyrene	Indeno(1,2,3-cd)pyrene	3470	0.119863014	3.00E-02	NR
7439-92-1	Lead	lead	10000	15	5.00E-01	NR
117-84-0	Di-n-octylphthalate	di-n-octyl phthalate	83200	192	3.30E-01	NR
65794-96-9	3+4 Methylphenol (cresol, m+p)	methylphenol,3+4 (cresol, m+p)	--	--	3.30E-01	NA
7440-69-9	Bismuth	Bismuth	--	--	1.00E+01	NA
24959-67-9	Bromide	Bromide	--	--	2.50E+00	NA
7440-70-2	Calcium	Calcium	--	--	1.00E+02	NA
PCB1242/1016	Co-elution of Aroclor 1242 and Aroclor 1016	Co-elution of Aroclor 1242 and Aroclor 1017	--	--	---	NA
14265-44-2	Phosphate	Phosphate	--	--	5.00E+00	NA
7440-21-3	Silicon	Silicon	--	--	2.00E+00	NA

a. ECF-HANFORD-12-0023, 2013, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*, Rev. 2, CH2M-HILL Plateau Remediation Company, Richland, Washington.

b. DOE/RL-2009-42, 2010, *Sampling and Analysis Plan for the 100 NR-1 and 100-NR-2 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington (Appendix A).

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). The threshold for breakthrough occurs at K_d = 2.04 mL/g for preliminary remediation goals, denoted in this table by a red threshold line.
- 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 389,000 mg/kg, based on the maximum pore space contaminant mass capacity.

d. Scale preliminary remediation goal value by waste site dimension (m) parallel to groundwater flow direction.

e. The preliminary remediation goal for hexavalent chromium was limited to a maximum value of 6.0 mg/kg because the K_d value used in the model for residual hexavalent chromium was derived from experiments with soil concentrations below than that value.

f. No Value Required. Uranium is not modeled because uranium was not identified in the groundwater risk assessment as a COC.

Note: this table is presented in order of ascending K_d to display the relationship between K_d and soil screening level values.

Table C-2. Preliminary Remediation Goals Protective of Surface Water for Non-radionuclides in the 100-NR-1 Operable Unit (K_d order)

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)	Preliminary Remediation Goal Protective of Surface Water [c,d] (mg/kg·m)
16887-00-6	Chloride	chloride	0	230,000	2.00E+00	4.69E+03
14797-55-8	Nitrate	Nitrate	0	--	2.50E+00	NA
14797-65-0	Nitrite	Nitrite	0	--	2.50E+00	NA
NO3-N	Nitrogen in Nitrate	Nitrogen in Nitrate	0	--	7.50E-01	NA
NO2-N	Nitrogen in Nitrite	Nitrogen in Nitrite	0	--	7.50E-01	NA
NO2+NO3-N	Nitrogen in Nitrite and Nitrate	Nitrogen in Nitrite and Nitrate	0	--	---	NA
14808-79-8	Sulfate	sulfate	0	--	5.00E+00	NA
51-28-5	2,4-Dinitrophenol	dinitrophenol;2,4-	0.00001	--	8.25E-01	NA
67-64-1	Acetone	Acetone	0.0006	--	2.00E-02	NA
111-76-2	2-Butoxyethanol	ethylene glycol monobutyl ether (EGBE)	0.0028	--	---	NA
75-99-0	Dalapon	Dalapon	0.0032	--	---	NA
78-93-3	2-Butanone	methyl ethyl ketone (MEK; 2-butanone)	0.0045	--	1.00E-02	NA
74-87-3	Chloromethane	chloromethane	0.0060	--	1.00E-02	NA
74-83-9	Bromomethane	bromomethane	0.0090	--	1.00E-02	NA
75-09-2	Methylene chloride	methylene chloride	0.0100	--	5.00E-03	NA
108-10-1	4-Methyl-2-pentanone	methyl isobutyl ketone	0.0126	--	1.00E-02	NA
111-91-1	Bis(2-Chloroethoxy)methane	bis(2-chloroethoxyl)methane	0.0144	--	3.30E-01	NA
591-78-6	2-Hexanone	HEXANONE;2-[MBK, methyl butyl ketone]	0.0150	--	2.00E-02	NA
75-01-4	Vinyl chloride	vinyl chloride [chloroethene; 1-]	0.0186	--	5.00E-03	NA
75-00-3	Chloroethane	ethyl chloride	0.0217	--	1.00E-02	NA
621-64-7	n-Nitrosodi-n-dipropylamine	nitroso-di-n-propylamine;N-	0.0240	--	3.30E-01	NA
10061-01-5	cis-1,3-Dichloropropene	dichloropropene;1,2-,cis	0.0270	--	5.00E-03	NA
10061-02-6	trans-1,3-Dichloropropene	dichloropropene;1,3-,trans	0.0270	--	5.00E-03	NA
1918-00-9	Dicamba	Dicamba	0.0288	--	---	NA
108-95-2	Phenol	Phenol	0.0288	--	3.30E-01	NA
131-11-3	Dimethyl phthalate	dimethyl phthalate	0.0316	--	3.30E-01	NA
156-59-2	cis-1,2-Dichloroethylene	dichloroethylene;1,2-,cis	0.0355	--	5.00E-03	NA
107-06-2	1,2-Dichloroethane	dichloroethane;1,2-	0.0380	--	5.00E-03	NA
156-60-5	trans-1,2-Dichloroethylene	dichloroethylene;1,2-,trans	0.0380	--	5.00E-03	NA
1918-02-1	4-Amino-3,5,6-trichloropicolinic acid	picloram	0.0388	--	---	NA
540-59-0	1,2-Dichloroethene (Total)	dichloroethylene,1,2- (mixed isomers)	0.0396	--	5.00E-03	NA
75-69-4	Trichloromonofluoromethane	trichlorofluoromethane	0.0439	--	---	NA
75-15-0	Carbon disulfide	carbon disulfide	0.0457	--	5.00E-03	NA
78-59-1	Isophorone	isophorone	0.0468	--	3.30E-01	NA
78-87-5	1,2-Dichloropropane	dichloropropane;1,2-	0.0470	--	5.00E-03	NA
93-65-2	2-(2-methyl-4-chlorophenoxy) propionic acid	Mecoprop (MCPP)	0.0485	--	2.10E+00	NA
75-34-3	1,1-Dichloroethane	dichloroethane;1,1-	0.0530	--	1.00E-02	NA
67-66-3	Chloroform	chloroform	0.0530	--	5.00E-03	NA
75-27-4	Bromodichloromethane	bromodichloromethane	0.0550	--	5.00E-03	NA
71-43-2	Benzene	Benzene	0.0620	--	5.00E-03	NA

Table C-2. Preliminary Remediation Goals Protective of Surface Water for Non-radionuclides in the 100-NR-1 Operable Unit (K_d order)

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)	Preliminary Remediation Goal Protective of Surface Water [c,d] (mg/kg·m)
124-48-1	Dibromochloromethane	chlorodibromomethane [dibromochloromethane]	0.0631	--	5.00E-03	NA
75-35-4	1,1-Dichloroethene	Dichloroethene;1,1-	0.0650	--	1.00E-02	NA
106-47-8	4-Chloroaniline	chloroaniline;p-	0.0661	--	3.30E-01	NA
606-20-2	2,6-Dinitrotoluene	dinitrotoluene;2,6-	0.0692	--	3.30E-01	NA
79-00-5	1,1,2-Trichloroethane	trichloroethane;1,1,2-	0.0750	--	5.00E-03	NA
111-44-4	Bis(2-chloroethyl) ether	bis(2-chloroethyl)ether	0.0760	--	3.30E-01	NA
79-34-5	1,1,2,2-Tetrachloroethane	tetrachloroethane;1,1,2,2-	0.0790	--	5.00E-03	NA
84-66-2	Diethylphthalate	diethyl phthalate	0.0820	--	3.30E-01	NA
108-60-1	Bis(2-chloro-1-methylethyl)ether	bis(2-chloro-1-methyl-ethyl)ether	0.0829	--	3.30E-01	NA
95-48-7	2-Methylphenol (cresol, o-)	cresol;o-	0.0912	--	3.30E-01	NA
79-01-6	Trichloroethene	trichloroethylene (TCE)	0.0940	--	5.00E-03	NA
121-14-2	2,4-Dinitrotoluene	dinitrotoluene;2,4-	0.0955	--	3.30E-01	NA
94-82-6	2,4-DB(4-(2,4-Dichlorophenoxy)butanoic acid)	Dichlorophenoxy)butyric Acid, 4-(2,4-	0.0984	--	1.30E-02	NA
99-09-2	3-Nitroaniline	nitroaniline, 3-	0.1090	--	3.30E-01	NA
100-01-6	4-Nitroaniline	nitroaniline, 4-	0.1091	--	3.30E-01	NA
88-74-4	2-Nitroaniline	nitroaniline, 2-	0.1113	--	3.30E-01	NA
98-95-3	Nitrobenzene	Nitrobenzene	0.1190	--	3.30E-01	NA
75-25-2	Bromoform	bromoform	0.1260	--	5.00E-03	NA
71-55-6	1,1,1-Trichloroethane	Trichloroethane;1,1,1-	0.1350	--	5.00E-03	NA
108-88-3	Toluene	Toluene	0.1400	--	5.00E-03	NA
120-83-2	2,4-Dichlorophenol	dichlorophenol;2,4-	0.1470	--	3.30E-01	NA
56-23-5	Carbon tetrachloride	carbon tetrachloride	0.1520	--	5.00E-03	NA
108-38-3	m-Xylene	Xylene, m-	0.1960	--	---	NA
100-41-4	Ethylbenzene	ethylbenzene	0.2040	--	5.00E-03	NA
105-67-9	2,4-Dimethylphenol	dimethylphenol;2,4-	0.2090	--	3.30E-01	NA
108-90-7	Chlorobenzene	chlorobenzene	0.2240	--	5.00E-03	NA
1330-20-7	Xylenes (total)	Xylenes (total)	0.2330	--	1.00E-02	NA
95-47-6	o-Xylene	xylene,o-	0.2410	--	---	NA
127-18-4	Tetrachloroethene	tetrachloroethylene	0.2650	--	5.00E-03	NA
100-02-7	4-Nitrophenol	nitrophenol;4-	0.2910	--	6.60E-01	NA
88-75-5	2-Nitrophenol	nitrophenol;2-	0.30	--	6.60E-01	NA
106-44-5	4-Methylphenol (cresol, p-)	cresol;p-	0.30	--	---	NA
541-73-1	1,3-Dichlorobenzene	dichlorobenzene;1,3	0.38	--	3.30E-01	NA
95-50-1	1,2-Dichlorobenzene	dichlorobenzene;1,2- (ortho-Dichlorobenzene)	0.38	--	3.30E-01	NA
88-06-2	2,4,6-Trichlorophenol	Trichlorophenol2,4,6-	0.38	--	3.30E-01	NA
95-57-8	2-Chlorophenol	Chlorophenol;2-	0.39	--	3.30E-01	NA
59-50-7	4-Chloro-3-methylphenol	chloro-3-methylphenol;4-	0.49	--	3.30E-01	NA
87-86-5	Pentachlorophenol	pentachlorophenol	0.59	13	3.30E-01	9.38E+00
106-46-7	1,4-Dichlorobenzene	dichlorobenzene;1,4- (para-Dichlorobenzene)	0.62	--	5.00E-03	NA
91-94-1	3,3'-Dichlorobenzidine	dichlorobenzidine;3,3'-	0.72	--	3.30E-01	NA

Table C-2. Preliminary Remediation Goals Protective of Surface Water for Non-radionuclides in the 100-NR-1 Operable Unit (K_d order)

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)	Preliminary Remediation Goal Protective of Surface Water [c,d] (mg/kg·m)
534-52-1	4,6-Dinitro-2-methylphenol	dinitro-2-methylphenol;4,6-	0.75	--	3.30E-01	NA
18540-29-9	Hexavalent Chromium	chromium(VI)	0.80	10	---	6 [e]
100-42-5	Styrene	styrene	0.91	--	5.00E-03	NA
91-20-3	Naphthalene	naphthalene	1.19	--	1.00E-01	NA
86-30-6	n-Nitrosodiphenylamine	nitrosodiphenylamine;N-	1.29	--	3.30E-01	NA
58-89-9	Gamma-BHC (Lindane)	lindane [gamma-BHC] (see hexachlorocyclohexane)	1.35	0.080	1.65E-03	3.78E-01
84-74-2	Di-n-butylphthalate	di-butyl phthalate	1.57	--	3.30E-01	NA
95-95-4	2,4,5-Trichlorophenol	Trichlorophenol;2,4,5-	1.60	--	3.30E-01	NA
120-82-1	1,2,4-Trichlorobenzene	trichlorobenzene;1,2,4-	1.66	--	3.30E-01	NA
319-84-6	Alpha-BHC	hexachlorocyclohexane;alpha (alpha-BHC, HCH)	1.76	--	1.65E-03	NA
67-72-1	Hexachloroethane	hexachloroethane	1.78	--	3.30E-01	NA
959-98-8	Endosulfan I	Endosulfan I	2.04	0.056	1.65E-03	NR
33213-65-9	Endosulfan II	Endosulfan II	2.04	0.056	3.30E-03	NR
319-85-7	beta-1,2,3,4,5,6-Hexachlorocyclohexane (beta-BHC)	hexachlorocyclohexane;beta-	2.14	--	1.65E-03	NA
126-73-8	Tributyl phosphate	Tributyl phosphate	2.35	--	---	NA
91-58-7	2-Chloronaphthalene	beta-chloronaphthalene	2.48	--	3.30E-01	NA
91-57-6	2-Methylnaphthalene	methylnapthalene;2-	2.48	--	3.30E-01	NA
319-86-8	Delta-BHC	hexachlorocyclohexane;delta-	2.81	--	1.65E-03	NA
7440-42-8	Boron	Boron	3.00	--	2.00E+00	NA
101-55-3	4-Bromophenylphenyl ether	bromodiphenyl ether;4-	3.08	--	3.30E-01	NA
7005-72-3	4-Chlorophenylphenyl ether	chlorodiphenyl ether;4-	3.08	--	3.30E-01	NA
7421-93-4	Endrin aldehyde	Endrin aldehyde	3.27	--	3.30E-03	NA
86-74-8	Carbazole	carbazole	3.39	--	3.30E-01	NA
7723-14-0	Phosphorus	phosphorus	3.50	--	5.00E+01	NA
PO4-P	Phosphorus in phosphate	Phosphorus in phosphate	3.50	--	---	NA
TPHDIESEL	Total petroleum hydrocarbons - diesel range	Total petroleum hydrocarbons - diesel range	4.00	--	---	NA
TPH/OILH	Total petroleum hydrocarbons - motor oil (high boiling)	Total petroleum hydrocarbons - motor oil (high boiling)	4.00	--	---	NA
88-85-7	Dinoseb(2-secButyl-4,6-dinitrophenol)	Dinoseb	4.29	--	1.50E-03	NA
7439-95-4	Magnesium	Magnesium (Not in CLARC database Tables)	4.50	--	7.50E+01	NA
83-32-9	Acenaphthene	acenaphthene	4.90	--	1.00E-01	NA
7782-49-2	Selenium	selenium and compounds	5.00	5.0	1.00E+00	NR
208-96-8	Acenaphthylene	acenaphthylene (Not in CLARC database tables; use acenaphthene as surrogate)	5.03	--	1.00E-01	NA
7440-09-7	Potassium	Potassium	5.50	--	4.00E+02	NA

Table C-2. Preliminary Remediation Goals Protective of Surface Water for Non-radionuclides in the 100-NR-1 Operable Unit (K_d order)

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)	Preliminary Remediation Goal Protective of Surface Water [c,d] (mg/kg·m)
7440-43-9	Cadmium	cadmium	6.70	0.25	2.00E-01	NR
86-73-7	Fluorene	fluorene	7.7	--	3.00E-02	NA
7440-22-4	Silver	silver	8.3	2.6	2.00E-01	NR
11104-28-2	Aroclor-1221	aroclor 1221 [PCB]	8.4	0.014	1.65E-02	NR
11141-16-5	Aroclor-1232	aroclor 1232 [PCB]	8.4	0.014	1.65E-02	NR
132-64-9	Dibenzofuran	dibenzofuran	9.2	--	3.30E-01	NA
76-44-8	Heptachlor	heptachlor	9.5	0.0038	1.65E-03	NR
53494-70-5	Endrin ketone	Endrin ketone	9.7	--	3.30E-03	NA
1031-07-8	Endosulfan sulfate	Endosulfan sulfate	9.9	--	3.30E-03	NA
57-12-5	Cyanide	cyanide	9.9	5.2	---	NR
72-20-8	Endrin	endrin	10.8	0.0023	3.30E-03	NR
85-68-7	Butylbenzylphthalate	butyl benzyl phthalate	13.8	--	3.30E-01	NA
85-01-8	Phenanthrene	Phenanthrene	16.7	--	5.00E-02	NA
7439-98-7	Molybdenum	molybdenum	20.0	--	2.00E+00	NA
7440-50-8	Copper	copper	22.0	9.0	1.00E+00	NR
120-12-7	Anthracene	anthracene	23.5	--	5.00E-02	NA
7439-89-6	Iron	Iron	25.0	1,000	5.00E+00	NR
60-57-1	Dieldrin	dieldrin	25.6	0.0019	3.30E-03	NR
7440-38-2	Arsenic	arsenic, inorganic	29.0	150	1.00E+00	NR
7440-24-6	Strontium	strontium	35.0	--	1.00E+00	NA
7440-39-3	Barium	Barium	41.0	--	5.00E-01	NA
7440-36-0	Antimony	antimony	45.0	--	6.00E-01	NA
7440-48-4	cobalt	Cobalt	45.0	--	2.00E+00	NA
72-54-8	4,4'-DDD (Dichlorodiphenyldichloroethane)	ddd	45.8	--	3.30E-03	NA
309-00-2	Aldrin	aldrin	48.7	0.0019	1.65E-03	NR
206-44-0	Fluoranthene	fluoranthene	49	--	5.00E-02	NA
5103-71-9	Alpha-Chlordane	Alpha-Chlordane	51	0.0043	1.65E-02	NR
57-74-9	Chlordane	chlordane	51	0.0043	1.65E-02	NR
7439-97-6	Mercury	mercury (using mercruric chloride)	52	0.012	---	NR
87-68-3	Hexachlorobutadiene	hexachlorobutadiene	54	--	3.30E-01	NA
7440-66-6	Zinc	zinc	62	91	1.00E+00	NR
7439-96-5	Manganese	manganese	65	--	5.00E+00	NA
7440-02-0	Nickel	nickel soluble salts	65	52	4.00E+00	NR
129-00-0	Pyrene	pyrene	68	--	5.00E-02	NA
7440-28-0	Thallium	Thallium, soluble salts	71	--	5.00E-01	NA
12672-29-6	Aroclor-1248	aroclor 1248 [PCB]	77	0.014	1.65E-02	NR
53469-21-9	Aroclor-1242	aroclor 1242 [PCB]	78	0.014	1.65E-02	NR
118-74-1	Hexachlorobenzene	hexachlorobenzene	80	--	3.30E-01	NA
72-43-5	Methoxychlor	methoxychlor	80	0.030	1.65E-02	NR
1024-57-3	Heptachlor epoxide	Heptachlor epoxide	83	0.0038	1.65E-03	NR
72-55-9	4,4'-DDE (Dichlorodiphenyldichloroethylene)	dde	86	--	3.30E-03	NA
8001-35-2	Toxaphene	toxaphene	96	2.00E-04	1.65E-01	NR
7440-23-5	Sodium	Sodium	100	--	5.00E+01	NA
12674-11-2	Aroclor-1016	aroclor 1016 (PCB)	107	0.014	1.65E-02	NR
117-81-7	Bis(2-ethylhexyl) phthalate	bis(2-ethylhexyl) phthalate	111	--	3.30E-01	NA
11097-69-1	Aroclor-1254	aroclor 1254 (PCB)	131	0.014	1.65E-02	NR

Table C-2. Preliminary Remediation Goals Protective of Surface Water for Non-radionuclides in the 100-NR-1 Operable Unit (K_d order)

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)	Preliminary Remediation Goal Protective of Surface Water [c,d] (mg/kg·m)
16984-48-8	Fluoride	fluoride (using fluorine)	150	--	5.00E+00	NA
77-47-4	Hexachlorocyclopentadiene	hexachlorocyclopentadiene	200	--	3.30E-01	NA
7440-31-5	Tin	tin	250	--	1.00E+01	NA
7439-93-2	Lithium	Lithium	300	--	2.50E+00	NA
56-55-3	Benzo(a)anthracene	Benzo(a)anthracene	358	--	1.50E-02	NA
218-01-9	chrysene	Chrysene	398	--	1.00E-01	NA
7440-61-1	Uranium	Uranium	NVR [f]	--	---	NVR [f]
50-29-3	4,4'-DDT (Dichlorodiphenyltrichloroethane)	ddt	678	0.0010	3.30E-03	NR
7440-41-7	Beryllium	beryllium	790	--	2.00E-01	NA
11096-82-5	Aroclor-1260	aroclor 1260 (PCB)	822	0.014	1.65E-02	NR
50-32-8	Benzo(a)pyrene	Benzo(a)pyrene	969	--	1.50E-02	NA
7440-47-3	Chromium	chromium (total)	1000	65	2.00E-01	NR
7440-62-2	Vanadium	vanadium	1000	--	2.50E+00	NA
205-99-2	Benzo(b)fluoranthene	Benzo(b)fluoranthene	1230	--	1.50E-02	NA
207-08-9	Benzo(k)fluoranthene	Benzo(k)fluoranthene	1230	--	1.50E-02	NA
7429-90-5	Aluminum	Aluminum (soluble)	1500	87	5.00E+00	NR
53-70-3	Dibenz[a,h]anthracene	Dibenz[a,h]anthracene	1789	--	3.00E-02	NA
191-24-2	Benzo(ghi)perylene	BENZO(g,h,i)PERYLENE (using pyrene as a surrogate)	1950	--	3.00E-02	NA
193-39-5	Indeno(1,2,3-cd)pyrene	Indeno(1,2,3-cd)pyrene	3470	--	3.00E-02	NA
7439-92-1	Lead	lead	10000	2.1	5.00E-01	NR
117-84-0	Di-n-octylphthalate	di-n-octyl phthalate	83200	--	3.30E-01	NA
65794-96-9	3+4 Methylphenol (cresol, m+p)	methylphenol,3+4 (cresol, m+p)	--	--	3.30E-01	NA
7440-69-9	Bismuth	Bismuth	--	--	1.00E+01	NA
24959-67-9	Bromide	Bromide	--	--	2.50E+00	NA
7440-70-2	Calcium	Calcium	--	--	1.00E+02	NA
PCB1242/1016	Co-elution of Aroclor 1242 and Aroclor 1016	Co-elution of Aroclor 1242 and Aroclor 1017	--	--	---	NA
14265-44-2	Phosphate	Phosphate	--	--	5.00E+00	NA
7440-21-3	Silicon	Silicon	--	--	2.00E+00	NA

a. ECF-HANFORD-12-0023, 2013, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*, Rev. 2, CH2M-HILL Plateau Remediation Company, Richland, Washington.

b. DOE/RL-2009-42, 2010, *Sampling and Analysis Plan for the 100 NR-1 and 100-NR-2 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington (Appendix A).

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). The threshold for breakthrough occurs at K_d = 2.04 mL/g for preliminary remediation goals, denoted in this table by a red threshold line.
- 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 389,000 mg/kg, based on the maximum pore space contaminant mass capacity.

d. Scale preliminary remediation goal value by waste site dimension (m) parallel to groundwater flow direction.

e. The preliminary remediation goal for hexavalent chromium was limited to a maximum value of 6.0 mg/kg because the K_d value used in the model for residual hexavalent chromium was derived from experiments with soil concentrations below than that value.

f. No Value Required. Uranium is not modeled because uranium was not identified in the groundwater risk assessment as a COC.

Note: this table is presented in order of ascending K_d to display the relationship between K_d and soil screening level values.

Table C-3. Preliminary Remediation Goals Protective of Groundwater for Radionuclides in the 100-NR-1 Operable Unit (K_d order)

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)	Preliminary Remediation Goal Protective of Groundwater [d,e] (pCi/g·m)
Carbon-14 [f]	0	2000	5.7300E+03	---	4.08E+01
Technetium-99	0	900	2.1300E+05	---	1.84E+01
Tritium	0	20000	1.2350E+01	---	6.03E+02
Iodine-129	1	1	1.5700E+07	---	2.23E+00
Neptunium-237	15	15	2.1400E+06	---	NR
Strontium-90 [g]	25	8	2.9120E+01	---	NR
Nickel-63	30	50	9.6000E+01	---	NR
Cesium-137	50	200	3.0000E+01	1.00E-01	NR
Cobalt-60	50	100	5.7210E+00	5.00E-02	NR
Americium-241	200	15	4.32E+02	1.00E+00	NR
Carbon-14 [h]	200	2,000	5.73E+03	---	NR
Curium-243	200	15	2.85E+01	---	NR
Europium-152	200	200	1.33E+01	1.00E-01	NR
Europium-154	200	60	8.80E+00	1.00E-01	NR
Europium-155	200	600	4.96E+00	1.00E-01	NR
Niobium-94	200	--	2.03E+04	---	NA
Plutonium-238	200	15	8.77E+01	1.00E+00	NR
Plutonium-239	200	15	2.41E+04	1.00E+00	NR
Plutonium-240	200	15	6.54E+03	1.00E+00	NR
Plutonium-241	200	300	1.40E+01	---	NR
Radium-226	200	5	1.60E+03	---	NR
Radium-228	200	5	5.75E+00	2.00E-01	NR
Thorium-228	200	15	1.91E+00	---	NR
Thorium-230	200	15	7.70E+04	---	NR
Thorium-232	200	15	1.41E+10	---	NR

a. ECF-HANFORD-12-0023, 2013, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*, Rev. 2, CH2M-HILL Plateau Remediation Company, Richland, Washington.

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

c. DOE/RL-2009-42, 2010, *Sampling and Analysis Plan for the 100 NR-1 and 100-NR-2 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington (Appendix A).

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/m^3 (a value set as the lower limit of numerical significance). The threshold for breakthrough occurs at K_d = 15 mL/g for preliminary remediation goals, denoted in this table by a red threshold line.
- Value defaults to the estimated quantitation limit for any analyte where the calculated value is less than the estimated quantitation limit.

e. Scale preliminary remediation goal value by waste site dimension (m) parallel to groundwater flow direction.

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

g. The preliminary remediation goal for strontium-90 reported here is superseded by site-specific modeling results reported in ECF-100NR1-12-0056, *Vadose Zone Transport Modeling to Calculate Strontium-90 Flux to Groundwater and Preliminary Remediation Goal in Support of the 100-N Remedial Investigation/Feasibility Study*.

h. Carbon-14 in solid form (typically associated with graphite). This value is only applicable to waste sites not located over the strontium-90 plume because a preliminary remediation goal protective of groundwater cannot be defined where the groundwater is already above the pertinent water quality standard.

Note: this table is presented in order of ascending K_d to display the relationship between K_d and preliminary remediation goal values.

Table C-4. Preliminary Remediation Goals Protective of Groundwater for Non-radionuclides in the 100-NR-1 Operable Unit (analyte order)

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)	Preliminary Remediation Goal Protective of Groundwater [c,d] (mg/kg·m)
71-55-6	1,1,1-Trichloroethane	Trichloroethane;1,1,1-	0.1350	200	5.00E-03	1.80E+01
79-34-5	1,1,2,2-Tetrachloroethane	tetrachloroethane;1,1,2,2-	0.0790	0.2	5.00E-03	1.26E-02
79-00-5	1,1,2-Trichloroethane	trichloroethane;1,1,2-	0.0750	1	5.00E-03	4.26E-02
75-34-3	1,1-Dichloroethane	dichloroethane;1,1-	0.0530	7.68	1.00E-02	3.43E-01
75-35-4	1,1-Dichloroethene	Dichloroethene;1,1-	0.0650	7.00	1.00E-02	3.54E-01
120-82-1	1,2,4-Trichlorobenzene	trichlorobenzene;1,2,4-	1.66	1.5	3.30E-01	1.21E+01
95-50-1	1,2-Dichlorobenzene	dichlorobenzene;1,2- (ortho-Dichlorobenzene)	0.38	0,600	3.30E-01	2.02E+02
107-06-2	1,2-Dichloroethane	dichloroethane;1,2-	0.0380	0.5	5.00E-03	1.81E-02
540-59-0	1,2-Dichloroethene (Total)	dichloroethylene,1,2- (mixed isomers)	0.0396	72.00	5.00E-03	2.77E+00
78-87-5	1,2-Dichloropropane	dichloropropane;1,2-	0.0470	1	5.00E-03	5.09E-02
541-73-1	1,3-Dichlorobenzene	dichlorobenzene;1,3	0.38	--	3.30E-01	NA
106-46-7	1,4-Dichlorobenzene	dichlorobenzene;1,4- (para-Dichlorobenzene)	0.62	8	5.00E-03	6.31E+00
93-65-2	2-(2-methyl-4-chlorophenoxy) propionic acid	Mecoprop (MCPP)	0.0485	16.000	2.10E+00	2.10E+00
95-95-4	2,4,5-Trichlorophenol	Trichlorophenol;2,4,5-	1.60	800	3.30E-01	5.98E+03
88-06-2	2,4,6-Trichlorophenol	Trichlorophenol2,4,6-	0.38	4	3.30E-01	1.35E+00
94-82-6	2,4-DB(4-(2,4-Dichlorophenoxy)butanoic acid)	Dichlorophenoxy)butyric Acid, 4-(2,4-	0.0984	128.0	1.30E-02	8.70E+00
120-83-2	2,4-Dichlorophenol	dichlorophenol;2,4-	0.1470	24	3.30E-01	2.34E+00
105-67-9	2,4-Dimethylphenol	dimethylphenol;2,4-	0.2090	160.00	3.30E-01	2.32E+01
51-28-5	2,4-Dinitrophenol	dinitrophenol;2,4-	0.00001	0,032	8.25E-01	8.25E-01
121-14-2	2,4-Dinitrotoluene	dinitrotoluene;2,4-	0.0955	0,000	3.30E-01	3.30E-01
606-20-2	2,6-Dinitrotoluene	dinitrotoluene;2,6-	0.0692	16.0	3.30E-01	8.42E-01
78-93-3	2-Butanone	methyl ethyl ketone (MEK; 2-butanone)	0.0045	4800.0	1.00E-02	1.08E+02
111-76-2	2-Butoxyethanol	ethylene glycol monobutyl ether (EGBE)	0.0028	800	---	1.74E+01
91-58-7	2-Chloronaphthalene	beta-chloronaphthalene	2.48	640	3.30E-01	NR
95-57-8	2-Chlorophenol	Chlorophenol;2-	0.39	40.0	3.30E-01	1.40E+01
591-78-6	2-Hexanone	HEXANONE;2-[MBK, methyl butyl ketone]	0.0150	0,040	2.00E-02	1.09E+00
91-57-6	2-Methylnaphthalene	methylnapthalene;2-	2.48	32	3.30E-01	NR
95-48-7	2-Methylphenol (cresol, o-)	cresol;o-	0.0912	400	3.30E-01	2.56E+01
88-74-4	2-Nitroaniline	nitroaniline, 2-	0.1113	0,160	3.30E-01	1.20E+01
88-75-5	2-Nitrophenol	nitrophenol;2-	0.30	--	6.60E-01	NA
91-94-1	3,3'-Dichlorobenzidine	dichlorobenzidine;3,3'-	0.72	0.194	3.30E-01	3.30E-01
65794-96-9	3+4 Methylphenol (cresol, m+p)	methylphenol,3+4 (cresol, m+p)	--	--	3.30E-01	NA
99-09-2	3-Nitroaniline	nitroaniline, 3-	0.1090	4	3.30E-01	3.30E-01
72-54-8	4,4'-DDD (Dichlorodiphenyldichloroethane)	ddd	45.8	0.36	3.30E-03	NR
72-55-9	4,4'-DDE (Dichlorodiphenyldichloroethylene)	dde	86	0	3.30E-03	NR

Table C-4. Preliminary Remediation Goals Protective of Groundwater for Non-radionuclides in the 100-NR-1 Operable Unit (analyte order)

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)	Preliminary Remediation Goal Protective of Groundwater [c,d] (mg/kg·m)
50-29-3	4,4'-DDT (Dichlorodiphenyltric hloroethane)	ddt	678	0.257352941	3.30E-03	NR
534-52-1	4,6-Dinitro-2-methylphenol	dinitro-2-methylphenol;4,6-	0.75	1.3	3.30E-01	1.51E+00
1918-02-1	4-Amino-3,5,6-trichloropicolinic acid	picloram	0.0388	500.00	---	1.90E+01
101-55-3	4-Bromophenylphenyl ether	bromodiphenyl ether;4-	3.08	--	3.30E-01	NA
59-50-7	4-Chloro-3-methylphenol	chloro-3-methylphenol;4-	0.49	1600.000	3.30E-01	8.25E+02
106-47-8	4-Chloroaniline	chloroaniline;p-	0.0661	0.2	3.30E-01	3.30E-01
7005-72-3	4-Chlorophenylphenyl ether	chlorodiphenyl ether;4-	3.08	--	3.30E-01	NA
108-10-1	4-Methyl-2-pentanone	methyl isobutyl ketone	0.0126	640.00	1.00E-02	1.69E+01
106-44-5	4-Methylphenol (cresol, p-)	cresol;p-	0.30	800	---	1.89E+02
100-01-6	4-Nitroaniline	nitroaniline, 4-	0.1091	0,004	3.30E-01	3.30E-01
100-02-7	4-Nitrophenol	nitrophenol;4-	0.2910	--	6.60E-01	NA
83-32-9	Acenaphthene	acenaphthene	4.90	480	1.00E-01	NR
208-96-8	Acenaphthylene	acenaphthylene (Not in CLARC database tables; use acenaphthene as surrogate)	5.03	--	1.00E-01	NA
67-64-1	Acetone	Acetone	0.0006	7200	2.00E-02	1.49E+02
309-00-2	Aldrin	aldrin	48.7	0.003	1.65E-03	NR
319-84-6	Alpha-BHC	hexachlorocyclohex ane;alpha (alpha-BHC, HCH)	1.76	0.013888889	1.65E-03	1.18E-01
5103-71-9	Alpha-Chlordane	Alpha-Chlordane	51	0.25	1.65E-02	NR
7429-90-5	Aluminum	Aluminum (soluble)	1500	16000	5.00E+00	NR
120-12-7	Anthracene	anthracene	23.5	2400	5.00E-02	NR
7440-36-0	Antimony	antimony	45.0	6	6.00E-01	NR
12674-11-2	Aroclor-1016	aroclor 1016 (PCB)	107	0.50	1.65E-02	NR
11104-28-2	Aroclor-1221	aroclor 1221 [PCB]	8.4	0,000	1.65E-02	NR
11141-16-5	Aroclor-1232	aroclor 1232 [PCB]	8.4	0.0	1.65E-02	NR
53469-21-9	Aroclor-1242	aroclor 1242 [PCB]	78	0.04	1.65E-02	NR
12672-29-6	Aroclor-1248	aroclor 1248 [PCB]	77	0	1.65E-02	NR
11097-69-1	Aroclor-1254	aroclor 1254 (PCB)	131	0.04	1.65E-02	NR
11096-82-5	Aroclor-1260	aroclor 1260 (PCB)	822	0.04375	1.65E-02	NR
7440-38-2	Arsenic	arsenic, inorganic	29.0	0.058	1.00E+00	NR
7440-39-3	Barium	Barium	41.0	2000.000	5.00E-01	NR
71-43-2	Benzene	Benzene	0.0620	1	5.00E-03	3.90E-02
56-55-3	Benzo(a)anthracene	Benzo(a)anthracene	358	0.119863014	1.50E-02	NR
50-32-8	Benzo(a)pyrene	Benzo(a)pyrene	969	0.011986301	1.50E-02	NR
205-99-2	Benzo(b)fluoranthen e	Benzo(b)fluoranthen e	1230	0.119863014	1.50E-02	NR
191-24-2	Benzo(ghi)perylene	BENZO(g,h,i)PERY LENE (using pyrene as a surrogate)	1950	--	3.00E-02	NA
207-08-9	Benzo(k)fluoranthen e	Benzo(k)fluoranthen e	1230	0.119863014	1.50E-02	NR
7440-41-7	Beryllium	beryllium	790	4	2.00E-01	NR
319-85-7	beta-1,2,3,4,5,6-Hexachlorocyclohex ane (beta-BHC)	hexachlorocyclohex ane;beta-	2.14	0.048611111	1.65E-03	NR
108-60-1	Bis(2-chloro-1-methylethyl)ether	bis(2-chloro-1-methyl-ethyl)ether	0.0829	1	3.30E-01	3.30E-01

Table C-4. Preliminary Remediation Goals Protective of Groundwater for Non-radionuclides in the 100-NR-1 Operable Unit (analyte order)

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)	Preliminary Remediation Goal Protective of Groundwater [c,d] (mg/kg·m)
111-91-1	Bis(2-Chloroethoxy)methane	bis(2-chloroethoxyl)methane	0.0144	48	3.30E-01	1.29E+00
111-44-4	Bis(2-chloroethyl) ether	bis(2-chloroethyl)ether	0.0760	0	3.30E-01	3.30E-01
117-81-7	Bis(2-ethylhexyl) phthalate	bis(2-ethylhexyl) phthalate	111	0,006	3.30E-01	NR
7440-69-9	Bismuth	Bismuth	--	--	1.00E+01	NA
7440-42-8	Boron	Boron	3.00	3200.0	2.00E+00	NR
24959-67-9	Bromide	Bromide	--	--	2.50E+00	NA
75-27-4	Bromodichloromethane	bromodichloromethane	0.0550	0.71	5.00E-03	3.22E-02
75-25-2	Bromoform	bromoform	0.1260	5.537974684	5.00E-03	4.66E-01
74-83-9	Bromomethane	bromomethane	0.0090	11.2	1.00E-02	2.75E-01
85-68-7	Butylbenzylphthalate	butyl benzyl phthalate	13.8	46.1	3.30E-01	NR
7440-43-9	Cadmium	cadmium	6.70	5.0000	2.00E-01	NR
7440-70-2	Calcium	Calcium	--	--	1.00E+02	NA
86-74-8	Carbazole	carbazole	3.39	4.375	3.30E-01	NR
75-15-0	Carbon disulfide	carbon disulfide	0.0457	800.0	5.00E-03	3.30E+01
56-23-5	Carbon tetrachloride	carbon tetrachloride	0.1520	1	5.00E-03	6.31E-02
57-74-9	Chlordane	chlordane	51	0.3	1.65E-02	NR
16887-00-6	Chloride	chloride	0	250,000	2.00E+00	5.10E+03
108-90-7	Chlorobenzene	chlorobenzene	0.2240	100.0	5.00E-03	1.58E+01
75-00-3	Chloroethane	ethyl chloride	0.0217	--	1.00E-02	NA
67-66-3	Chloroform	chloroform	0.0530	0,001	5.00E-03	6.31E-02
74-87-3	Chloromethane	chloromethane	0.0060	--	1.00E-02	NA
7440-47-3	Chromium	chromium (total)	1000	100	2.00E-01	NR
218-01-9	chrysene	Chrysene	398	1.198630137	1.00E-01	NR
156-59-2	cis-1,2-Dichloroethylene	dichloroethylene;1,2-,cis	0.0355	16.0	5.00E-03	5.89E-01
10061-01-5	cis-1,3-Dichloropropene	dichloropropene;1,2-,cis	0.0270	0	5.00E-03	1.43E-02
7440-48-4	cobalt	Cobalt	45.0	4.8000	2.00E+00	NR
PCB1242/1016	Co-elution of Aroclor 1242 and Aroclor 1016	Co-elution of Aroclor 1242 and Aroclor 1017	--	--	---	NA
7440-50-8	Copper	copper	22.0	640	1.00E+00	NR
57-12-5	Cyanide	cyanide	9.9	4.80	---	NR
75-99-0	Dalapon	Dalapon	0.0032	200	---	4.37E+00
319-86-8	Delta-BHC	hexachlorocyclohexane;delta-	2.81	--	1.65E-03	NA
53-70-3	Dibenz[a,h]anthracene	Dibenz[a,h]anthracene	1789	0.119863014	3.00E-02	NR
132-64-9	Dibenzofuran	dibenzofuran	9.2	8.0	3.30E-01	NR
124-48-1	Dibromochloromethane	chlorodibromomethane [dibromochloromethane]	0.0631	0.52	5.00E-03	2.58E-02
1918-00-9	Dicamba	Dicamba	0.0288	480	---	1.61E+01
60-57-1	Dieldrin	dieldrin	25.6	0.01	3.30E-03	NR
84-66-2	Diethylphthalate	diethyl phthalate	0.0820	12800	3.30E-01	7.57E+02
131-11-3	Dimethyl phthalate	dimethyl phthalate	0.0316	--	3.30E-01	NA
84-74-2	Di-n-butylphthalate	di-butyl phthalate	1.57	1600	3.30E-01	1.13E+04
117-84-0	Di-n-octylphthalate	di-n-octyl phthalate	83200	192	3.30E-01	NR
88-85-7	Dinoseb(2-secButyl-4,6-dinitrophenol)	Dinoseb	4.29	7	1.50E-03	NR
959-98-8	Endosulfan I	Endosulfan I	2.04	96	1.65E-03	NR
33213-65-9	Endosulfan II	Endosulfan II	2.04	96	3.30E-03	NR

Table C-4. Preliminary Remediation Goals Protective of Groundwater for Non-radionuclides in the 100-NR-1 Operable Unit (analyte order)

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)	Preliminary Remediation Goal Protective of Groundwater [c,d] (mg/kg·m)
PO4-P	Phosphorus in phosphate	Phosphorus in phosphate	3.50	--	---	NA
7440-09-7	Potassium	Potassium	5.50	--	4.00E+02	NA
129-00-0	Pyrene	pyrene	68	240.00	5.00E-02	NR
7782-49-2	Selenium	selenium and compounds	5.00	50	1.00E+00	NR
7440-21-3	Silicon	Silicon	--	--	2.00E+00	NA
7440-22-4	Silver	silver	8.3	0,080	2.00E-01	NR
7440-23-5	Sodium	Sodium	100	--	5.00E+01	NA
7440-24-6	Strontium	strontium	35.0	9600.000	1.00E+00	NR
100-42-5	Styrene	styrene	0.91	100	5.00E-03	1.79E+02
14808-79-8	Sulfate	sulfate	0	250,000	5.00E+00	5.10E+03
127-18-4	Tetrachloroethene	tetrachloroethylene	0.2650	5	5.00E-03	9.87E-01
7440-28-0	Thallium	Thallium, soluble salts	71	0.2	5.00E-01	NR
7440-31-5	Tin	tin	250	9600	1.00E+01	NR
108-88-3	Toluene	Toluene	0.1400	640	5.00E-03	5.95E+01
TPHDIESEL	Total petroleum hydrocarbons - diesel range	Total petroleum hydrocarbons - diesel range	4.00	500	---	NR
TPH/OILH	Total petroleum hydrocarbons - motor oil (high boiling)	Total petroleum hydrocarbons - motor oil (high boiling)	4.00	500.0	---	NR
8001-35-2	Toxaphene	toxaphene	96	0	1.65E-01	NR
156-60-5	trans-1,2-Dichloroethylene	dichloroethylene;1,2-,trans	0.0380	100.0	5.00E-03	3.77E+00
10061-02-6	trans-1,3-Dichloropropene	dichloropropene;1,3-,trans	0.0270	0	5.00E-03	1.43E-02
126-73-8	Tributyl phosphate	Tributyl phosphate	2.35	10	---	NR
79-01-6	Trichloroethene	trichloroethylene (TCE)	0.0940	0.95	5.00E-03	6.23E-02
75-69-4	Trichloromonofluoromethane	trichlorofluoromethane	0.0439	2400.00	---	9.71E+01
7440-61-1	Uranium	Uranium	NVR [f]	30	---	NVR [f]
7440-62-2	Vanadium	vanadium	1000	80	2.50E+00	NR
75-01-4	Vinyl chloride	vinyl chloride [chloroethene; 1-]	0.0186	0.060763889	5.00E-03	5.00E-03
1330-20-7	Xylenes (total)	Xylenes (total)	0.2330	1600.00	1.00E-02	2.66E+02
7440-66-6	Zinc	zinc	62	4800	1.00E+00	NR

a. ECF-HANFORD-12-0023, 2013, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*, Rev. 2, CH2M-HILL Plateau Remediation Company, Richland, Washington.

b. DOE/RL-2009-42, 2010, *Sampling and Analysis Plan for the 100 NR-1 and 100-NR-2 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington (Appendix A).

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 389,000 mg/kg, based on the maximum pore space contaminant mass capacity.

d. Scale preliminary remediation goal value by waste site dimension (m) parallel to groundwater flow direction.

e. The preliminary remediation goal for hexavalent chromium was limited to a maximum value of 6.0 mg/kg because the K_d value used in the model for residual hexavalent chromium was derived from experiments with soil concentrations below than that value.

f. No Value Required. Uranium is not modeled because uranium was not identified in the groundwater risk assessment as a COC.

Note: this table is presented in order of ascending analyte name order for lookup convenience.

Table C-5. Preliminary Remediation Goals Protective of Surface Water for Non-radionuclides in the 100-NR-1 Operable Unit (analyte order)

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)	Preliminary Remediation Goal Protective of Surface Water [c,d] (mg/kg·m)
71-55-6	1,1,1-Trichloroethane	Trichloroethane;1,1,1-	0.1350	--	5.00E-03	NA
79-34-5	1,1,2,2-Tetrachloroethane	tetrachloroethane;1,1,2,2-	0.0790	--	5.00E-03	NA
79-00-5	1,1,2-Trichloroethane	trichloroethane;1,1,2-	0.0750	--	5.00E-03	NA
75-34-3	1,1-Dichloroethane	dichloroethane;1,1-	0.0530	--	1.00E-02	NA
75-35-4	1,1-Dichloroethene	Dichloroethene;1,1-	0.0650	--	1.00E-02	NA
120-82-1	1,2,4-Trichlorobenzene	trichlorobenzene;1,2,4-	1.66	--	3.30E-01	NA
95-50-1	1,2-Dichlorobenzene	dichlorobenzene;1,2- (ortho-Dichlorobenzene)	0.38	--	3.30E-01	NA
107-06-2	1,2-Dichloroethane	dichloroethane;1,2-	0.0380	--	5.00E-03	NA
540-59-0	1,2-Dichloroethene (Total)	dichloroethylene,1,2- (mixed isomers)	0.0396	--	5.00E-03	NA
78-87-5	1,2-Dichloropropane	dichloropropane;1,2-	0.0470	--	5.00E-03	NA
541-73-1	1,3-Dichlorobenzene	dichlorobenzene;1,3	0.38	--	3.30E-01	NA
106-46-7	1,4-Dichlorobenzene	dichlorobenzene;1,4- (para-Dichlorobenzene)	0.62	--	5.00E-03	NA
93-65-2	2-(2-methyl-4-chlorophenoxy) propionic acid	Mecoprop (MCPP)	0.0485	--	2.10E+00	NA
95-95-4	2,4,5-Trichlorophenol	Trichlorophenol;2,4,5-	1.60	--	3.30E-01	NA
88-06-2	2,4,6-Trichlorophenol	Trichlorophenol2,4,6-	0.38	--	3.30E-01	NA
94-82-6	2,4-DB(4-(2,4-Dichlorophenoxy)butanoic acid)	Dichlorophenoxy)butyric Acid, 4-(2,4-	0.0984	--	1.30E-02	NA
120-83-2	2,4-Dichlorophenol	dichlorophenol;2,4-	0.1470	--	3.30E-01	NA
105-67-9	2,4-Dimethylphenol	dimethylphenol;2,4-	0.2090	--	3.30E-01	NA
51-28-5	2,4-Dinitrophenol	dinitrophenol;2,4-	0.00001	--	8.25E-01	NA
121-14-2	2,4-Dinitrotoluene	dinitrotoluene;2,4-	0.0955	--	3.30E-01	NA
606-20-2	2,6-Dinitrotoluene	dinitrotoluene;2,6-	0.0692	--	3.30E-01	NA
78-93-3	2-Butanone	methyl ethyl ketone (MEK; 2-butanone)	0.0045	--	1.00E-02	NA
111-76-2	2-Butoxyethanol	ethylene glycol monobutyl ether (EGBE)	0.0028	--	---	NA
91-58-7	2-Chloronaphthalene	beta-chloronaphthalene	2.48	--	3.30E-01	NA
95-57-8	2-Chlorophenol	Chlorophenol;2-	0.39	--	3.30E-01	NA
591-78-6	2-Hexanone	HEXANONE;2- [MBK, methyl butyl ketone]	0.0150	--	2.00E-02	NA
91-57-6	2-Methylnaphthalene	methylnapthalene;2-	2.48	--	3.30E-01	NA
95-48-7	2-Methylphenol (cresol, o-)	cresol;o-	0.0912	--	3.30E-01	NA
88-74-4	2-Nitroaniline	nitroaniline, 2-	0.1113	--	3.30E-01	NA
88-75-5	2-Nitrophenol	nitrophenol;2-	0.30	--	6.60E-01	NA
91-94-1	3,3'-Dichlorobenzidine	dichlorobenzidine;3,3'-	0.72	--	3.30E-01	NA
65794-96-9	3+4 Methylphenol (cresol, m+p)	methylphenol,3+4 (cresol, m+p)	--	--	3.30E-01	NA
99-09-2	3-Nitroaniline	nitroaniline, 3-	0.1090	--	3.30E-01	NA
72-54-8	4,4'-DDD (Dichlorodiphenyldichloroethane)	ddd	45.8	--	3.30E-03	NA
72-55-9	4,4'-DDE (Dichlorodiphenyldichloroethylene)	dde	86	--	3.30E-03	NA

Table C-5. Preliminary Remediation Goals Protective of Surface Water for Non-radionuclides in the 100-NR-1 Operable Unit (analyte order)

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)	Preliminary Remediation Goal Protective of Surface Water [c,d] (mg/kg·m)
50-29-3	4,4'-DDT (Dichlorodiphenyltric hloroethane)	ddt	678	0.0010	3.30E-03	NR
534-52-1	4,6-Dinitro-2-methylphenol	dinitro-2-methylphenol;4,6-	0.75	--	3.30E-01	NA
1918-02-1	4-Amino-3,5,6-trichloropicolinic acid	picloram	0.0388	--	---	NA
101-55-3	4-Bromophenylphenyl ether	bromodiphenyl ether;4-	3.08	--	3.30E-01	NA
59-50-7	4-Chloro-3-methylphenol	chloro-3-methylphenol;4-	0.49	--	3.30E-01	NA
106-47-8	4-Chloroaniline	chloroaniline;p-	0.0661	--	3.30E-01	NA
7005-72-3	4-Chlorophenylphenyl ether	chlorodiphenyl ether;4-	3.08	--	3.30E-01	NA
108-10-1	4-Methyl-2-pentanone	methyl isobutyl ketone	0.0126	--	1.00E-02	NA
106-44-5	4-Methylphenol (cresol, p-)	cresol;p-	0.30	--	---	NA
100-01-6	4-Nitroaniline	nitroaniline, 4-	0.1091	--	3.30E-01	NA
100-02-7	4-Nitrophenol	nitrophenol;4-	0.2910	--	6.60E-01	NA
83-32-9	Acenaphthene	acenaphthene	4.90	--	1.00E-01	NA
208-96-8	Acenaphthylene	acenaphthylene (Not in CLARC database tables; use acenaphthene as surrogate)	5.03	--	1.00E-01	NA
67-64-1	Acetone	Acetone	0.0006	--	2.00E-02	NA
309-00-2	Aldrin	aldrin	48.7	0.0019	1.65E-03	NR
319-84-6	Alpha-BHC	hexachlorocyclohex ane;alpha (alpha-BHC, HCH)	1.76	--	1.65E-03	NA
5103-71-9	Alpha-Chlordane	Alpha-Chlordane	51	0.0043	1.65E-02	NR
7429-90-5	Aluminum	Aluminum (soluble)	1500	87	5.00E+00	NR
120-12-7	Anthracene	anthracene	23.5	--	5.00E-02	NA
7440-36-0	Antimony	antimony	45.0	--	6.00E-01	NA
12674-11-2	Aroclor-1016	aroclor 1016 (PCB)	107	0.014	1.65E-02	NR
11104-28-2	Aroclor-1221	aroclor 1221 [PCB]	8.4	0.014	1.65E-02	NR
11141-16-5	Aroclor-1232	aroclor 1232 [PCB]	8.4	0.014	1.65E-02	NR
53469-21-9	Aroclor-1242	aroclor 1242 [PCB]	78	0.014	1.65E-02	NR
12672-29-6	Aroclor-1248	aroclor 1248 [PCB]	77	0.014	1.65E-02	NR
11097-69-1	Aroclor-1254	aroclor 1254 (PCB)	131	0.014	1.65E-02	NR
11096-82-5	Aroclor-1260	aroclor 1260 (PCB)	822	0.014	1.65E-02	NR
7440-38-2	Arsenic	arsenic, inorganic	29.0	150	1.00E+00	NR
7440-39-3	Barium	Barium	41.0	--	5.00E-01	NA
71-43-2	Benzene	Benzene	0.0620	--	5.00E-03	NA
56-55-3	Benzo(a)anthracene	Benzo(a)anthracene	358	--	1.50E-02	NA
50-32-8	Benzo(a)pyrene	Benzo(a)pyrene	969	--	1.50E-02	NA
205-99-2	Benzo(b)fluoranthen e	Benzo(b)fluoranthen e	1230	--	1.50E-02	NA
191-24-2	Benzo(ghi)perylene	BENZO(g,h,i)PERY LENE (using pyrene as a surrogate)	1950	--	3.00E-02	NA
207-08-9	Benzo(k)fluoranthen e	Benzo(k)fluoranthen e	1230	--	1.50E-02	NA
7440-41-7	Beryllium	beryllium	790	--	2.00E-01	NA
319-85-7	beta-1,2,3,4,5,6-Hexachlorocyclohex ane (beta-BHC)	hexachlorocyclohex ane;beta-	2.14	--	1.65E-03	NA
108-60-1	Bis(2-chloro-1-methylethyl)ether	bis(2-chloro-1-methyl-ethyl)ether	0.0829	--	3.30E-01	NA

Table C-5. Preliminary Remediation Goals Protective of Surface Water for Non-radionuclides in the 100-NR-1 Operable Unit (analyte order)

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)	Preliminary Remediation Goal Protective of Surface Water [c,d] (mg/kg·m)
111-91-1	Bis(2-Chloroethoxy)methane	bis(2-chloroethoxyl)methane	0.0144	--	3.30E-01	NA
111-44-4	Bis(2-chloroethyl) ether	bis(2-chloroethyl)ether	0.0760	--	3.30E-01	NA
117-81-7	Bis(2-ethylhexyl) phthalate	bis(2-ethylhexyl) phthalate	111	--	3.30E-01	NA
7440-69-9	Bismuth	Bismuth	--	--	1.00E+01	NA
7440-42-8	Boron	Boron	3.00	--	2.00E+00	NA
24959-67-9	Bromide	Bromide	--	--	2.50E+00	NA
75-27-4	Bromodichloromethane	bromodichloromethane	0.0550	--	5.00E-03	NA
75-25-2	Bromoform	bromoform	0.1260	--	5.00E-03	NA
74-83-9	Bromomethane	bromomethane	0.0090	--	1.00E-02	NA
85-68-7	Butylbenzylphthalate	butyl benzyl phthalate	13.8	--	3.30E-01	NA
7440-43-9	Cadmium	cadmium	6.70	0.25	2.00E-01	NR
7440-70-2	Calcium	Calcium	--	--	1.00E+02	NA
86-74-8	Carbazole	carbazole	3.39	--	3.30E-01	NA
75-15-0	Carbon disulfide	carbon disulfide	0.0457	--	5.00E-03	NA
56-23-5	Carbon tetrachloride	carbon tetrachloride	0.1520	--	5.00E-03	NA
57-74-9	Chlordane	chlordane	51	0.0043	1.65E-02	NR
16887-00-6	Chloride	chloride	0	230,000	2.00E+00	4.69E+03
108-90-7	Chlorobenzene	chlorobenzene	0.2240	--	5.00E-03	NA
75-00-3	Chloroethane	ethyl chloride	0.0217	--	1.00E-02	NA
67-66-3	Chloroform	chloroform	0.0530	--	5.00E-03	NA
74-87-3	Chloromethane	chloromethane	0.0060	--	1.00E-02	NA
7440-47-3	Chromium	chromium (total)	1000	65	2.00E-01	NR
218-01-9	chrysene	Chrysene	398	--	1.00E-01	NA
156-59-2	cis-1,2-Dichloroethylene	dichloroethylene;1,2-,cis	0.0355	--	5.00E-03	NA
10061-01-5	cis-1,3-Dichloropropene	dichloropropene;1,2-,cis	0.0270	--	5.00E-03	NA
7440-48-4	cobalt	Cobalt	45.0	--	2.00E+00	NA
PCB1242/1016	Co-elution of Aroclor 1242 and Aroclor 1016	Co-elution of Aroclor 1242 and Aroclor 1017	--	--	---	NA
7440-50-8	Copper	copper	22.0	9.0	1.00E+00	NR
57-12-5	Cyanide	cyanide	9.9	5.2	---	NR
75-99-0	Dalapon	Dalapon	0.0032	--	---	NA
319-86-8	Delta-BHC	hexachlorocyclohexane;delta-	2.81	--	1.65E-03	NA
53-70-3	Dibenz[a,h]anthracene	Dibenz[a,h]anthracene	1789	--	3.00E-02	NA
132-64-9	Dibenzofuran	dibenzofuran	9.2	--	3.30E-01	NA
124-48-1	Dibromochloromethane	chlorodibromomethane [dibromochloromethane]	0.0631	--	5.00E-03	NA
1918-00-9	Dicamba	Dicamba	0.0288	--	---	NA
60-57-1	Dieldrin	dieldrin	25.6	0.0019	3.30E-03	NR
84-66-2	Diethylphthalate	diethyl phthalate	0.0820	--	3.30E-01	NA
131-11-3	Dimethyl phthalate	dimethyl phthalate	0.0316	--	3.30E-01	NA
84-74-2	Di-n-butylphthalate	di-butyl phthalate	1.57	--	3.30E-01	NA
117-84-0	Di-n-octylphthalate	di-n-octyl phthalate	83200	--	3.30E-01	NA
88-85-7	Dinoseb(2-secButyl-4,6-dinitrophenol)	Dinoseb	4.29	--	1.50E-03	NA
959-98-8	Endosulfan I	Endosulfan I	2.04	0.056	1.65E-03	NR
33213-65-9	Endosulfan II	Endosulfan II	2.04	0.056	3.30E-03	NR

Table C-5. Preliminary Remediation Goals Protective of Surface Water for Non-radionuclides in the 100-NR-1 Operable Unit (analyte order)

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)	Preliminary Remediation Goal Protective of Surface Water [c,d] (mg/kg·m)
1031-07-8	Endosulfan sulfate	Endosulfan sulfate	9.9	--	3.30E-03	NA
72-20-8	Endrin	endrin	10.8	0.0023	3.30E-03	NR
7421-93-4	Endrin aldehyde	Endrin aldehyde	3.27	--	3.30E-03	NA
53494-70-5	Endrin ketone	Endrin ketone	9.7	--	3.30E-03	NA
100-41-4	Ethylbenzene	ethylbenzene	0.2040	--	5.00E-03	NA
206-44-0	Fluoranthene	fluoranthene	49	--	5.00E-02	NA
86-73-7	Fluorene	fluorene	7.7	--	3.00E-02	NA
16984-48-8	Fluoride	fluoride (using fluorine)	150	--	5.00E+00	NA
58-89-9	Gamma-BHC (Lindane)	lindane [gamma-BHC] (see hexachlorocyclohexane)	1.35	0.080	1.65E-03	3.78E-01
76-44-8	Heptachlor	heptachlor	9.5	0.0038	1.65E-03	NR
1024-57-3	Heptachlor epoxide	Heptachlor epoxide	83	0.0038	1.65E-03	NR
118-74-1	Hexachlorobenzene	hexachlorobenzene	80	--	3.30E-01	NA
87-68-3	Hexachlorobutadiene	hexachlorobutadiene	54	--	3.30E-01	NA
77-47-4	Hexachlorocyclopentadiene	hexachlorocyclopentadiene	200	--	3.30E-01	NA
67-72-1	Hexachloroethane	hexachloroethane	1.78	--	3.30E-01	NA
18540-29-9	Hexavalent Chromium	chromium(VI)	0.80	10	---	6 [e]
193-39-5	Indeno(1,2,3-cd)pyrene	Indeno(1,2,3-cd)pyrene	3470	--	3.00E-02	NA
7439-89-6	Iron	Iron	25.0	1,000	5.00E+00	NR
78-59-1	Isophorone	isophorone	0.0468	--	3.30E-01	NA
7439-92-1	Lead	lead	10000	2.1	5.00E-01	NR
7439-93-2	Lithium	Lithium	300	--	2.50E+00	NA
7439-95-4	Magnesium	Magnesium (Not in CLARC database Tables)	4.50	--	7.50E+01	NA
7439-96-5	Manganese	manganese	65	--	5.00E+00	NA
7439-97-6	Mercury	mercury (using mercruric chloride)	52	0.012	---	NR
72-43-5	Methoxychlor	methoxychlor	80	0.030	1.65E-02	NR
75-09-2	Methylene chloride	methylene chloride	0.0100	--	5.00E-03	NA
7439-98-7	Molybdenum	molybdenum	20.0	--	2.00E+00	NA
108-38-3	m-Xylene	Xylene, m-	0.1960	--	---	NA
91-20-3	Naphthalene	naphthalene	1.19	--	1.00E-01	NA
7440-02-0	Nickel	nickel soluble salts	65	52	4.00E+00	NR
14797-55-8	Nitrate	Nitrate	0	--	2.50E+00	NA
14797-65-0	Nitrite	Nitrite	0	--	2.50E+00	NA
98-95-3	Nitrobenzene	Nitrobenzene	0.1190	--	3.30E-01	NA
NO3-N	Nitrogen in Nitrate	Nitrogen in Nitrate	0	--	7.50E-01	NA
NO2-N	Nitrogen in Nitrite	Nitrogen in Nitrite	0	--	7.50E-01	NA
NO2+NO3-N	Nitrogen in Nitrite and Nitrate	Nitrogen in Nitrite and Nitrate	0	--	---	NA
621-64-7	n-Nitrosodi-n-dipropylamine	nitroso-di-n-propylamine;N-	0.0240	--	3.30E-01	NA
86-30-6	n-Nitrosodiphenylamine	nitrosodiphenylamine;N-	1.29	--	3.30E-01	NA
95-47-6	o-Xylene	xylene,o-	0.2410	--	---	NA
87-86-5	Pentachlorophenol	pentachlorophenol	0.59	13	3.30E-01	9.38E+00
85-01-8	Phenanthrene	Phenanthrene	16.7	--	5.00E-02	NA
108-95-2	Phenol	Phenol	0.0288	--	3.30E-01	NA
14265-44-2	Phosphate	Phosphate	--	--	5.00E+00	NA
7723-14-0	Phosphorus	phosphorus	3.50	--	5.00E+01	NA

Table C-5. Preliminary Remediation Goals Protective of Surface Water for Non-radionuclides in the 100-NR-1 Operable Unit (analyte order)

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)	Preliminary Remediation Goal Protective of Surface Water [c,d] (mg/kg·m)
PO4-P	Phosphorus in phosphate	Phosphorus in phosphate	3.50	--	---	NA
7440-09-7	Potassium	Potassium	5.50	--	4.00E+02	NA
129-00-0	Pyrene	pyrene	68	--	5.00E-02	NA
7782-49-2	Selenium	selenium and compounds	5.00	5.0	1.00E+00	NR
7440-21-3	Silicon	Silicon	--	--	2.00E+00	NA
7440-22-4	Silver	silver	8.3	2.6	2.00E-01	NR
7440-23-5	Sodium	Sodium	100	--	5.00E+01	NA
7440-24-6	Strontium	strontium	35.0	--	1.00E+00	NA
100-42-5	Styrene	styrene	0.91	--	5.00E-03	NA
14808-79-8	Sulfate	sulfate	0	--	5.00E+00	NA
127-18-4	Tetrachloroethene	tetrachloroethylene	0.2650	--	5.00E-03	NA
7440-28-0	Thallium	Thallium, soluble salts	71	--	5.00E-01	NA
7440-31-5	Tin	tin	250	--	1.00E+01	NA
108-88-3	Toluene	Toluene	0.1400	--	5.00E-03	NA
TPHDIESEL	Total petroleum hydrocarbons - diesel range	Total petroleum hydrocarbons - diesel range	4.00	--	---	NA
TPH/OILH	Total petroleum hydrocarbons - motor oil (high boiling)	Total petroleum hydrocarbons - motor oil (high boiling)	4.00	--	---	NA
8001-35-2	Toxaphene	toxaphene	96	2.00E-04	1.65E-01	NR
156-60-5	trans-1,2-Dichloroethylene	dichloroethylene;1,2-,trans	0.0380	--	5.00E-03	NA
10061-02-6	trans-1,3-Dichloropropene	dichloropropene;1,3-,trans	0.0270	--	5.00E-03	NA
126-73-8	Tributyl phosphate	Tributyl phosphate	2.35	--	---	NA
79-01-6	Trichloroethene	trichloroethylene (TCE)	0.0940	--	5.00E-03	NA
75-69-4	Trichloromonofluoromethane	trichlorofluoromethane	0.0439	--	---	NA
7440-61-1	Uranium	Uranium	NVR [f]	--	---	NVR [f]
7440-62-2	Vanadium	vanadium	1000	--	2.50E+00	NA
75-01-4	Vinyl chloride	vinyl chloride [chloroethene; 1-]	0.0186	--	5.00E-03	NA
1330-20-7	Xylenes (total)	Xylenes (total)	0.2330	--	1.00E-02	NA
7440-66-6	Zinc	zinc	62	91	1.00E+00	NR

a. ECF-HANFORD-12-0023, 2013, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*, Rev. 2, CH2M-HILL Plateau Remediation Company, Richland, Washington.

b. DOE/RL-2009-42, 2010, *Sampling and Analysis Plan for the 100 NR-1 and 100-NR-2 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington (Appendix A).

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 389,000 mg/kg, based on the maximum pore space contaminant mass capacity.

d. Scale preliminary remediation goal value by waste site dimension (m) parallel to groundwater flow direction.

e. The preliminary remediation goal for hexavalent chromium was limited to a maximum value of 6.0 mg/kg because the K_d value used in the model for residual hexavalent chromium was derived from experiments with soil concentrations below than that value.

f. No Value Required. Uranium is not modeled because uranium was not identified in the groundwater risk assessment as a COC.

Note: this table is presented in order of ascending analyte name order for lookup convenience.

Table C-6. Preliminary Remediation Goals Protective of Groundwater for Radionuclides in the 100-NR-1 Operable Unit (analyte order)

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)	Preliminary Remediation Goal Protective of Groundwater [d,e] (pCi/g·m)
Americium-241	200	15	4.32E+02	1.00E+00	NR
Carbon-14 [f]	0	2000	5.7300E+03	---	4.08E+01
Carbon-14 [g]	200	2,000	5.73E+03	---	NR
Cesium-137	50	200	3.0000E+01	1.00E-01	NR
Cobalt-60	50	100	5.7210E+00	5.00E-02	NR
Curium-243	200	15	2.85E+01	---	NR
Europium-152	200	200	1.33E+01	1.00E-01	NR
Europium-154	200	60	8.80E+00	1.00E-01	NR
Europium-155	200	600	4.96E+00	1.00E-01	NR
Iodine-129	1	1	1.5700E+07	---	2.23E+00
Neptunium-237	15	15	2.1400E+06	---	NR
Nickel-63	30	50	9.6000E+01	---	NR
Niobium-94	200	--	2.03E+04	---	NA
Plutonium-238	200	15	8.77E+01	1.00E+00	NR
Plutonium-239	200	15	2.41E+04	1.00E+00	NR
Plutonium-240	200	15	6.54E+03	1.00E+00	NR
Plutonium-241	200	300	1.40E+01	---	NR
Radium-226	200	5	1.60E+03	---	NR
Radium-228	200	5	5.75E+00	2.00E-01	NR
Strontium-90 [h]	25	8	2.9120E+01	---	NR
Technetium-99	0	900	2.1300E+05	---	1.84E+01
Thorium-228	200	15	1.91E+00	---	NR
Thorium-230	200	15	7.70E+04	---	NR
Thorium-232	200	15	1.41E+10	---	NR
Tritium	0	20000	1.2350E+01	---	6.03E+02

a. ECF-HANFORD-12-0023, 2013, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*, Rev. 2, CH2M-HILL Plateau Remediation Company, Richland, Washington.

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

c. DOE/RL-2009-42, 2010, *Sampling and Analysis Plan for the 100 NR-1 and 100-NR-2 Operable Units Remedial Investigation/Feasibility Study*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington (Appendix A).

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/m^3 (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. Scale preliminary remediation goal value by waste site dimension (m) parallel to groundwater flow direction.

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

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

h. The preliminary remediation goal for strontium-90 reported here is superseded by site-specific modeling results reported in ECF-100NR1-12-0056, *Vadose Zone Transport Modeling to Calculate Strontium-90 Flux to Groundwater and Preliminary Remediation Goal in Support of the 100-N Remedial Investigation/Feasibility Study*. This value is only applicable to waste sites not located over the strontium-90 plume because a preliminary remediation goal protective of groundwater cannot be defined where the groundwater is already above the pertinent water quality standard.

Note: this table is presented in order of ascending analyte name order for lookup convenience.

Attachment D

Software Installation and Checkout Forms for STOMP

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Note

This attachment provides a copy of the completed Software Installation and Checkout Form for the tested, approved installation of STOMP used for the calculations reported in this ECF.

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.: Bld 4

EXECUTABLE INFORMATION:

2. Executable Name (include path):

All executable files installed in directory /srv/samba/saved_data/bin

MD5 File Signature	Executable File Name
6536b8e12d8c5b83dca76f2c947b6153	stomp-wae-bcg-chprc04i.x
e0cdf04bc1a2f6c55c5a1b499939f663	stomp-wae-bcg-chprc04l.x
6e72340bb39f6056e232fe5ff241c4d4	stomp-wae-bd-chprc04i.x
3f837a0fb8d9f47dbcada686f542d7fc	stomp-wae-bd-chprc04l.x
7e5b4cc36a8991b3d5a8ea2ed155ce47	stomp-wae-cgsq-chprc04i.x
00a898c0c3ec06817485781ad1c9ec46	stomp-wae-cgsq-chprc04l.x
f18ff5ab5667065d8ab12657344fb6a0	stomp-wae-cgst-chprc04i.x
061af86cf21ad8435b046d0efabe971b	stomp-wae-cgst-chprc04l.x
3c8111a9855dc0e430bf3c8a7abcf37e	stomp-w-bcg-chprc04i.x
20436d615a94955a2ce8eecdb8cba546	stomp-w-bcg-chprc04l.x
8b3df29df21d040189c3e2a50ef823bb	stomp-w-bd-chprc04i.x
066a289a75aedb933eb2536da5d7d1ff	stomp-w-bd-chprc04l.x
c8e62ad7a0d9b6fca39d8a8952ef5d8e	stomp-w-cgsq-chprc04i.x
28ad16806e1307aca51fd7bf89793e75	stomp-w-cgsq-chprc04l.x
6c25051016db2fe1f883a7caaaab1e97	stomp-w-cgst-chprc04i.x
ff9ff6f29b3469419ffaece87d7e772b	stomp-w-cgst-chprc04l.x
0c3e3fba40f5b93e71bcf9586432fd27	stomp-w-r-bcg-chprc04i.x
78492aee80a8c2d0a4e82aabf4a9c213	stomp-w-r-bcg-chprc04l.x
84b129786aba9c4be884e15e45a67389	stomp-w-r-bd-chprc04i.x
e990f1566c8099a8d54508de3da9cd88	stomp-w-r-bd-chprc04l.x
18a589a2b55aab2db290efea19b39351	stomp-w-r-cgsq-chprc04i.x
6569959476772a137df35ce874821889	stomp-w-r-cgsq-chprc04l.x

3. Executable Size (bytes): MD5 signatures above uniquely identify each executable file

COMPILATION INFORMATION:

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

Tellus Subsurface Modeling Platform

5. Operating System (include version number):

Linux tellusmgmt.rl.gov 2.6.18-308.4.1.el5 #1 SMP Tue Apr 17 17:08:00 EDT 2012 x86_64 x86_64 x86_64 GNU/Linux

INSTALLATION AND CHECKOUT INFORMATION:

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

Green Linux Cluster

7. Operating System (include version number):

Linux green 3.2.0-35-generic #55-Ubuntu SMP Wed Dec 5 17:42:16 UTC 2012 x86_64 x86_64 x86_64 GNU/Linux

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: STOMP (Subsurface Transport Over Multiple Phases) Software Version No.: Bld 4

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

TEST CASE INFORMATION:

9. Directory/Path:

/srv/samba/saved data/test/stomp/build-04/itc

10. Procedure(s):

CHPRC-00211 Rev 1, STOMP Software Test Plan

11. Libraries:

N/A (static linking)

12. Input Files:

Input files for ITC-STOMP-1, ITC-STOMP-2, and ITC-STOMP-2
(Baseline for comparison are results files from ATC-STOMP-1, ATC-STOMP-2, and ATC-STOMP-3 prepared on Tellus during acceptance testing)

13. Output Files:

plot.* files produced by STOMP in testing

14. Test Cases:

ITC-STOMP-1, ITC-STOMP-2, and ITC-STOMP-3

15. Test Case Results:

Pass for all executable files listed above.

16. Test Performed By: WE Nichols

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

18. Disposition (include HISI update):

Accepted; Installation noted in HISI for users TJ Budge, N Hasan, A Mayenna, WJ McMahon, WE Nichols, S Mehta, H Rashid.

Prepared By:

19.	WE Nichols	25 April 2013
Software Owner (Signature)	Print	Date

20. Test Personnel:

	WE Nichols	25 April 2013
Sign	Print	Date
Sign	Print	Date
Sign	Print	Date

Approved By:

21.	N/R (per CHPRC-00211 Rev 1)	
Software SME (Signature)	Print	Date

A-6005-149 (REV 0)

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