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Revision 0

Modeling Evaluation of Waste Sites Near 100-KE Reactor

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

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

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J. L. Ludwig
INTERA

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

APPROVED
By Shauna E. Adams at 3:53 pm, Jun 21, 2012

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Environmental Calculation Cover Page

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Preparer: JL Ludwig	**Basis of Qualification:** Education & experience
Checker: H. Rashid	**Basis of Qualification:** Education & experience
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Preparer:
JL Ludwig / Modeler (INTERA)
NAME/POSITION
Jan Ludwig
SIGNATURE
5/29/12
DATE

Checker:
H. Rashid
NAME/POSITION
On file for H. RASHID
SIGNATURE
5/29/12
DATE

Senior Reviewer:
Sunil Mehta/Environmental Scientist
NAME/POSITION
SIGNATURE
5/29/12
DATE

Responsible Manager:
AH Aly / Risk & Modeling Integration Manager (CHPRC)
NAME/POSITION
SIGNATURE
5/29/12
DATE

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Terms

CHPRC	CH2M HILL Plateau Remediation Company
COC	contaminant of concern
ECF	environmental calculation file
FEPs	features, events, and processes
HISI	Hanford Information System Inventory (software database)
MCL	maximum contaminant level
OU	Operable Unit
RTD	remove, treat, dispose
STOMP	Subsurface Transport Over Multiple Phases (modeling software)
WIDS	Waste Information Data System (waste site database)

1 Purpose

The purpose of this environmental calculation file (ECF) is to evaluate the possible future impact to groundwater from residual soil contamination under the 116-KE-1, 116-KE-3, and UPR-100-K-1 waste sites that received discharges associated with 105-KE Reactor operations. This evaluation investigates whether the interim action of placing a surface recharge barrier over the waste sites will be protective of groundwater from possible future impacts until the 105-KE reactor building and underlying contaminated soil can be removed in approximately 75 years. The three waste sites are in close proximity to the reactor building and the remove, treat, and dispose (RTD) remedy cannot be fully implemented as it may jeopardize the stability of the reactor building.

This evaluation relies on readily available information to build the site conceptual models and numerical simulation to predict the effect of surface recharge barrier on reducing contaminant flux to groundwater over approximately the next 75 years, while the 105-KE reactor stays in place.

2 Background

The conceptual model that is the basis for the numerical simulations in this calculation is presented in Section 2.1, and the implications of treating the gas condensate stream as a primary contaminant source is discussed in Section 2.2.

2.1 Conceptual Site Model Development

The 105-KE reactor building (Waste Information Data System identification [WIDS ID]: 118-KE-1) along with the three waste sites mentioned above fall within the 100-KR-4 Groundwater Operable Unit (OU). The groundwater risk evaluation for this OU identified tritium, carbon-14, strontium-90, total chromium (including hexavalent chromium, or Cr(VI)), trichloroethene, and nitrate as contaminants warranting further evaluation in the feasibility study. Of these contaminants of concern (COCs) only tritium, carbon-14, strontium-90, and nitrate are contaminants observed in monitoring wells around the three waste sites in any appreciable concentrations. Figure 1 shows the location map of the area of interest. The three waste sites (116-KE-1, 116-KE-3, and UPR-100-K-1) are shown along with carbon-14, tritium, and strontium-90 plumes in groundwater based on recent monitoring data (2009-2010). Also shown is the water table map based on the 2009 annual averaged water levels indicating a northwest flow direction. Figure 2 presents the same information but with higher spatial resolution near the waste sites. The monitoring wells are shown as triangles.

The COCs evaluated are listed in Table 1 for each waste site based on the observed groundwater concentrations in the nearby monitoring wells. Figure 3 and Figure 4 show the disposal system layout for 116-KE-1 and 116-KE-3, respectively. These both show waste stream discharge occurred over a wide area and provide some information on the lateral extent of the zone of contamination, assuming most of the flow was vertically downward. Figure 5 and Figure 7 show the conceptual site models for the same waste sites while Figure 6 and Figure 8 present the contaminant concentrations available from monitoring wells close to the sites. This information along with recent data collected during waste RTD activities provide the basis for the model setup detailed in the methodology (Section 3).

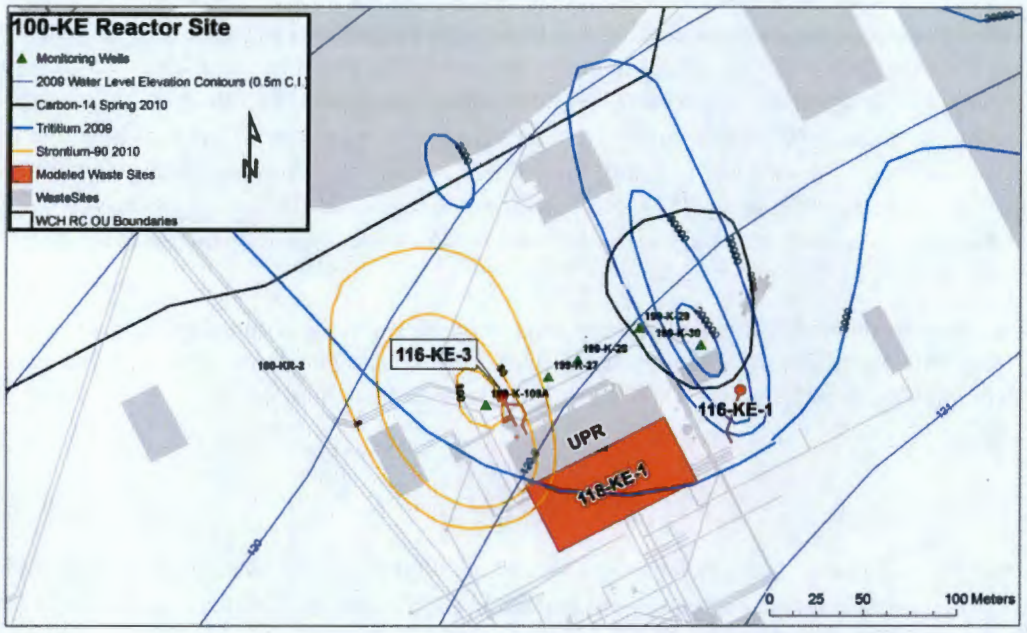


Figure 1. Location Map of the Area of Interest Showing the Waste Sites near the 105-KE reactor (118-KE-1) along with the Contaminant Plumes and the Annually Averaged Water Table

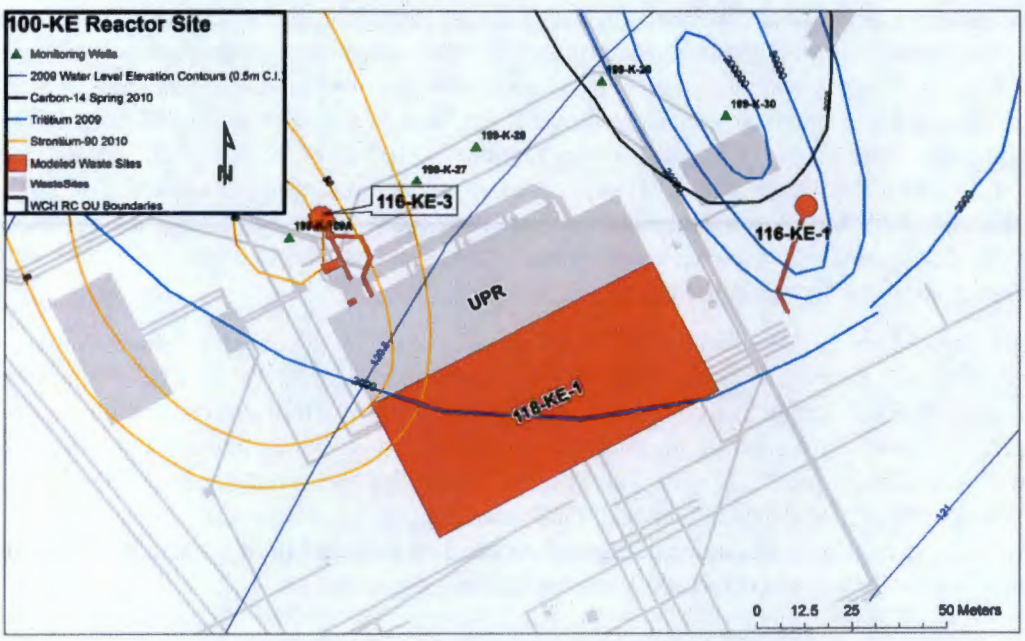


Figure 2. 105-KE Reactor Site with Waste Sites of Interest (zoomed image)

Table 1. Contaminants of Concern in Groundwater at Waste Sites in the Vicinity of the 105-KE Reactor

Waste Site	Contaminants Evaluated
116-KE-1	carbon-14, tritium, Nitrate
116-KE-3	strontium-90, tritium
UPR-100-K-1	strontium-90, tritium

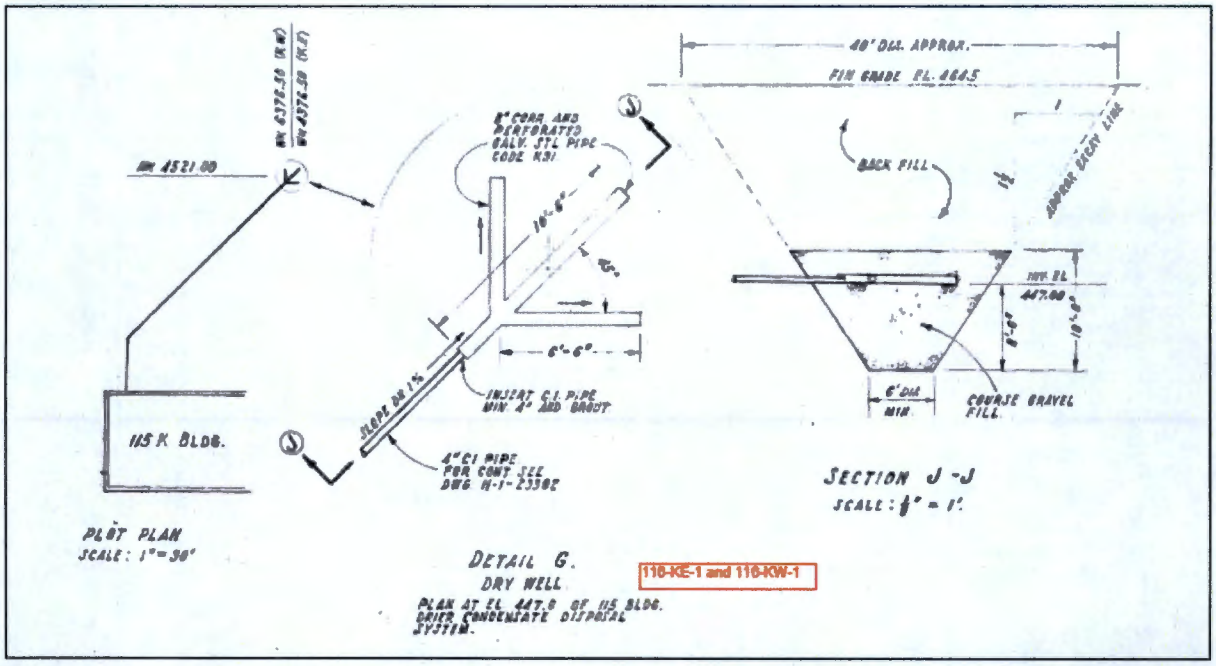


Figure 3. 116-KE-1 Disposal System

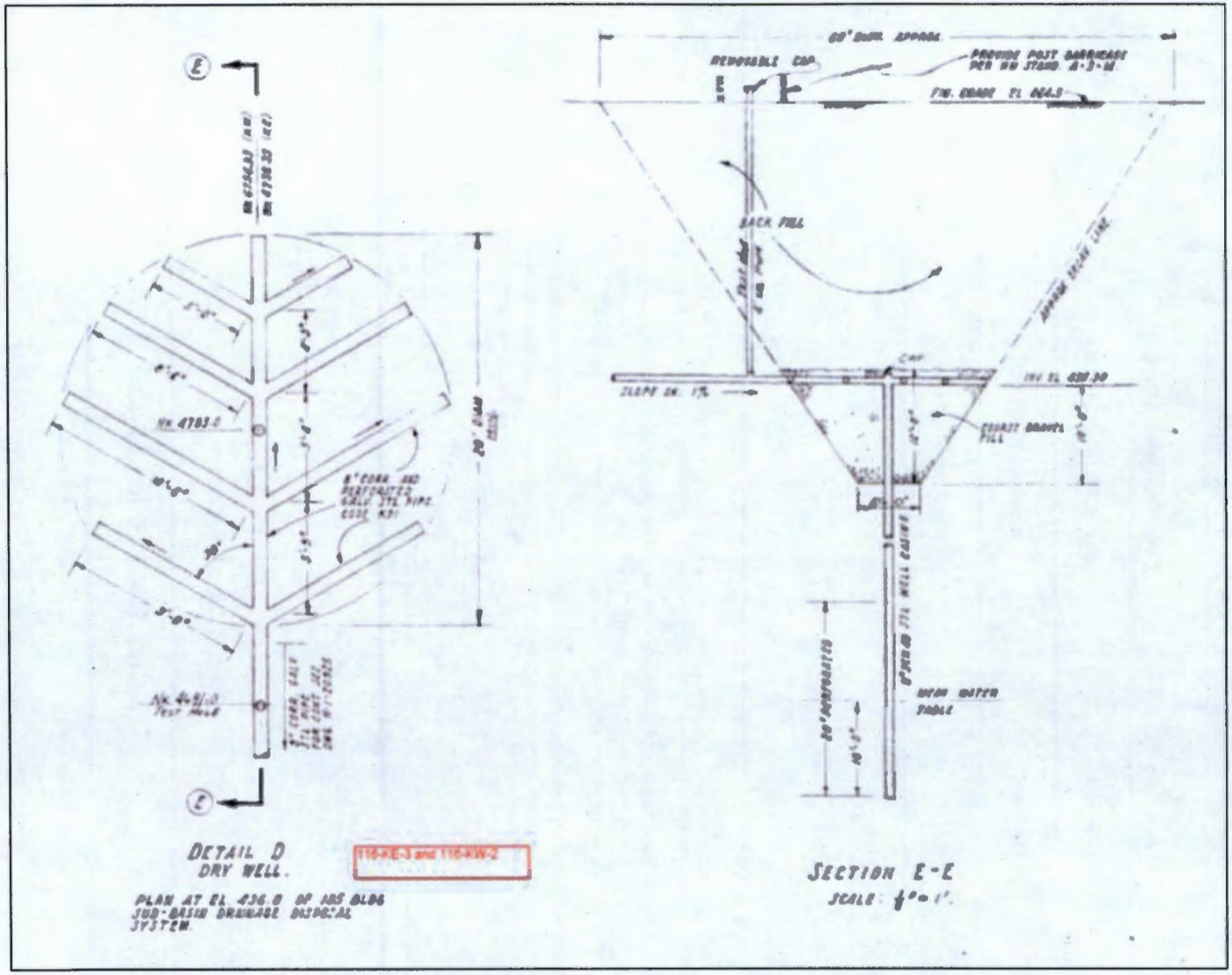


Figure 4. 116-KE-3 Disposal System

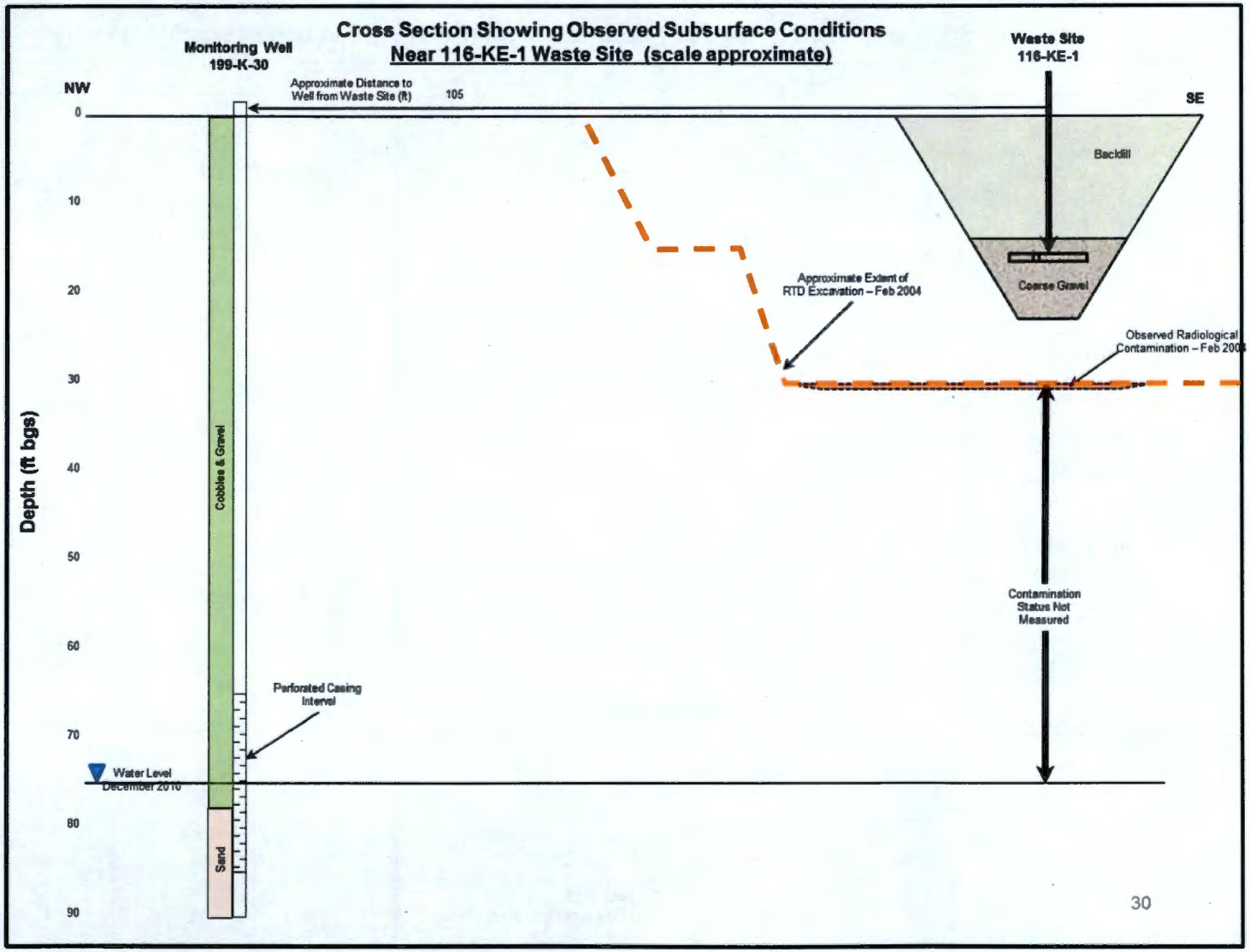


Figure 5. Conceptual Site Model for 116-KE-1

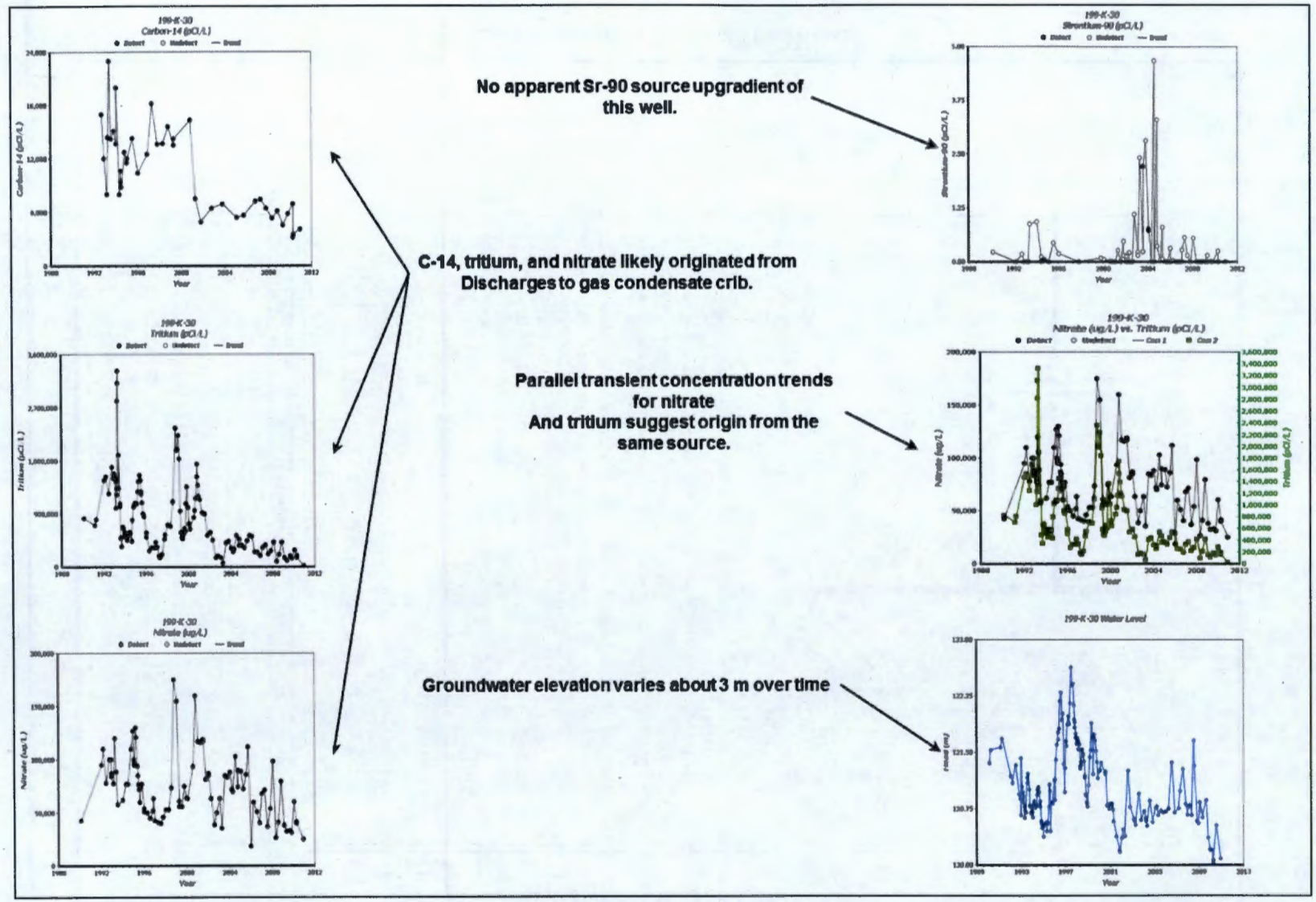


Figure 6. Contaminant Concentration Time Series in Monitoring Well 199-K-30 in vicinity of 116-KE-1 Gas Condensate Crib

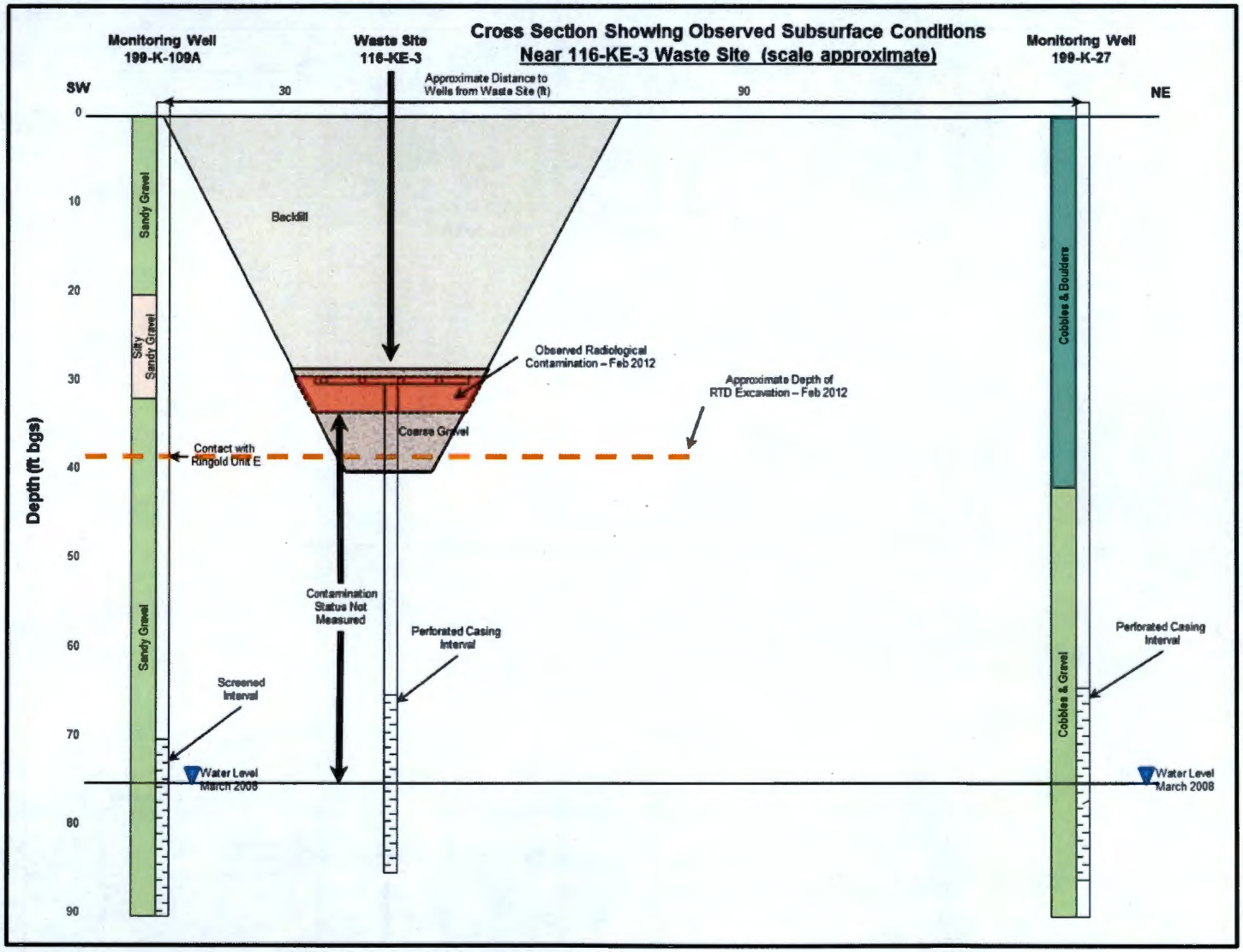


Figure 7. Conceptual Site Model for 116-KE-3

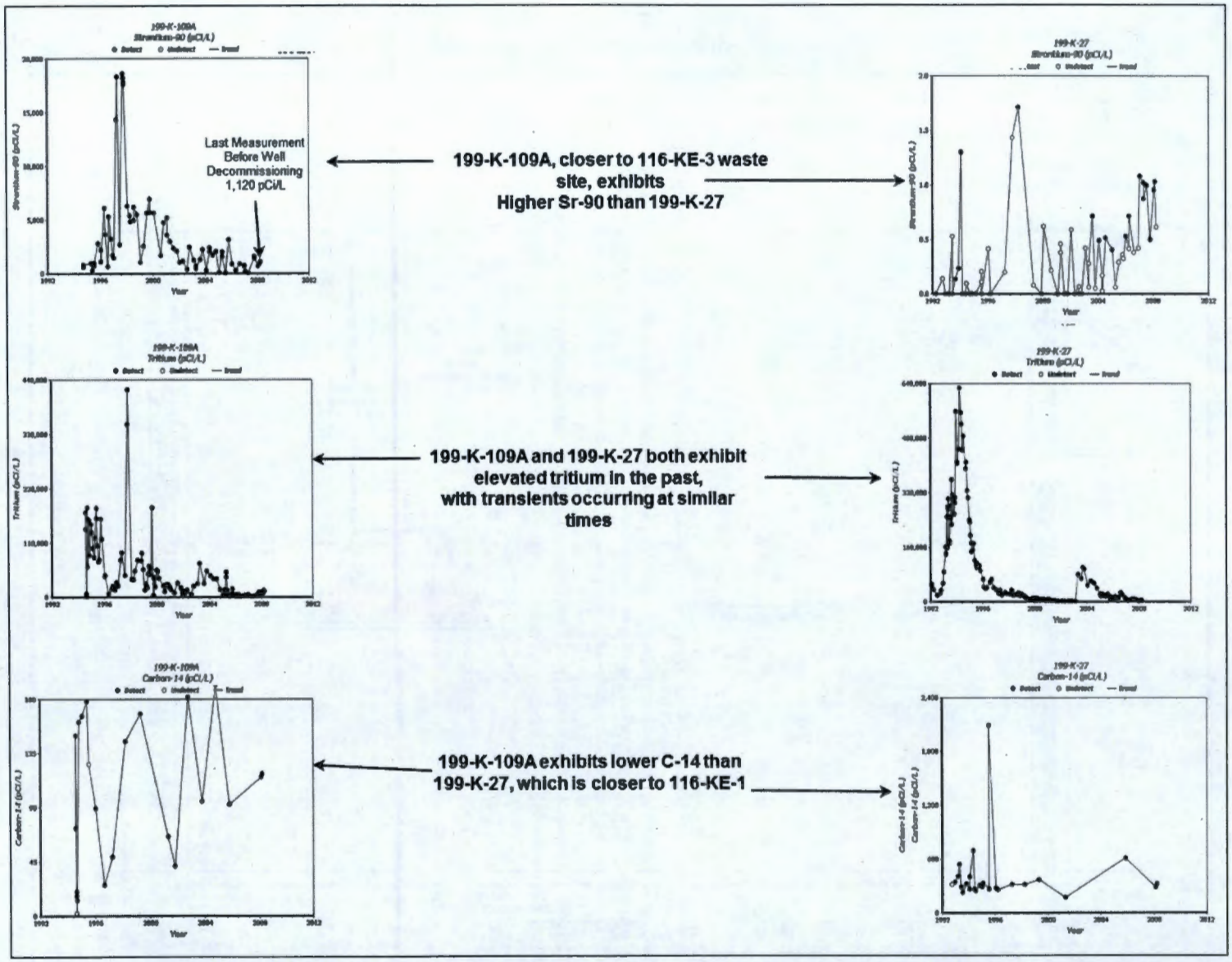


Figure 8. Contaminant Concentration Time Series in Monitoring Wells 199-K-109A and 199-K-27 in the Vicinity of 116-KE-3 Crib

2.1.1 WIDS Description of the 116-KE-1 Waste Site

The 116-KE-1 crib was located north of 115-KE and east of 118-KE-1 (105-KE Reactor Building). The base of the crib was 1.8 m (6 ft) in diameter and is positioned 7.8 m (25.5 ft) below the ground surface. The top of the crib measured 12.2 m (40 ft) in diameter. The crib and pipeline were removed in calendar year 2004, with contaminated soil under the crib remaining in place. The site was backfilled with clean soil to about 3 m (10 ft) below the grade elevation. The details of the 116-KE-1 disposal system are shown in Figure 3.

The crib was filled with coarse gravel to 3 m (10 ft) above the base. The remainder of the crib was backfilled with dirt to grade. The site included the feed pipeline coming from the 115-KE Building. The distribution system was composed of a 10.2-cm (4-in.) pipe that led into a 20.3-cm (8-in.) corrugated galvanized steel perforated pipe, 3.2 m (10.5 ft) long, with two 2-m (6.5-ft) sections branching off at 45 degrees.

The site received condensate and other waste from reactor gas purification systems. Beta/gamma concentrations within the crib, taken from two sample boreholes drilled in 1976, range from 4.5×10^5 pCi/g to 8.6×10^5 pCi/g. The radionuclide inventory (in curies) decayed through April 1, 1986, includes tritium (56.5 Ci), carbon-14 (110 Ci), and small amounts of other radionuclides.

2.1.2 WIDS Description of the 116-KE-3 Waste Site

The 116-KE-3 site is part of the sub-basin drainage disposal system for the 105-KE Fuel Storage Basin (100-K-42). The site operated from 1955 to 1971 as an overflow crib for sub-basin drainage from the 105-KE Fuel Storage Basin (100-K-42). The site received process effluent from the fuel storage basin sub-basin drainage system. The details of the 116-KE-3 disposal system are shown in Figure 4. The crib was excavated and removed with all structures down to about 12 m (40 ft) below grade. The dry well was removed down to excavation depth but still extends below the excavation depth into the groundwater.

The site includes the following components: a feed pipe, crib structure, dry well, and test hole. A 20.3-cm (8-in.) corrugated galvanized steel feed pipe 8.8 m (29 ft) below grade comes from the fuel storage basin. The feed pipe enters the crib structure at elevation 133 m (435.5 ft). The crib structure, in plan view, is trapezoid shaped with the top at grade level (Elevation: 142 m [464.5 ft]) and approximately 18.3 m (60 ft) in width (excavation and backfill width) and the bottom (at elevation 425.5 ft) is 3.05 m (10 ft) in width. The bottom 3.7 m (12 ft) of the crib is filled with coarse gravel. The distribution system (drain field) within the crib is a central feeder with side feeders ("fishbone") located 8.8 m (29 ft) below grade. All feeder piping is composed of 20.3-cm (8-in.) corrugated and perforated galvanized steel pipe. The main feeder pipe within the drain field is 6.1 m (20 ft) long. The drain field is 6.1 m (20 ft) in diameter.

A dry well (injection well) was installed at the midpoint (Washington State Plane Coordinates: Easting 569,130.985 m, Northing 146,753.534 m) of the drain field main feeder pipe. The dry well is constructed of 20.3-cm (8-in.) schedule 40 steel well casing. The dry well casing runs from elevation 435.5 ft (8.8 m [29 ft] below grade) downward to a point 3.05 m (10 ft) below the mean water table. The bottom 6.1 m (20 ft) of the well casing is perforated. The site is located north of the 105-KE Reactor Building (118-KE-1) about 23 m (75 ft).

Based on the information presented above and the RTD remedial action taken to date, a conceptual site model is presented in a cross-sectional view in Figure 5 for 116-KE-1 and in Figure 7 for 116-KE-3 waste sites. The nearby monitoring wells are also shown along with their approximate distance from the waste site. The approximate excavation depth is also presented. The concentration history of contaminants in the monitoring wells is presented in Figure 6 and Figure 8, indicating past high concentrations with a declining trend over time. The intermittent increases in concentrations are likely due to Columbia River

stage fluctuations that result in mass leaching from the periodically rewetted zone within the deeper portion of the vadose zone.

2.2 Implications of the Gas Condensate Stream as a Primary Contaminant Source

The gas condensate waste stream is reported to have been discharged to the gas condensate cribs, 116-KE-1 and 116-KW-1 located at 105-KE and 105-KW Reactors, respectively, over the course of reactor operations. The total estimated discharges to the two cribs are 800,000 L (211,000 gal) at each crib. The elevated concentrations of beta-emitting radionuclides and ammonia present in the gas condensate stream indicate that this waste stream is likely the principal primary source of the residual contamination of groundwater in the vicinity of the K Reactors by carbon-14 and nitrate and a major contributor to the tritium contamination observed in groundwater in the vicinity of the reactors. Elevated activity concentration of carbon-14 has been observed in vadose zone soil at the 116-KE-1 crib site.

The primary constituents of concern at these crib sites (i.e., carbon-14, tritium, and nitrate) are all very mobile in soil and groundwater, with carbon-14 likely present at the soluble carbonate ion, tritium present as tritiated water, and nitrate present as the soluble oxyanion.

3 Methodology

One-dimensional flow and transport of contaminants at the 116-KE-1, 116-KE-3, and UPR-100-K-1 Waste Sites were simulated using the Subsurface Transport Over Multiple Phases (STOMP) code (PNNL-15782, *STOMP Subsurface Transport Over Multiple Phases: User's Guide Version 4.0*). The STOMP-W (water) operational mode was used for this calculation. STOMP was selected to perform the simulations on the basis of this code's ability to adequately simulate the vadose zone features, events, and processes (FEPs) relevant to 105-KE reactor area and to satisfy the criteria identified in DOE/RL-2011-50, *Regulatory Basis and Implementation of a Graded Approach to Evaluation of Groundwater Protection,* a document that describes the approach and provides the regulatory basis for using STOMP in this type of evaluation.

3.1 Model Set-Up

One-dimensional vertical columns for each waste site, consistent with the descriptions in the conceptual site models were developed to represent the hydrogeologic conditions at each of the three sites. Figure 9 presents the model domain set-up along with the boundary conditions. The grid cell dimensions are 10 m (west to east), 1.0 m (south to north), and 0.25 (bottom to top) with the total vertical length spanning from the ground surface down to 5 m below the water table and into the saturated zone. The 10 m length of the waste site is modeled based on the information presented regarding the extent of waste disposal system. The modeling parameters such as recharge, hydraulic conductivity and water-retention relationships, etc. are consistent with those used in the PRG calculations for the 100-K area (ECF-Hanford-11-0063, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for 100 Area D, H, and K Source Areas*). The groundwater concentrations are evaluated at the edge of the 10 m length assuming that the contaminant mass is mixed over the 5 m interval within the saturated zone.

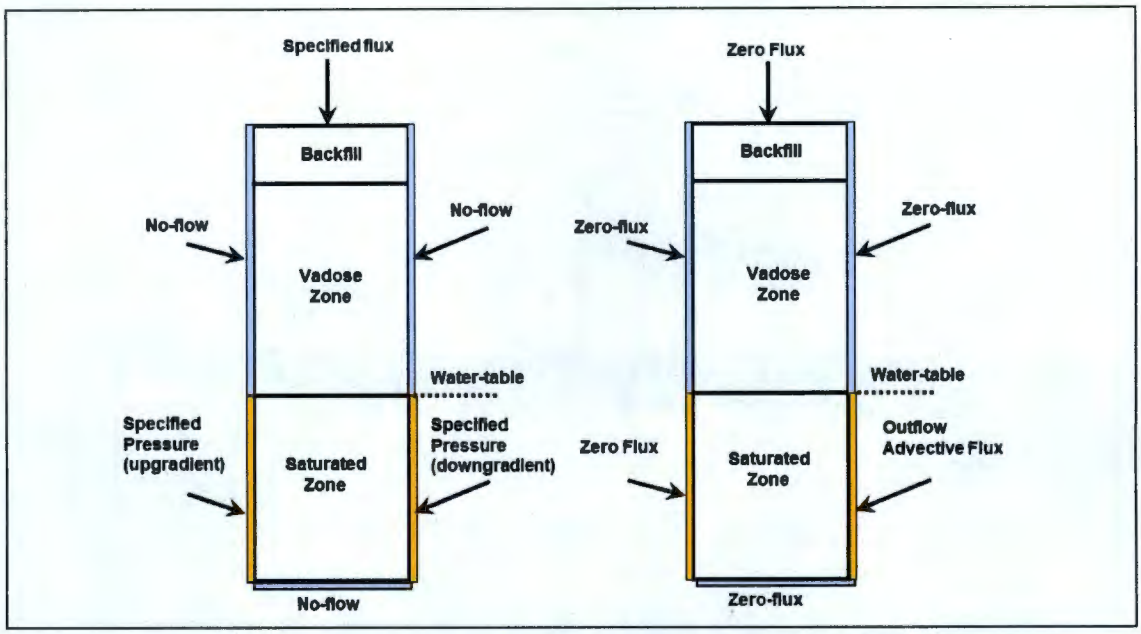


Figure 9. Simulated Boundary Conditions for (a) Flow and (b) Solute Transport

3.2 Initial Conditions (Initial Contaminant Distribution)

The initial contaminant distribution is based in part on data and on judgment based on site knowledge. The primary data gap is contaminant concentrations in the deep vadose zone as no direct measurements were available below the RTD depth. In order to estimate the concentration in deep vadose zone an inverse modeling approach was adopted based on: (a) bounding the groundwater concentrations over the last 5 to 10 years in the monitoring well down gradient of the waste site, (b) comparing the predicted initial dissolved concentrations with the measured discharge concentrations in the effluent waste stream, (c) performing the simulation from the time when active discharge ended and matching the trend of simulated groundwater concentrations with the observed values, and (d) using available leach test information to determine sorption parameters. This approach is not intended to determine the initial contaminant distribution in the deep vadose zone with great accuracy but rather to bound the initial contaminant concentrations such that the uncertainty range (upper and lower bound values) in the initial concentrations can be predicted with confidence.

Figure 10 and Figure 12 show available data for strontium-90 and carbon-14, respectively. Figure 11 and Figure 13 show three-dimensional interpolations of soil concentration in the vadose zone using the available data. The interpolations were performed using Leapfrog Hydro™[1] software to aid in conceptualizing vadose zone plume distributions for all three sites. Figure 11 and Figure 13 show the assumed distribution in the model below 116-KE-3 for strontium-90 and 116-KE-1 for carbon-14, respectively, in the deep vadose zone (primarily below the Ringold E contact) where data were not available. The uncertainty in the source term was evaluated through calibration as described in the following section. The UPR-100-K-1 site was the only site where a deep vadose distribution was not assigned using judgment and instead the Leapfrog Hydro™ interpolation was relied on. This produced results consistent with groundwater monitoring data for the area. Data used for the interpolations are presented in Attachment A, Tables A1-A3.

[1] Leapfrog Hydro™ is a trademark of ARANZ Hydro, Christchurch, New Zealand.

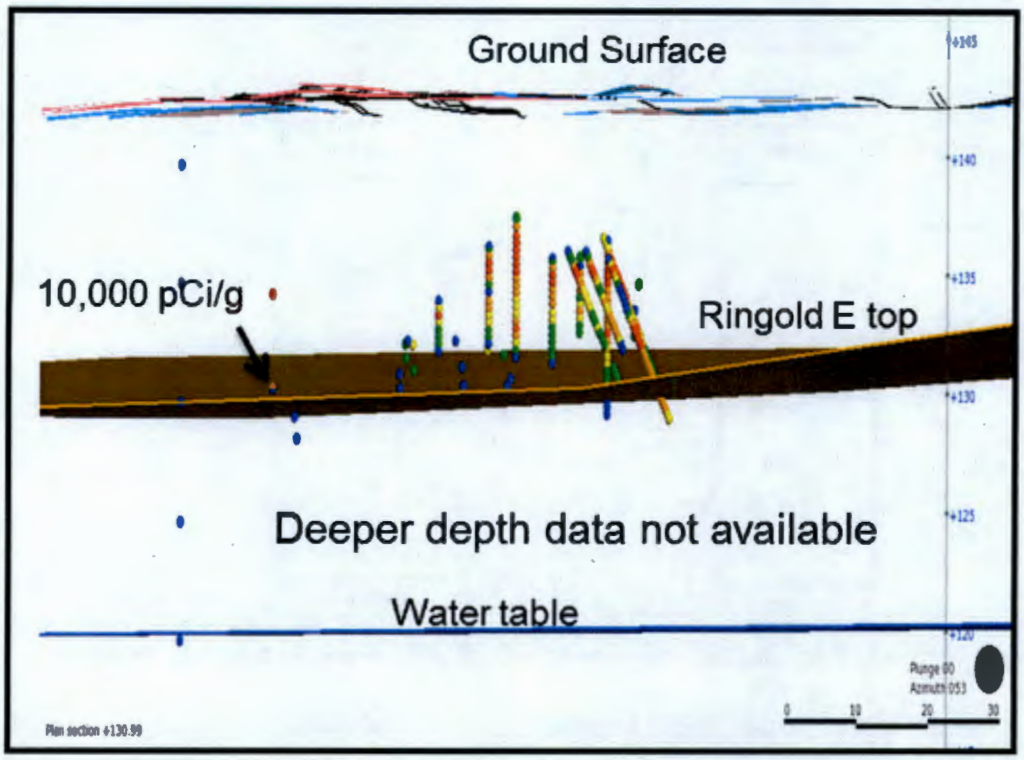


Figure 10. Strontium-90 Soil Concentration Data

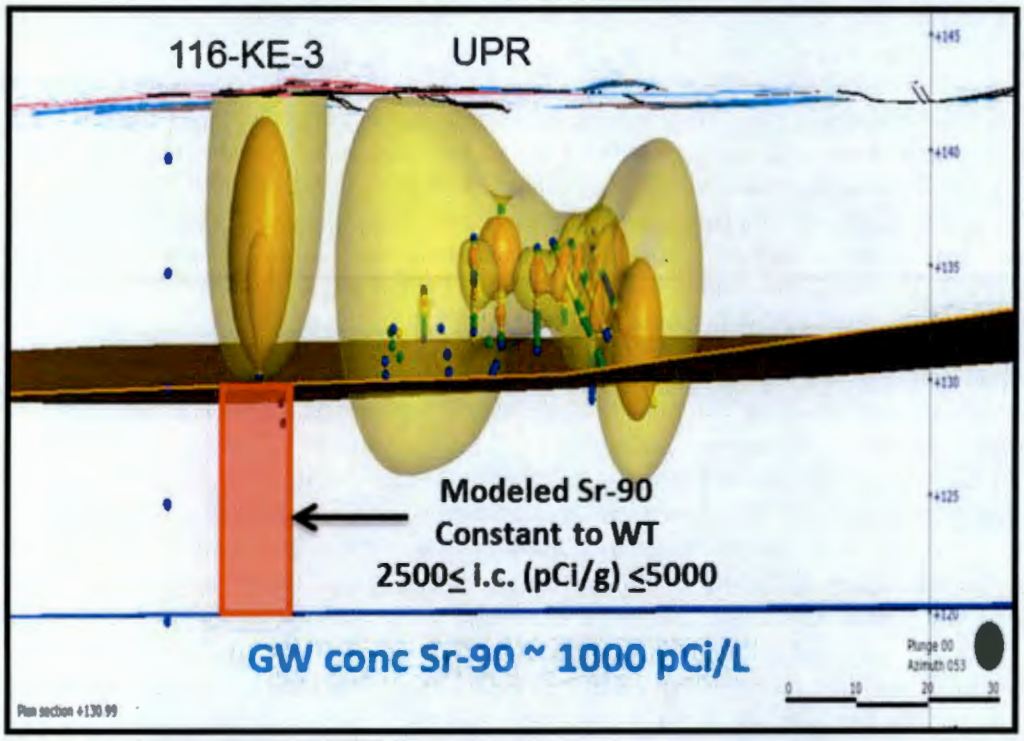


Figure 11. Strontium-90 Plume Interpolation and Modeled Initial Concentration Distribution Range

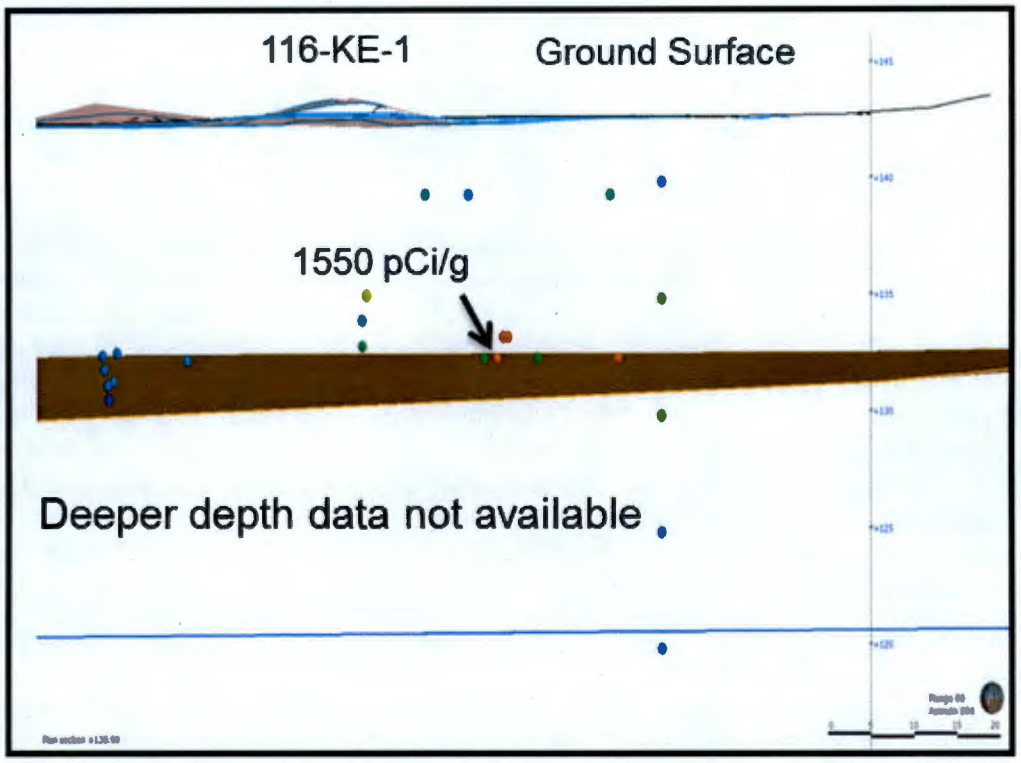


Figure 12. Carbon-14 Soil Concentration Data

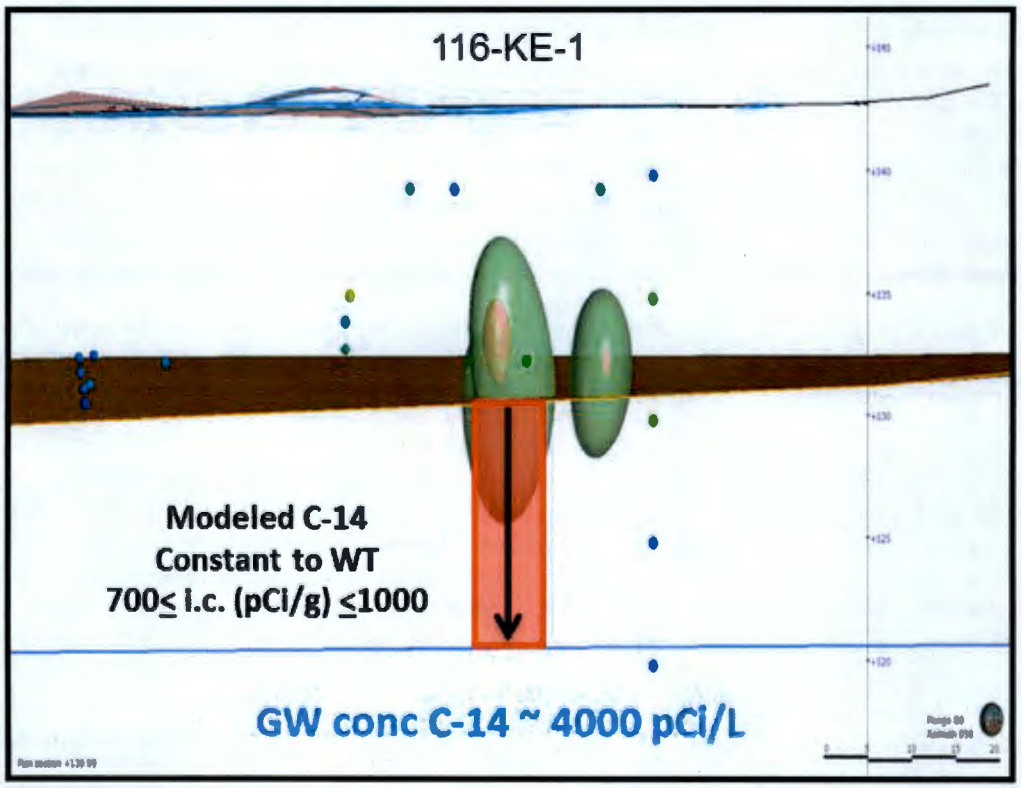


Figure 13. Carbon-14 Plume Interpolation and Modeled Initial Concentration Distribution Range

3.3 Model Calibration

Model calibration was performed by comparing the model predictions with the historic data (especially over the past 5 to 10 years) from nearby monitoring wells. As mentioned in the previous section, the initial contaminant concentration was varied within a range to bracket the observed groundwater concentrations.

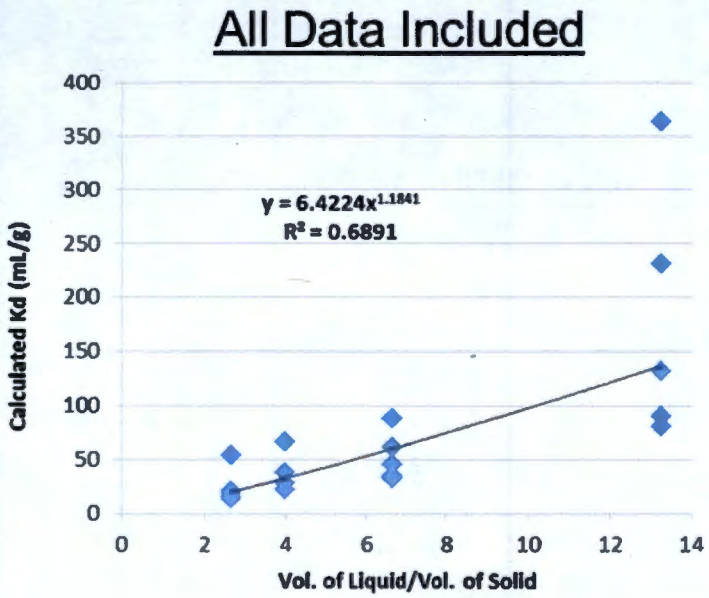
Recently available leach test results for carbon-14 were used to develop the site specific K_d for carbon-14 that is used in predicting the present day soil concentrations. Leach test data is presented in Attachment A, Table A4. Figure 14 shows the calculated K_d results based on the leach test data by varying the liquid (water) to solid ratio. Note that these tests were performed under conditions where water to solid ratio is larger than physically possible under the fully saturated field conditions. The regression equation is used to estimate the K_d value under near saturated field conditions where the water to solid ratio is estimated to be about 0.33 (assuming 0.25 effective porosity). The K_d value using entire leach test dataset is estimated to be about 2 mL/g, which matches with the value calculated using just the high soil concentration leach test data. Figure 15 presents the sorbed to leachate mass ratio as a function of initial sorbed mass from the leach tests. The ratio typically ranges from 10 to 30 over the soil concentration range evaluated. This ratio is also used during the calibration of the model.

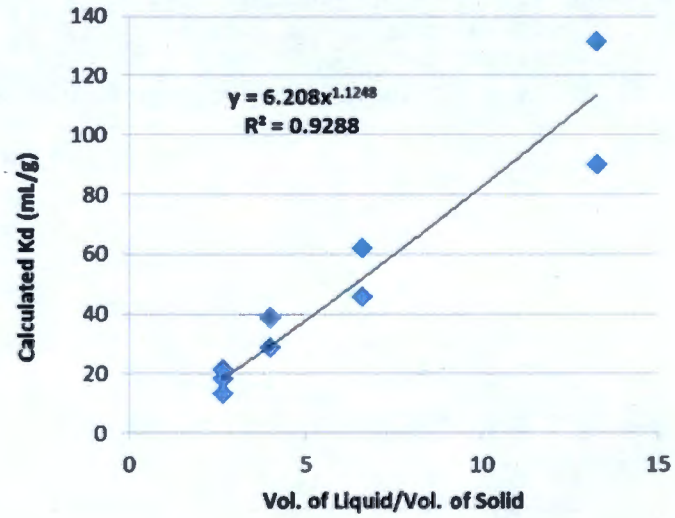
For strontium-90 and tritium, the initial aqueous concentrations predicted in the vadose zone were compared to gas condensate concentrations measured prior to the discharge. Figure 16 and Figure 17 show the range in concentration measured in gas condensate and Figure 18 portrays the concentration discharge history of the 105-KE basin. Note that around 1986 the strontium-90 concentrations dropped in the 105-KE basin. These observed concentrations of strontium-90, carbon-14, and tritium, in the effluent discharges were used during the calibration.

The gas condensate streams at 100-K were described in HW-76258, *Reactor Gas Drier Condensate Waste Decontamination Studies*, as a dark blue aqueous solution of alkaline pH and containing free ammonia. The dark blue color was attributed to the presence of copper ions in solution originating from corrosion of the gas condenser heat exchangers. The stream also contained substantial carbonate ions (CO3-), cyanide ions (CN-), and dissolved iron. The measured specific content of the stream, based on analysis of samples collected from KE, KW, D and F reactors are summarized in Table 2. Note that the condensate content of sulfur-35, pH, and ammonium ion were presented as ranges of measured concentrations for the K reactors.

The relative activity concentrations of carbon-14 and tritium in the reported gas condensate samples are illustrated in Figure 16 and Figure 17, respectively. The K reactors contained about an order of magnitude greater activity concentration of carbon-14 and tritium than the condensate from D and F reactors.

The condensate stream was observed to be alkaline (pH at 100-K ranging from 9.1 to 10.4) and exhibiting free ammonia. The distribution of ammonia between gaseous ammonia and dissolved ammonium hydroxide in an aqueous solution is pH dependent. At the pH reported, there would be a substantial fraction of gaseous ammonia. The ammonium ion measured in the condensate stream (reported at a concentration ranging from 0.5 to 2 moles/L) would lead to an equivalent nitrate concentration range of about 9,000 to 36,000 mg/L (this is nearly 1 wt % to greater than 3 wt % in the solution) considering mole-per-mole conversion. The ammonium ion is subject to bio-oxidation to nitrate ($NO3^-$) in the soil column by common soil microorganisms. Loss of gaseous ammonia in the vapor phase would be expected and could reduce the nitrate concentration appreciably. The condensate stream is likely the primary source of the groundwater nitrate plume observed in the vicinity of the condensate cribs at 100-K.





Parameters:

Particle Density	2650 g/L
Effective Porosity	0.25
Solid Vol Frac	0.75
Vol of Liquid/Vol of Solid	0.33 (at Saturation)

Kd Calculated At Liquid/Solid Ratio of 0.33

Kd (with High Conc Data)	1.80
Kd (with all Data)	1.75
Kd (with Avg. Data)	1.88

Figure 14. Evaluation of Carbon-14 Leach Test for Deriving K_d

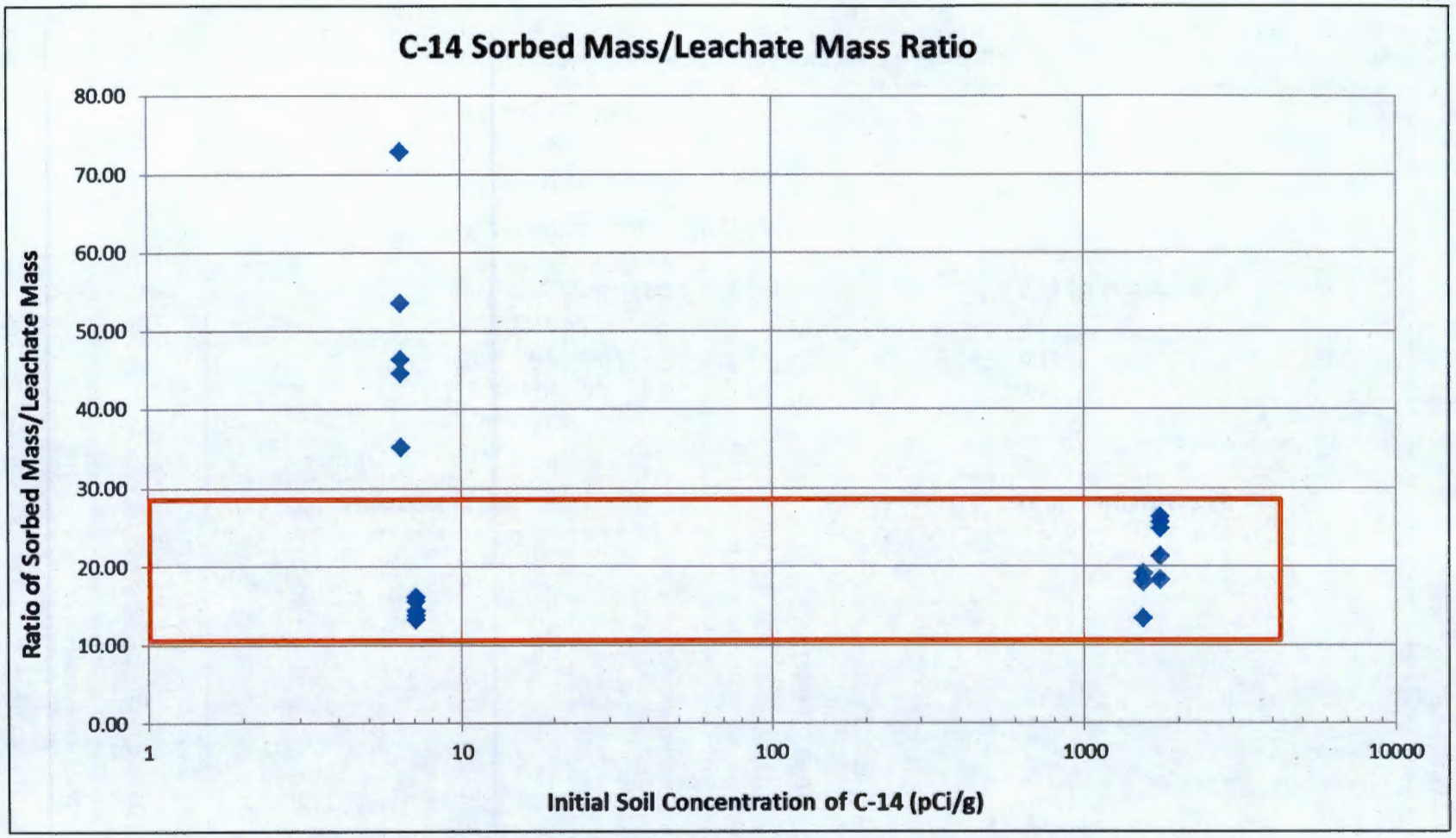


Figure 15. Evaluation of Carbon-14 Leach Test for Verifying Initial Soil Concentrations

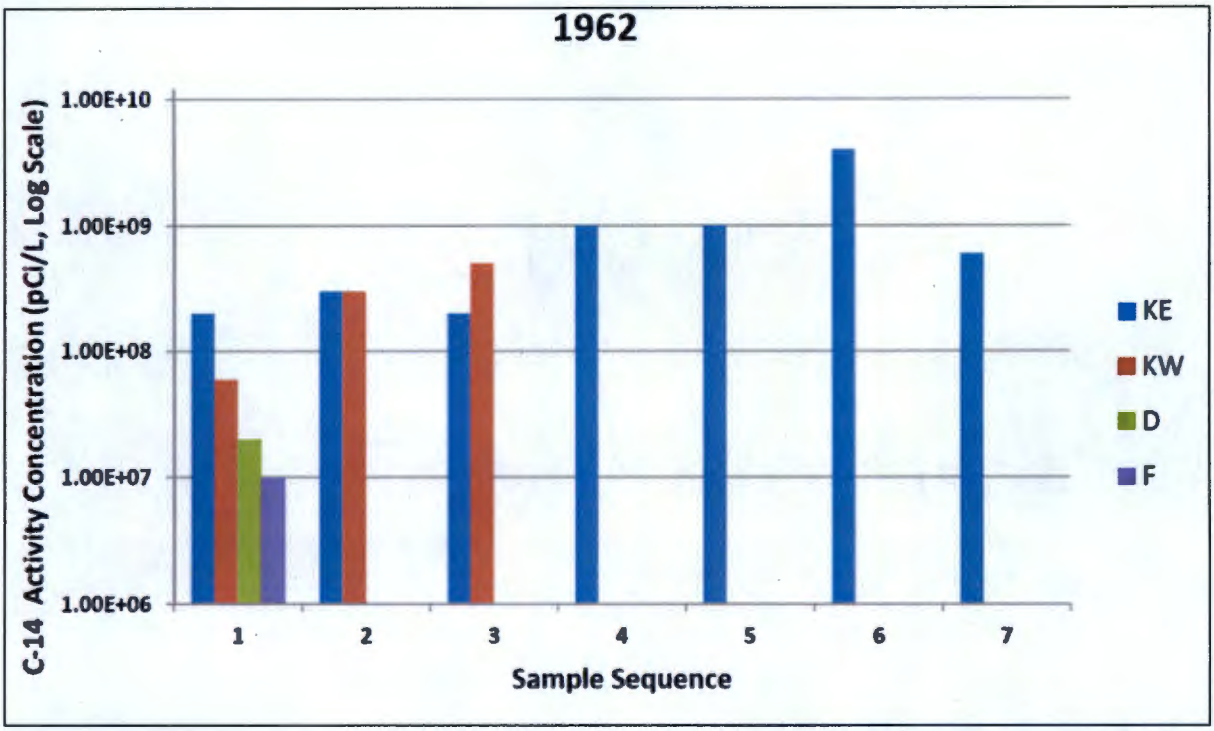


Figure 16. Carbon-14 Gas Condensate Measurements for Comparison to Predicted Initial Concentrations

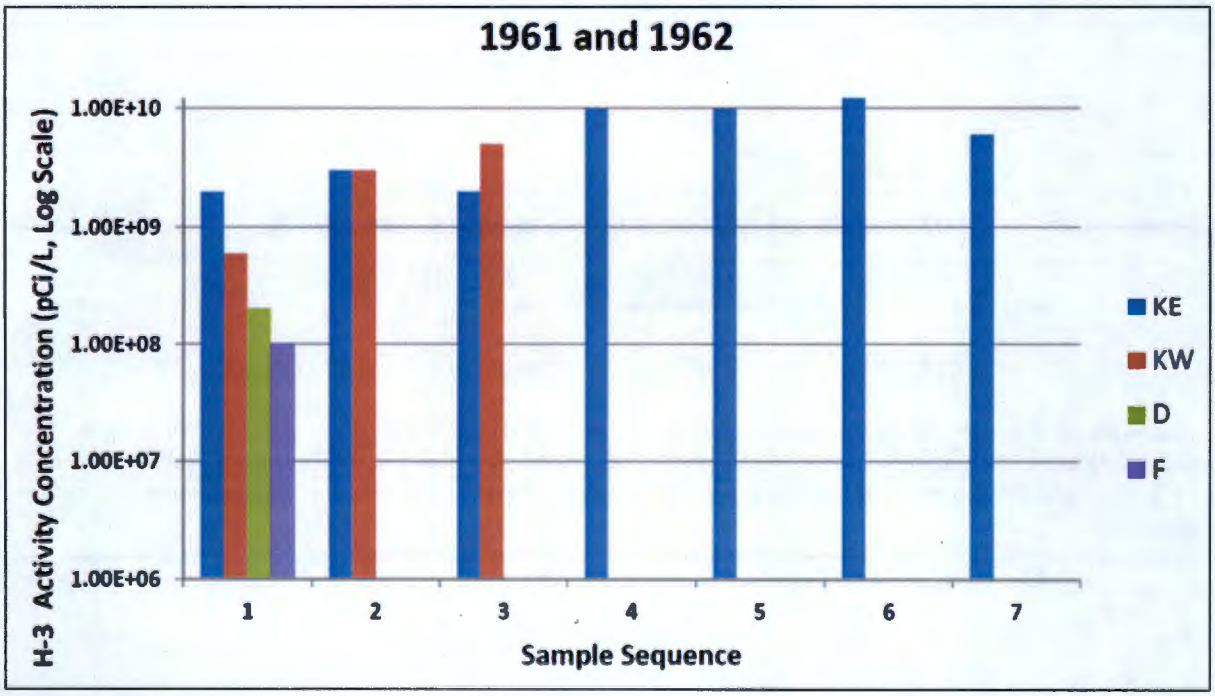
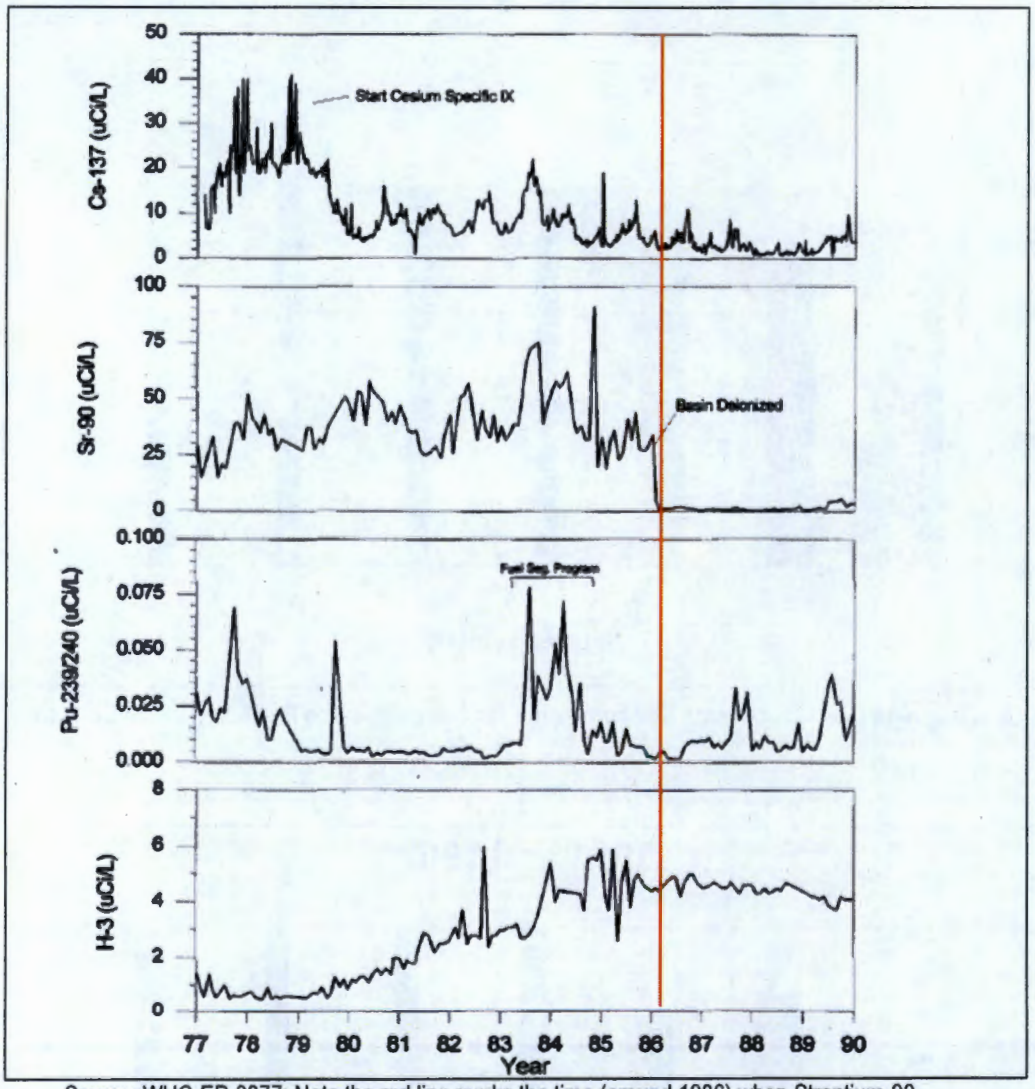


Figure 17. Tritium Gas Condensate Measurements for Comparison to Predicted Initial Concentrations



Source: WHC-EP-0877; Note the red line marks the time (around 1986) when Strontium-90 concentrations are reduced sharply due to Basin deionization.

Figure 18. 105-KE Basin Radionuclide Concentration Discharge History

Table 3 presents the predicted initial concentrations for comparison to the observed values in the gas condensate waste stream and effluent discharges. These results compare favorably given that the effects of fractionation of carbon-14 to the gas phase and dilution effects in the effluent waste streams are not factored in.

Table 2. Results of Reactor Gas Condensate Analysis (as presented in HW-76258)

Reactor	Date	Total Beta (µCi/ml)	Est. C-14 (µCi/ml)	S-35 (µCi/ml)	pH	NH4+ (moles/L)	Remarks
KE	8/31/1961	0.2	0.2		9.1 - 10.4	0.5 - 2	Contains CO3 -2, CN-, Cu, Fe
KE	9/3/1961	0.3	0.3				
KE	10/29/1961	0.2	0.2				
KE	9/28/1962	2	1	0.1 - 7			0.8M/L CO3-2; 0.03 M/L CN-
KE	10/24/1962	6	1				
KE	11/12/1962	11	4				
KE	11/30/1962	1	0.6				
KW	9/18/1962	0.1	0.06				
KW	10/25/1962	0.6	0.3				
KW	12/3/1962	0.6	0.5				
D	11/30/1962	0.03	0.02	0.01	5	0.02	.01 M/L CO3 -2
F	11/30/1962	0.02	0.01	0.01	7.6		
KE	8/31/1961	0.2	0.2		9.1 - 10.4	0.5 - 2	Contains CO3 -2, CN-, Cu, Fe
KE	9/3/1961	0.3	0.3				

Note: Total beta excludes H-3 (tritium), estimated to be about 10× the carbon-14 activity concentration.

Table 3. Predicted Initial Aqueous Concentrations in the Deep Vadose Zone for Selected Model Cases

Site	Initial Aqueous Concentration			
	Strontium-90 (pCi/L)	Carbon-14 (pCi/L)	Tritium (pCi/L)	Nitrate (µg/L)
116-KE-1	n/a	3.37E+05 – 4.82E+05	1.12E+08 – 4.46E+08	5.2E+06 – 2.62E+07
116-KE-3	1.65E+05 – 3.32E+05	n/a	n/a	n/a
UPR-100-K-1	~3.32E+03	n/a	n/a	n/a

Note: Aqueous concentrations were calculated at 2.5 m above the water table.

4 Assumptions and Inputs

The effects of river stage fluctuations leading to variable hydraulic gradient in the saturated zone near the waste sites were not considered. Instead the median hydraulic gradient of 0.0039 for the 100-K area was applied consistent with the PRG model calculation parameters described in ECF-Hanford-11-0063. The hydraulic parameter values are summarized in Table 4.

Table 4. Hydraulic Parameters used for Waste Sites in the 105-KE Reactor Vicinity

Soil Type[a]	Formation	Total Porosity n_T	Diffusive Porosity n_D	van Genuchten α (1/cm)	van Genuchten n	Residual saturation s_r	Horizontal Saturated $K_{s,h}$ (cm/s)	Vertical Saturated $K_{s,v}$ (cm/s)
BF	Hanford	0.276	0.262	0.019	1.4	0.162	5.98E-04	5.98E-04
VZ	Hanford	0.28	0.25	0.168	1.189	0	2.83E-01	2.83E-02
VZ	Ringold E	0.28	0.28	0.151	1.189	0	5.83E-01	5.83E-02
SZ	Ringold E	0.28	0.28	0.008	1.66	0.093	4.86E-03	4.86E-04

Source: Parameterization taken from PRG calculations for 100 K described in ECF-Hanford-11-0063.

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

The assumed surface soil is Rupert sand. Recharge rates for the simulations are summarized in Table 5. A recharge rate of 44 mm/yr was used from start of the simulation, set in calendar year 1971 for 116-KE-1 and 116-KE-3 (corresponding to the end of active discharge) and calendar year 1986 for site UPR-100-K-1. 44 mm/yr recharge rate was applied until the present (calendar year 2012), assuming bare soil. In calendar year 2012, the recharge rate is reduced to 1.0 mm/yr, reflecting the installation of a surface barrier, and maintained at that reduced rate for 79 years (until calendar year 2091).

The simulation time frame commences in calendar year 1971 for 116-KE1 and 116-KE-3 and continues for 120 years through calendar year 2091. The calendar year 1971 start time (simulation time 0 years) is consistent with the cessation of discharges to these waste sites. The present (calendar year 2012) is then consistent with a model time of 41 years and model end time of 120 years is consistent with future time at calendar year 2091 allowing for approximately 79 years of recharge barrier effects. The operational period for the UPR-100-K-1 extended until calendar year 1986 (based on Figure 18) so the time frame for this site is shifted by 15 years and the calculation performed for 26 years (until calendar year 2012) with a 44 mm/yr recharge rate. Then the barrier recharge rate is applied and maintained through calendar year 2091 for total simulation time of 105 years.

Table 5. Recharge Rates used in Simulations

Soil Type	Site	Pre-Barrier Period (Calendar Years)	Recharge Rate (mm/yr)	
			Pre-Barrier	Post-Barrier
Rupert Sand	116-KE-1; 116-KE--3	1971-2011	44	1
Rupert Sand	UPR-100-K-1	1986-2011	44	1

Note: Parameterization taken from PRG calculations for 100 K described in ECF-Hanford-11-0063.

Backfill was assumed beneath surface barrier in existing open excavations. The zone of contamination is assumed to be 10 m wide parallel to the groundwater flow direction and is the reason for the grid cell length of 10 m. The predicted groundwater concentrations are calculated at the downgradient edge of the zone of contamination and the contributing mass from the vadose zone is averaged over the assumed 5 m screened interval in the saturated zone.

The K_d for strontium-90 was set to 15 mL/g based on column leach tests presented in PNL-10899, *Strontium-90 Adsorption-Desorption Properties and Sediment Characterization at the 100 N-Area* (Table 4.2 and 4.3 of PNL-10899). The K_d for carbon-14 is set to 2 mL/g based on leach results presented in Figure 14 and Figure 15. A K_d of zero was applied for tritium and nitrate transport calculations. Contaminant decay was included in the simulations.

5 Software Applications

The vadose zone fate and transport calculations are performed using the CH2M HILL Plateau Remediation Company (CHPRC) Build 2 of the STOMP software, registered in the Hanford Information System Inventory (HISI) under identification number 2471. STOMP use by CHPRC is managed under the following software lifecycle documents: CHPRC-00222, *STOMP Functional Requirements 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.*

STOMP was executed on the GREEN Linux®[2] server that is owned and managed by INTERA, Inc., a pre-selected subcontractor to CHPRC. This server (a Dell PowerEdge R510 with two 6-core Intel Xeon X5660 processors @ 2.80GHz and 48 GB of RAM) is located in INTERA's Richland, Washington office and has property tag INTERA-00469. As given by the command "uname –a", the operating system details are:

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

A copy of the *Software Installation and Checkout Form* for the STOMP installation on GREEN, used for this calculation, is provided in Attachment B.

Microsoft Excel®[3] spreadsheets were used to evaluate and display the results produced by STOMP. These spreadsheet-based utility calculations were performed on a laptop (equipped with Intel® Core™ i5 CPU M460@2.53GHz, 2534 MHz, 2 Core(s), 4 Logical Processor(s) loaded with the Microsoft Windows® 7 Home Premium 64-bit operating system) is identified by property tag INTERA-00468.

DOE/RL-2011-50 summarizes 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

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

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

addresses code selection criteria, including quality assurance documentation of verification studies for specific model attributes (e.g., unsaturated flow, solute transport, infiltration, and drainage), and includes a discussion of other code related criteria (i.e., inter-code comparisons, hardware requirements, solution methodology, dimensionality, and output capability).

The results of CHPRC acceptance testing, reported in CHPRC-00515, demonstrate that the STOMP software is acceptable for its intended use by the CHPRC. Installations of the software are operating correctly, as demonstrated by the INTERA Linux® Cluster system producing the same results as those presented for selected problems from the STOMP Application Guide (PNNL-11216, *STOMP Subsurface Transport Over Multiple Phases: Application Guide*) in accordance with CHPRC's software test plan for STOMP (CHPRC-00211).

Leapfrog Hydro™ was also recently approved for 3D visualization and volume and mass estimates for subsurface contaminant plumes use under HISI number 2874 as level C software (CHPRC-01753, *Leapfrog-Hydro Software Management Plan*; CHPRC-01754, *Leapfrog-Hydro Software Test Plan*; CHPRC-01755, *Leapfrog-Hydro Acceptance Test Report*).

6 Calculation

STOMP-W simulation input files were created using the methodology described in Section 3 with the assumptions and input (boundary conditions, initial conditions, and parameter values) described in Section 4 and run in the STOMP software detailed in Section 5. Post-processing necessary to extract simulation results was performed. The results are described, evaluated, and discussed in the next section.

7 Results

Results of the modeling for each contaminant at their respective waste site are presented in Figure 19 through Figure 23 below. All figures display predicted results of the calibration that best match or bound the observed groundwater data for the past 5 to 10 years from nearby monitoring wells. The groundwater data and the maximum contaminant level (MCL) are presented in the figures for comparison to the predicted results. Also presented in the figures are the results based on choosing one or more of the calibration scenarios and then applying a recharge barrier. After 41 years (equivalent to present time, calendar year 2012), when the barrier is in effect, the reader will notice where the concentrations begin to deviate from the calibration scenario. In some cases the Y-axis is logarithmically-scaled to adequately display concentrations over time.

The range of sorbed concentrations in the present (calendar year 2012), based on model simulations, is presented in Table 6, providing an estimate in case boreholes are drilled to sample the deep vadose zone.

No dilution in concentrations was considered based on the distance of observed groundwater monitoring data from the modeled columns located at the waste sites. For contaminants with low mobility this distance could lead to additional uncertainty in predicting results beneath the waste sites. Figure 1 and Figure 2 offer a view of the proximity of the monitoring wells relative to the modeled waste sites. For additional perspective, representative monitoring wells and the distance from the respective waste sites are presented in Table 7.

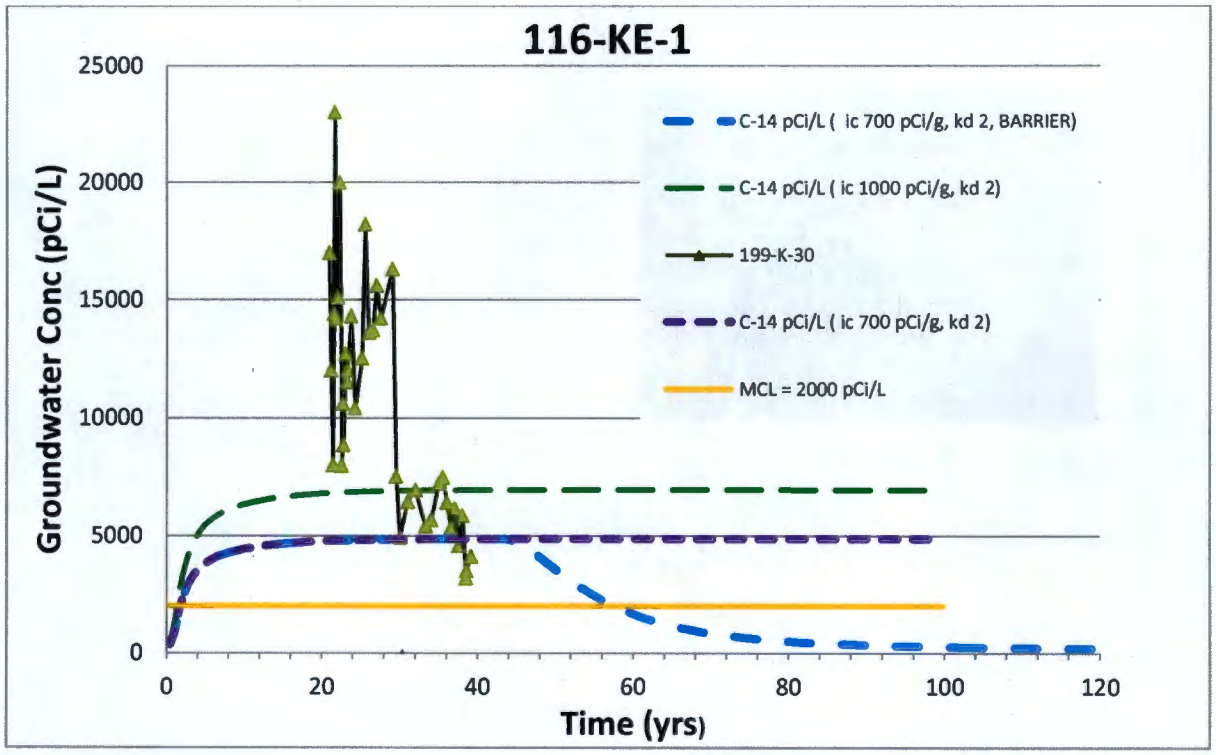


Figure 19. 116-KE-1 Carbon-14 Results

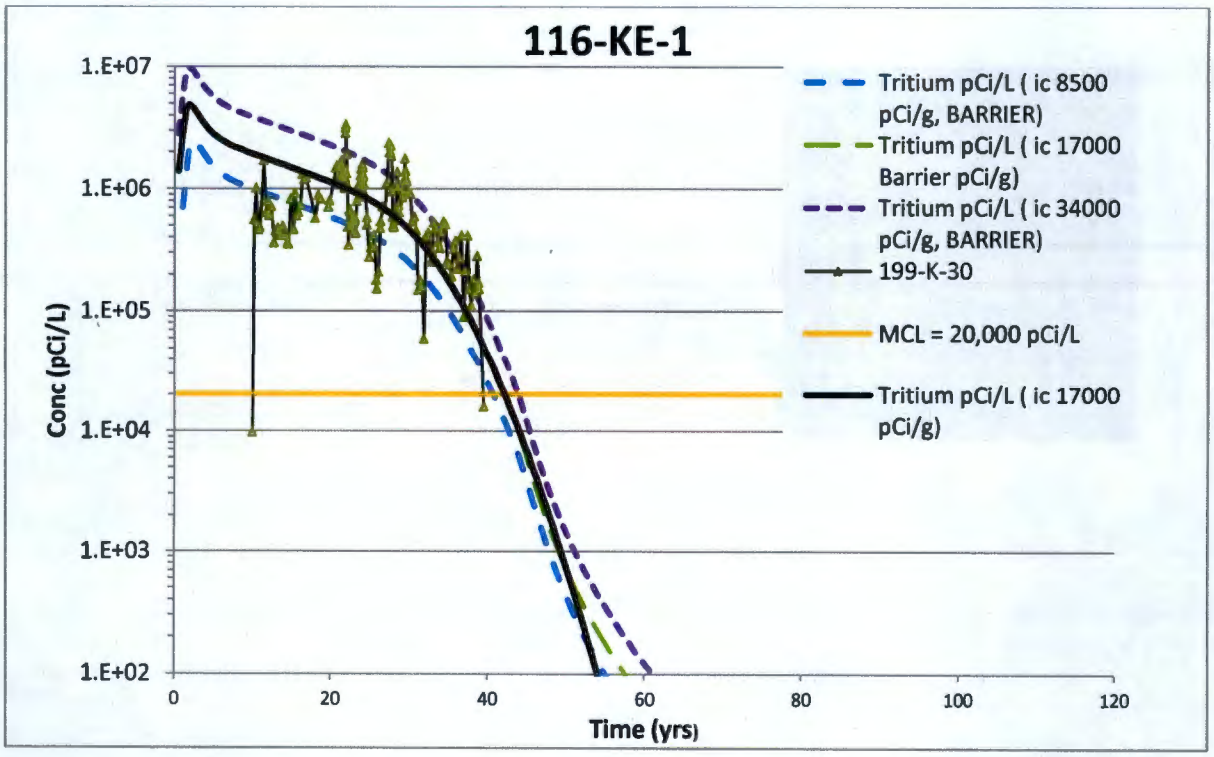


Figure 20. 116-KE-1 Tritium Results

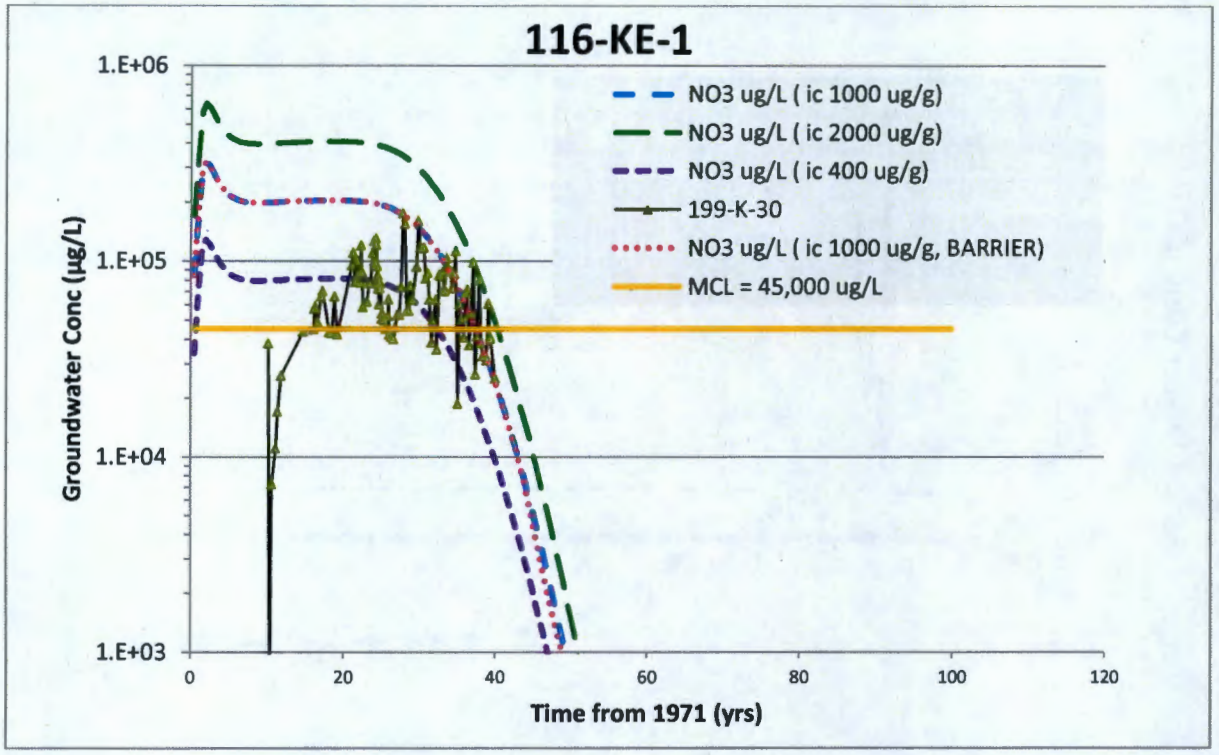


Figure 21. 116-KE-1 NO3 Results

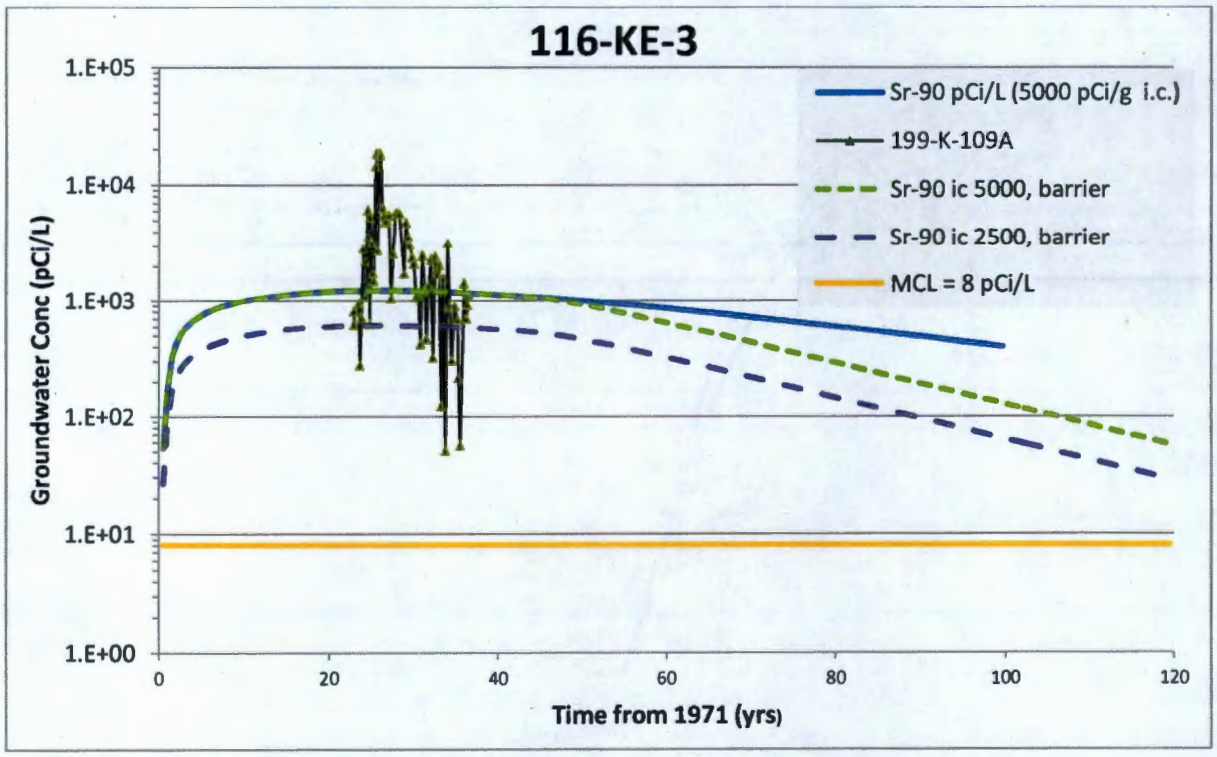


Figure 22. 116-KE-3 Strontium-90 Results

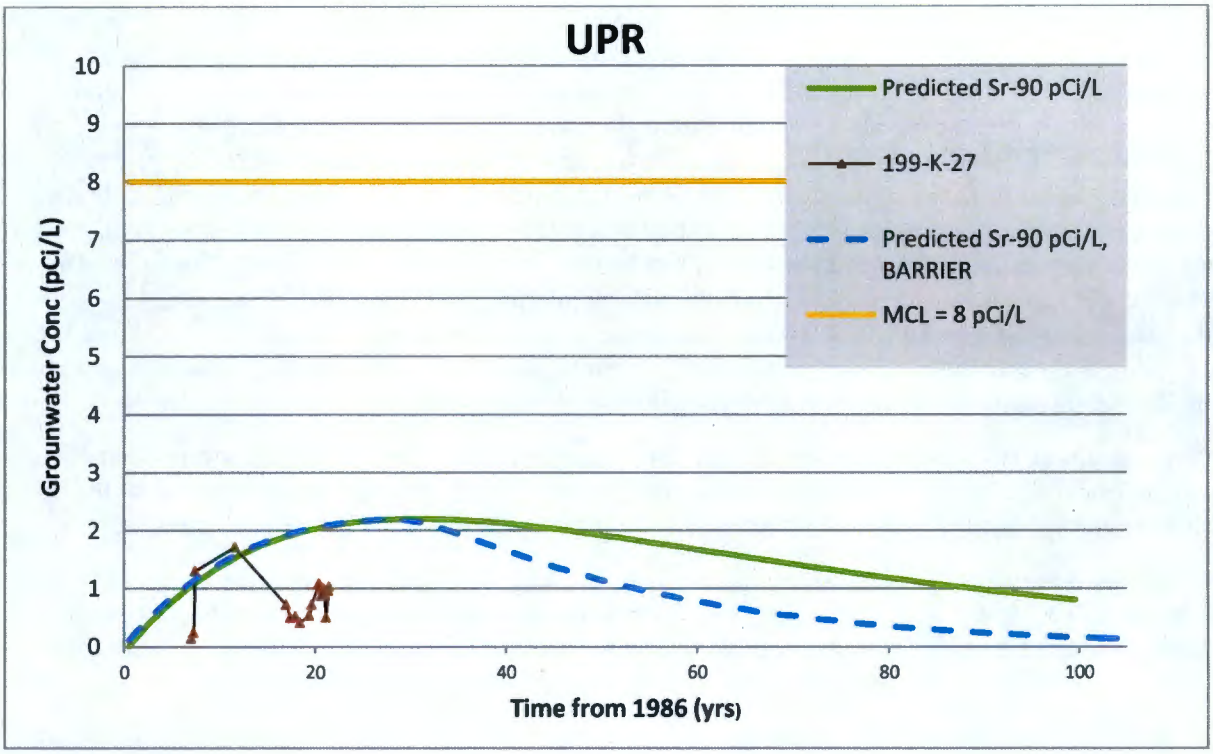


Figure 23. Strontium-90 UPR-100-K-1 Results

Table 6. Present Day Predicted Sorbed Concentrations in the Deep Vadose Zone for Selected Model Cases

Site	Present Day (Year 2012) Sorbed Concentration			
	Strontium-90 (pCi/g)	Carbon-14 (pCi/g)	Tritium (pCi/g)	Nitrate (µg/g)
116-KE-1	n/a	680-960	0	0
116-KE-3	930-1860	n/a	n/a	n/a
UPR-100-K-1	~0.6	n/a	n/a	n/a

Note: Sorbed concentrations were calculated at 2.5 m above the water table.

Table 7. Distances of Monitoring Wells From Waste Sites

Waste Site	Monitoring Well	Distance (m)
116-KE-1	199-K-30	30
116-KE-3	199-K-109A	10
UPR-100-K-1	199-K-27	35

Figure 19 displays the results at 116-KE-1 for carbon-14 with an initial sorbed concentration of 700 – 1000 pCi/g. The results with the barrier in effect (initial conditions of 700 pCi/g) indicate that the concentrations will drop below the MCL around year 57, approximately 16 years (equivalent to future time Year 2028) after the barrier is in place. Results indicate that without the barrier carbon-14 would not drop below MCL within the modeled timeframe. Predictions bound the last 5 to 10 years of data from monitoring well 199-K-30. Figure 20 displays the tritium results at 116-KE-1 on a logarithmic scale with initial concentrations ranging from 8,500 to 34,000 pCi/g. In all cases tritium drops below the MCL, with or without the barrier, shortly after present day due to short half-life (12.3 years) and high mobility. These results are in agreement with the data trend at nearby monitoring well 199-K-30. Tritium was not modeled at 116-KE-3 or the UPR-100-K-1 because the wells downgradient of the UPR-100-K-1 and 116-KE-3 do not observe recent tritium groundwater concentrations near the levels as at 116-KE-1. Therefore the 116-KE-1 results will bound 116-KE-3 and UPR-100-K-1 sites also.

Nitrate results at 116-KE-1 are shown in Figure 21 on a logarithmic scale with initial concentrations ranging from 400-2000 μg/g. Similar to tritium, under any modeled scenario, Nitrate drops below the MCL, with or without the barrier in effect, shortly after present day due to high mobility rates ($K_d = 0$).

Strontium-90 results at 116-KE-3 are shown in Figure 22. Initial soil concentrations ranging between 2500 to 5000 pCi/g produced results bounding groundwater concentrations consistent with present and recent past measurements. Under either of these conditions the predicted results do not drop below the MCL of 8.0 pCi/L within the period that the recharge barrier is expected to be effective.

Observed concentrations of the groundwater near the UPR-100-K-1 have not been above the MCL though high concentrations are present in the soil in the shallow vadose zone. Under these conditions the predicted results agree with measured groundwater data and show these shallow high concentrations will not impact groundwater with or without the barrier. See Figure 23. It should be noted, however, that in the absence of deep vadose zone data at the UPR-100-K-1 combined with the low mobility of strontium-90 and the distance (35 m) to the nearest monitoring well (199-K-27), there is high uncertainty of the potential impact to groundwater directly beneath the site.

8 Conclusion

In conclusion, for the mobile contaminants such as carbon-14, tritium, and nitrate, the surface barrier will be effective in reducing the contaminant flux to the groundwater over the next 75 years, or for the duration that the barrier is in place. The predicted groundwater concentrations will fall below the MCL. The predictive modeling of strontium-90 at 116-KE-3 indicates that reduced recharge will reduce the contaminant flux to the water table, but this may not be sufficient by itself to reduce the groundwater concentrations below MCL within the modeled timeframe. Additional data measuring the deep vadose zone strontium-90 concentrations at 116-KE-3 and carbon-14 concentrations at 116-KE-1 would improve the reliability of the predictions described herein.

9 References

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Attachment A

Soil Concentration and Carbon-14 Leach Data

Table A1. Strontium-90 Data

Sample Number	Sample Location	Contaminant	Result	Units	Lab Qualifier	Northing (m)	Easting (m)	Depth Below Grade (ft)	Angle from Vertical for DPTs
B2F178	Pothole 1 - 132.9 Bottom	Strontium-90	16.00	pCi/g		146740.13	569207.01	31.5	
B2F177	Pothole 1 - 134.04 Midpoint	Strontium-90	-0.03	pCi/g	U	146741.19	569208.5	27.8	
B2F176	Pothole 1 - 135.1 Surface	Strontium-90	30.00	pCi/g		146741.52	569209.84	24.3	
B2F183	Pothole 2 - 132.3 Surface	Strontium-90	400.00	pCi/g		146757.09	569195.65	33.5	
B2F182	Pothole 3 - 132.5 Surface	Strontium-90	360.00	pCi/g		146759.72	569181.88	32.8	
B2F181	Pothole 4 - 131.4 Bottom	Strontium-90	39.00	pCi/g		146747.66	569166.19	35.8	
B2F1B5	Pothole 4 - 131.9 Midpoint DUP	Strontium-90	11.00	pCi/g		146748.56	569165.66	34.1	
B2F180	Pothole 4 - 131.9 Midpont	Strontium-90	11.00	pCi/g		146748.56	569165.66	34.1	
B2F179	Pothole 4 - 132.5 Surface	Strontium-90	15.00	pCi/g		146748.89	569165.79	33.8	
B2F172	Pothole 5 - 130.6 Bottom	Strontium-90	0.91	pCi/g		146733.41	569144.04	39.0	
B2F171	Pothole 5 - 131.2 Midpoint	Strontium-90	1.20	pCi/g		146733.81	569144.42	37.1	
B2F170	Pothole 5 - 132.6 Surface	Strontium-90	0.05	pCi/g	U	146733.57	569146.06	32.5	
B2F169	Pothole 6 - 130.7 Bottom	Strontium-90	1.50	pCi/g		146724.96	569147.38	38.7	
B2F168	Pothole 6 - 131.5 Midpoint	Strontium-90	2.40	pCi/g		146725.11	569147.25	36.1	
B2F167	Pothole 6 - 132.6 Surface	Strontium-90	4.60	pCi/g		146725.24	569145.99	32.5	
B2F166	Pothole 7 - 130.7 Bottom	Strontium-90	7.40	pCi/g		146718.79	569149.35	38.7	
B2F165	Pothole 7 - 131.0 Midpoint	Strontium-90	3.30	pCi/g		146718.25	569149.39	37.7	
B2F164	Pothole 7 - 132.0 Surface	Strontium-90	86.00	pCi/g		146719.08	569148.91	34.4	
B2F175	Pothole 8 - 128.5 Bottom	Strontium-90	3.00	pCi/g		146746.1	569137.13	46.9	
B2F174	Pothole 8 - 129.4 Midpoint	Strontium-90	3.90	pCi/g		146746.77	569137.45	44.0	
B2F173	Pothole 8 - 130.6 Surface	Strontium-90	5.00	pCi/g		146747.56	569133.32	40.0	
	DPT Well C8307 - 3	Strontium-90	123.46	pCi/g		146735.12	569194.13	3.0	

Table A1. Strontium-90 Data

Sample Number	Sample Location	Contaminant	Result	Units	Lab Qualifier	Northing (m)	Easting (m)	Depth Below Grade (ft)	Angle from Vertical for DPTs
	DPT Well C8307 - 4	Strontium-90	1851.9	pCi/g		146735.12	569194.13	4.0	
	DPT Well C8307 - 5	Strontium-90	30865	pCi/g		146735.12	569194.13	5.0	
	DPT Well C8307 - 6	Strontium-90	123460	pCi/g		146735.12	569194.13	6.0	
	DPT Well C8307 - 7	Strontium-90	617300	pCi/g		146735.12	569194.13	7.0	
	DPT Well C8307 - 8	Strontium-90	9259500	pCi/g		146735.12	569194.13	8.0	
	DPT Well C8307 - 9	Strontium-90	277785	pCi/g		146735.12	569194.13	9.0	
	DPT Well C8307 - 10	Strontium-90	49384	pCi/g		146735.12	569194.13	10.0	
	DPT Well C8307 - 11	Strontium-90	49384	pCi/g		146735.12	569194.13	11.0	
	DPT Well C8307 - 12	Strontium-90	55557	pCi/g		146735.12	569194.13	12.0	
	DPT Well C8307 - 13	Strontium-90	43211	pCi/g		146735.12	569194.13	13.0	
	DPT Well C8307 - 14	Strontium-90	61730	pCi/g		146735.12	569194.13	14.0	
	DPT Well C8307 - 15	Strontium-90	123460	pCi/g		146735.12	569194.13	15.0	
	DPT Well C8307 - 16	Strontium-90	617300	pCi/g		146735.12	569194.13	16.0	
	DPT Well C8307 - 17	Strontium-90	27778.5	pCi/g		146735.12	569194.13	17.0	
	DPT Well C8307 - 18	Strontium-90	1851.9	pCi/g		146735.12	569194.13	18.0	
	DPT Well C8307 - 19	Strontium-90	3703.8	pCi/g		146735.12	569194.13	19.0	
	DPT Well C8307 - 20	Strontium-90	3086.5	pCi/g		146735.12	569194.13	20.0	
	DPT Well C8307 - 21	Strontium-90	1111.14	pCi/g		146735.12	569194.13	21.0	
	DPT Well C8307 - 22	Strontium-90	925.95	pCi/g		146735.12	569194.13	22.0	
	DPT Well C8307 - 23	Strontium-90	2160.55	pCi/g		146735.12	569194.13	23.0	
	DPT Well C8307 - 24	Strontium-90	92.595	pCi/g		146735.12	569194.13	24.0	
	DPT Well C8307 - 25	Strontium-90	3.27E+02	pCi/g		146735.12	569194.13	25.0	

Table A1. Strontium-90 Data

Sample Number	Sample Location	Contaminant	Result	Units	Lab Qualifier	Northing (m)	Easting (m)	Depth Below Grade (ft)	Angle from Vertical for DPTs
	DPT Well C8307 - 26	Strontium-90	4.20E+02	pCi/g		146735.12	569194.13	26.0	
	DPT Well C8307 - 27	Strontium-90	2.34E+02	pCi/g		146735.12	569194.13	27.0	
	DPT Well C8308 - 7	Strontium-90	67.903	pCi/g		146732.73	569188.09	7	40' push at 48 degrees
	DPT Well C8308 - 8	Strontium-90	2469.2	pCi/g		146732.73	569188.09	8	40' push at 48 degrees
	DPT Well C8308 - 9	Strontium-90	185190	pCi/g		146732.73	569188.09	9	40' push at 48 degrees
	DPT Well C8308 - 10	Strontium-90	123460	pCi/g		146732.73	569188.09	10	40' push at 48 degrees
	DPT Well C8308 - 11	Strontium-90	6173	pCi/g		146732.73	569188.09	11	40' push at 48 degrees
	DPT Well C8308 - 12	Strontium-90	1234.6	pCi/g		146732.73	569188.09	12	40' push at 48 degrees
	DPT Well C8308 - 13	Strontium-90	92.595	pCi/g		146732.73	569188.09	13	40' push at 48 degrees
	DPT Well C8308 - 14	Strontium-90	104.941	pCi/g		146732.73	569188.09	14	40' push at 48 degrees
	DPT Well C8308 - 15	Strontium-90	86.422	pCi/g		146732.73	569188.09	15	40' push at 48 degrees
	DPT Well C8308 - 16	Strontium-90	77.1625	pCi/g		146732.73	569188.09	16	40' push at 48 degrees
	DPT Well C8308 - 17	Strontium-90	80.249	pCi/g		146732.73	569188.09	17	40' push at 48 degrees
	DPT Well C8308 - 18	Strontium-90	1234.6	pCi/g		146732.73	569188.09	18	40' push at 48 degrees
	DPT Well C8308 - 19	Strontium-90	6173	pCi/g		146732.73	569188.09	19	40' push at 48 degrees
	DPT Well C8308 - 20	Strontium-90	123460	pCi/g		146732.73	569188.09	20	40' push at 48 degrees
	DPT Well C8308 - 21	Strontium-90	493840	pCi/g		146732.73	569188.09	21	40' push at 48 degrees
	DPT Well C8308 - 22	Strontium-90	339515	pCi/g		146732.73	569188.09	22	40' push at 48 degrees
	DPT Well C8308 - 23	Strontium-90	185190	pCi/g		146732.73	569188.09	23	40' push at 48 degrees
	DPT Well C8308 - 24	Strontium-90	154325	pCi/g		146732.73	569188.09	24	40' push at 48 degrees
	DPT Well C8308 - 25	Strontium-90	185190	pCi/g		146732.73	569188.09	25	40' push at 48 degrees
	DPT Well C8308 - 26	Strontium-90	123460	pCi/g		146732.73	569188.09	26	40' push at 48 degrees

Table A1. Strontium-90 Data

Sample Number	Sample Location	Contaminant	Result	Units	Lab Qualifier	Northing (m)	Easting (m)	Depth Below Grade (ft)	Angle from Vertical for DPTs
	DPT Well C8308 - 27	Strontium-90	92595	pCi/g		146732.73	569188.09	27	40' push at 48 degrees
	DPT Well C8308 - 28	Strontium-90	61730	pCi/g		146732.73	569188.09	28	40' push at 48 degrees
	DPT Well C8308 - 29	Strontium-90	111114	pCi/g		146732.73	569188.09	29	40' push at 48 degrees
	DPT Well C8308 - 30	Strontium-90	92595	pCi/g		146732.73	569188.09	30	40' push at 48 degrees
	DPT Well C8308 - 31	Strontium-90	61730	pCi/g		146732.73	569188.09	31	40' push at 48 degrees
	DPT Well C8308 - 32	Strontium-90	123460	pCi/g		146732.73	569188.09	32	40' push at 48 degrees
	DPT Well C8308 - 33	Strontium-90	7.01E+05	pCi/g		146732.73	569188.09	33	40' push at 48 degrees
	DPT Well C8308 - 34	Strontium-90	6.31E+05	pCi/g		146732.73	569188.09	34	40' push at 48 degrees
	DPT Well C8308 - 35	Strontium-90	3.50E+05	pCi/g		146732.73	569188.09	35	40' push at 48 degrees
	DPT Well C8308 - 36	Strontium-90	2.80E+05	pCi/g		146732.73	569188.09	36	40' push at 48 degrees
	DPT Well C8308 - 37	Strontium-90	2.34E+05	pCi/g		146732.73	569188.09	37	40' push at 48 degrees
	DPT Well C8308 - 38	Strontium-90	7.01E+04	pCi/g		146732.73	569188.09	38	40' push at 48 degrees
	DPT Well C8308 - 39	Strontium-90	4.67E+04	pCi/g		146732.73	569188.09	39	40' push at 48 degrees
	DPT Well C8308 - 40	Strontium-90	2.34E+04	pCi/g		146732.73	569188.09	40	40' push at 48 degrees
	DPT Well C8309 - 4	Strontium-90	67.903	pCi/g		146726.57	569176.02	4	40' push at 48 degrees
	DPT Well C8309 - 5	Strontium-90	617.3	pCi/g		146726.57	569176.02	5	40' push at 48 degrees
	DPT Well C8309 - 6	Strontium-90	30865	pCi/g		146726.57	569176.02	6	40' push at 48 degrees
	DPT Well C8309 - 7	Strontium-90	1234600	pCi/g		146726.57	569176.02	7	40' push at 48 degrees
	DPT Well C8309 - 8	Strontium-90	216055	pCi/g		146726.57	569176.02	8	40' push at 48 degrees
	DPT Well C8309 - 9	Strontium-90	61730	pCi/g		146726.57	569176.02	9	40' push at 48 degrees
	DPT Well C8309 - 10	Strontium-90	6173	pCi/g		146726.57	569176.02	10	40' push at 48 degrees
	DPT Well C8309 - 11	Strontium-90	1234.6	pCi/g		146726.57	569176.02	11	40' push at 48 degrees

Table A1. Strontium-90 Data

Sample Number	Sample Location	Contaminant	Result	Units	Lab Qualifier	Northing (m)	Easting (m)	Depth Below Grade (ft)	Angle from Vertical for DPTs
	DPT Well C8309 - 12	Strontium-90	1234.6	pCi/g		146726.57	569176.02	12	40' push at 48 degrees
	DPT Well C8309 - 13	Strontium-90	6173	pCi/g		146726.57	569176.02	13	40' push at 48 degrees
	DPT Well C8309 - 14	Strontium-90	15432.5	pCi/g		146726.57	569176.02	14	40' push at 48 degrees
	DPT Well C8309 - 15	Strontium-90	4938.4	pCi/g		146726.57	569176.02	15	40' push at 48 degrees
	DPT Well C8309 - 16	Strontium-90	12346	pCi/g		146726.57	569176.02	16	40' push at 48 degrees
	DPT Well C8309 - 17	Strontium-90	61730	pCi/g		146726.57	569176.02	17	40' push at 48 degrees
	DPT Well C8309 - 18	Strontium-90	117287	pCi/g		146726.57	569176.02	18	40' push at 48 degrees
	DPT Well C8309 - 19	Strontium-90	92595	pCi/g		146726.57	569176.02	19	40' push at 48 degrees
	DPT Well C8309 - 20	Strontium-90	92595	pCi/g		146726.57	569176.02	20	40' push at 48 degrees
	DPT Well C8309 - 21	Strontium-90	27778.5	pCi/g		146726.57	569176.02	21	40' push at 48 degrees
	DPT Well C8309 - 22	Strontium-90	6173	pCi/g		146726.57	569176.02	22	40' push at 48 degrees
	DPT Well C8309 - 23	Strontium-90	117.287	pCi/g		146726.57	569176.02	23	40' push at 48 degrees
	DPT Well C8309 - 24	Strontium-90	123.46	pCi/g		146726.57	569176.02	24	40' push at 48 degrees
	DPT Well C8310 - 4	Strontium-90	123.46	pCi/g		146723.2	569167.43	4	40' push at 50 degrees
	DPT Well C8310 - 5	Strontium-90	246.92	pCi/g		146723.2	569167.43	5	40' push at 50 degrees
	DPT Well C8310 - 6	Strontium-90	617.3	pCi/g		146723.2	569167.43	6	40' push at 50 degrees
	DPT Well C8310 - 7	Strontium-90	18519	pCi/g		146723.2	569167.43	7	40' push at 50 degrees
	DPT Well C8310 - 8	Strontium-90	1234600	pCi/g		146723.2	569167.43	8	40' push at 50 degrees
	DPT Well C8310 - 9	Strontium-90	1234600	pCi/g		146723.2	569167.43	9	40' push at 50 degrees
	DPT Well C8310 - 10	Strontium-90	123460	pCi/g		146723.2	569167.43	10	40' push at 50 degrees
	DPT Well C8310 - 11	Strontium-90	24692	pCi/g		146723.2	569167.43	11	40' push at 50 degrees
	DPT Well C8310 - 12	Strontium-90	5555.7	pCi/g		146723.2	569167.43	12	40' push at 50 degrees

Table A1. Strontium-90 Data

Sample Number	Sample Location	Contaminant	Result	Units	Lab Qualifier	Northing (m)	Easting (m)	Depth Below Grade (ft)	Angle from Vertical for DPTs
	DPT Well C8310 - 13	Strontium-90	9259.5	pCi/g		146723.2	569167.43	13	40' push at 50 degrees
	DPT Well C8310 - 14	Strontium-90	9876.8	pCi/g		146723.2	569167.43	14	40' push at 50 degrees
	DPT Well C8310 - 15	Strontium-90	11728.7	pCi/g		146723.2	569167.43	15	40' push at 50 degrees
	DPT Well C8310 - 16	Strontium-90	2469.2	pCi/g		146723.2	569167.43	16	40' push at 50 degrees
	DPT Well C8310 - 17	Strontium-90	925.95	pCi/g		146723.2	569167.43	17	40' push at 50 degrees
	DPT Well C8310 - 18	Strontium-90	1172.87	pCi/g		146723.2	569167.43	18	40' push at 50 degrees
	DPT Well C8310 - 19	Strontium-90	1234.6	pCi/g		146723.2	569167.43	19	40' push at 50 degrees
	DPT Well C8310 - 20	Strontium-90	2469.2	pCi/g		146723.2	569167.43	20	40' push at 50 degrees
	DPT Well C8310 - 21	Strontium-90	1172.87	pCi/g		146723.2	569167.43	21	40' push at 50 degrees
	DPT Well C8310 - 22	Strontium-90	370.38	pCi/g		146723.2	569167.43	22	40' push at 50 degrees
	DPT Well C8310 - 23	Strontium-90	617.3	pCi/g		146723.2	569167.43	23	40' push at 50 degrees
	DPT Well C8310 - 24	Strontium-90	555.57	pCi/g		146723.2	569167.43	24	40' push at 50 degrees
	DPT Well C8310 - 29	Strontium-90	216.055	pCi/g		146723.2	569167.43	29	40' push at 50 degrees
	DPT Well C8310 - 30	Strontium-90	154.325	pCi/g		146723.2	569167.43	30	40' push at 50 degrees
	DPT Well C8310 - 31	Strontium-90	154.325	pCi/g		146723.2	569167.43	31	40' push at 50 degrees
	DPT Well C8311 - 4	Strontium-90	3703.8	pCi/g		146736.45	569193.16	4	40' push at 46 degrees
	DPT Well C8311 - 5	Strontium-90	9259.5	pCi/g		146736.45	569193.16	5	40' push at 46 degrees
	DPT Well C8311 - 6	Strontium-90	12346	pCi/g		146736.45	569193.16	6	40' push at 46 degrees
	DPT Well C8311 - 7	Strontium-90	61730	pCi/g		146736.45	569193.16	7	40' push at 46 degrees
	DPT Well C8311 - 8	Strontium-90	555570	pCi/g		146736.45	569193.16	8	40' push at 46 degrees
	DPT Well C8311 - 9	Strontium-90	123460	pCi/g		146736.45	569193.16	9	40' push at 46 degrees
	DPT Well C8311 - 10	Strontium-90	6173000	pCi/g		146736.45	569193.16	10	40' push at 46 degrees

Table A1. Strontium-90 Data

Sample Number	Sample Location	Contaminant	Result	Units	Lab Qualifier	Northing (m)	Easting (m)	Depth Below Grade (ft)	Angle from Vertical for DPTs
	DPT Well C8311 - 11	Strontium-90	12346000	pCi/g		146736.45	569193.16	11	40' push at 46 degrees
	DPT Well C8311 - 12	Strontium-90	12346000	pCi/g		146736.45	569193.16	12	40' push at 46 degrees
	DPT Well C8311 - 13	Strontium-90	617300	pCi/g		146736.45	569193.16	13	40' push at 46 degrees
	DPT Well C8311 - 14	Strontium-90	172844	pCi/g		146736.45	569193.16	14	40' push at 46 degrees
	DPT Well C8311 - 15	Strontium-90	172844	pCi/g		146736.45	569193.16	15	40' push at 46 degrees
	DPT Well C8311 - 16	Strontium-90	308650	pCi/g		146736.45	569193.16	16	40' push at 46 degrees
	DPT Well C8311 - 17	Strontium-90	61730	pCi/g		146736.45	569193.16	17	40' push at 46 degrees
	DPT Well C8311 - 18	Strontium-90	12346	pCi/g		146736.45	569193.16	18	40' push at 46 degrees
	DPT Well C8311 - 19	Strontium-90	4938.4	pCi/g		146736.45	569193.16	19	40' push at 46 degrees
	DPT Well C8311 - 20	Strontium-90	4938.4	pCi/g		146736.45	569193.16	20	40' push at 46 degrees
	DPT Well C8311 - 21	Strontium-90	61730	pCi/g		146736.45	569193.16	21	40' push at 46 degrees
	DPT Well C8311 - 22	Strontium-90	308650	pCi/g		146736.45	569193.16	22	40' push at 46 degrees
	DPT Well C8311 - 23	Strontium-90	37038	pCi/g		146736.45	569193.16	23	40' push at 46 degrees
	DPT Well C8311 - 24	Strontium-90	5555.7	pCi/g		146736.45	569193.16	24	40' push at 46 degrees
	DPT Well C8311 - 25	Strontium-90	3086.5	pCi/g		146736.45	569193.16	25	40' push at 46 degrees
	DPT Well C8311 - 26	Strontium-90	185.19	pCi/g		146736.45	569193.16	26	40' push at 46 degrees
	DPT Well C8311 - 27	Strontium-90	185.19	pCi/g		146736.45	569193.16	27	40' push at 46 degrees
	DPT Well C8311 - 28	Strontium-90	185.19	pCi/g		146736.45	569193.16	28	40' push at 46 degrees
	DPT Well C8311 - 29	Strontium-90	308.65	pCi/g		146736.45	569193.16	29	40' push at 46 degrees
	DPT Well C8311 - 30	Strontium-90	617.3	pCi/g		146736.45	569193.16	30	40' push at 46 degrees
	DPT Well C8311 - 31	Strontium-90	617.3	pCi/g		146736.45	569193.16	31	40' push at 46 degrees
	DPT Well C8311 - 32	Strontium-90	370.38	pCi/g		146736.45	569193.16	32	40' push at 46 degrees

Table A1. Strontium-90 Data

Sample Number	Sample Location	Contaminant	Result	Units	Lab Qualifier	Northing (m)	Easting (m)	Depth Below Grade (ft)	Angle from Vertical for DPTs
	DPT Well C8311 - 33	Strontium-90	7.01E+02	pCi/g		146736.45	569193.16	33	40' push at 46 degrees
	DPT Well C8311 - 34	Strontium-90	7.01E+02	pCi/g		146736.45	569193.16	34	40' push at 46 degrees
	DPT Well C8311 - 35	Strontium-90	3.50E+02	pCi/g		146736.45	569193.16	35	40' push at 46 degrees
	DPT Well C8312 - 3.5	Strontium-90	154.325	pCi/g		146728.94	569179.5	3.5	
	DPT Well C8312 - 4	Strontium-90	1234.6	pCi/g		146728.94	569179.5	4	
	DPT Well C8312 - 5	Strontium-90	92.595	pCi/g		146728.94	569179.5	5	
	DPT Well C8312 - 6	Strontium-90	49384	pCi/g		146728.94	569179.5	6	
	DPT Well C8312 - 7	Strontium-90	9259.5	pCi/g		146728.94	569179.5	7	
	DPT Well C8312 - 8	Strontium-90	49384	pCi/g		146728.94	569179.5	8	
	DPT Well C8312 - 9	Strontium-90	617.3	pCi/g		146728.94	569179.5	9	
	DPT Well C8312 - 10	Strontium-90	1851.9	pCi/g		146728.94	569179.5	10	
	DPT Well C8312 - 11	Strontium-90	43211	pCi/g		146728.94	569179.5	11	
	DPT Well C8312 - 12	Strontium-90	6173	pCi/g		146728.94	569179.5	12	
	DPT Well C8312 - 13	Strontium-90	925.95	pCi/g		146728.94	569179.5	13	
	DPT Well C8312 - 14	Strontium-90	185.19	pCi/g		146728.94	569179.5	14	
	DPT Well C8313 - 3.5	Strontium-90	123.46	pCi/g		146724.26	569166.92	3.5	
	DPT Well C8313 - 4	Strontium-90	1234.6	pCi/g		146724.26	569166.92	4	
	DPT Well C8313 - 5	Strontium-90	123460	pCi/g		146724.26	569166.92	5	
	DPT Well C8313 - 6	Strontium-90	1234600	pCi/g		146724.26	569166.92	6	
	DPT Well C8313 - 7	Strontium-90	246920	pCi/g		146724.26	569166.92	7	
	DPT Well C8313 - 8	Strontium-90	92595	pCi/g		146724.26	569166.92	8	
	DPT Well C8313 - 9	Strontium-90	86422	pCi/g		146724.26	569166.92	9	

Table A1. Strontium-90 Data

Sample Number	Sample Location	Contaminant	Result	Units	Lab Qualifier	Northing (m)	Easting (m)	Depth Below Grade (ft)	Angle from Vertical for DPTs
	DPT Well C8313 - 10	Strontium-90	24692	pCi/g		146724.26	569166.92	10	
	DPT Well C8313 - 11	Strontium-90	3086.5	pCi/g		146724.26	569166.92	11	
	DPT Well C8313 - 12	Strontium-90	1851.9	pCi/g		146724.26	569166.92	12	
	DPT Well C8313 - 13	Strontium-90	617.3	pCi/g		146724.26	569166.92	13	
	DPT Well C8313 - 14	Strontium-90	432.11	pCi/g		146724.26	569166.92	14	
	DPT Well C8313 - 15	Strontium-90	154.325	pCi/g		146724.26	569166.92	15	
	DPT Well C8313 - 16	Strontium-90	216.055	pCi/g		146724.26	569166.92	16	
	DPT Well C8313 - 17	Strontium-90	246.92	pCi/g		146724.26	569166.92	17	
	DPT Well C8313 - 18	Strontium-90	123.46	pCi/g		146724.26	569166.92	18	
	DPT Well C8314 - 1.5	Strontium-90	216.055	pCi/g		146747.07	569188.84	1.5	
	DPT Well C8314 - 2	Strontium-90	617.3	pCi/g		146747.07	569188.84	2	
	DPT Well C8314 - 3	Strontium-90	61730	pCi/g		146747.07	569188.84	3	
	DPT Well C8314 - 4	Strontium-90	1851900	pCi/g		146747.07	569188.84	4	
	DPT Well C8314 - 5	Strontium-90	1234600	pCi/g		146747.07	569188.84	5	
	DPT Well C8314 - 6	Strontium-90	1234600	pCi/g		146747.07	569188.84	6	
	DPT Well C8314 - 7	Strontium-90	6173000	pCi/g		146747.07	569188.84	7	
	DPT Well C8314 - 8	Strontium-90	1234600	pCi/g		146747.07	569188.84	8	
	DPT Well C8314 - 9	Strontium-90	246920	pCi/g		146747.07	569188.84	9	
	DPT Well C8314 - 10	Strontium-90	92595	pCi/g		146747.07	569188.84	10	
	DPT Well C8314 - 11	Strontium-90	123460	pCi/g		146747.07	569188.84	11	
	DPT Well C8314 - 12	Strontium-90	18519	pCi/g		146747.07	569188.84	12	
	DPT Well C8314 - 13	Strontium-90	4321.1	pCi/g		146747.07	569188.84	13	

Table A1. Strontium-90 Data

Sample Number	Sample Location	Contaminant	Result	Units	Lab Qualifier	Northing (m)	Easting (m)	Depth Below Grade (ft)	Angle from Vertical for DPTs
	DPT Well C8314 - 14	Strontium-90	1543.25	pCi/g		146747.07	569188.84	14	
	DPT Well C8314 - 15	Strontium-90	1543.25	pCi/g		146747.07	569188.84	15	
	DPT Well C8314 - 16	Strontium-90	92595	pCi/g		146747.07	569188.84	16	
	DPT Well C8314 - 17	Strontium-90	154325	pCi/g		146747.07	569188.84	17	
	DPT Well C8314 - 18	Strontium-90	123460	pCi/g		146747.07	569188.84	18	
	DPT Well C8314 - 19	Strontium-90	4938.4	pCi/g		146747.07	569188.84	19	
	DPT Well C8314 - 20	Strontium-90	617.3	pCi/g		146747.07	569188.84	20	
	DPT Well C8314 - 21	Strontium-90	123.46	pCi/g		146747.07	569188.84	21	
	DPT Well C8316 - 2.5	Strontium-90	92.595	pCi/g		146731.35	569161.66	2.5	
	DPT Well C8316 - 3	Strontium-90	925.95	pCi/g		146731.35	569161.66	3	
	DPT Well C8316 - 4	Strontium-90	123460	pCi/g		146731.35	569161.66	4	
	DPT Well C8316 - 5	Strontium-90	555570	pCi/g		146731.35	569161.66	5	
	DPT Well C8316 - 6	Strontium-90	925950	pCi/g		146731.35	569161.66	6	
	DPT Well C8316 - 7	Strontium-90	61730	pCi/g		146731.35	569161.66	7	
	DPT Well C8316 - 8	Strontium-90	1234.6	pCi/g		146731.35	569161.66	8	
	DPT Well C8316 - 9	Strontium-90	111.114	pCi/g		146731.35	569161.66	9	
	DPT Well C8316 - 10	Strontium-90	18519	pCi/g		146731.35	569161.66	10	
	DPT Well C8316 - 11	Strontium-90	30865	pCi/g		146731.35	569161.66	11	
	DPT Well C8316 - 12	Strontium-90	3086.5	pCi/g		146731.35	569161.66	12	
	DPT Well C8316 - 13	Strontium-90	1543.25	pCi/g		146731.35	569161.66	13	
	DPT Well C8316 - 14	Strontium-90	555.57	pCi/g		146731.35	569161.66	14	
	DPT Well C8316 - 15	Strontium-90	246.92	pCi/g		146731.35	569161.66	15	

Table A1. Strontium-90 Data

Sample Number	Sample Location	Contaminant	Result	Units	Lab Qualifier	Northing (m)	Easting (m)	Depth Below Grade (ft)	Angle from Vertical for DPTs
	DPT Well C8316 - 16	Strontium-90	123.46	pCi/g		146731.35	569161.66	16	
	DPT Well C8662 - 7	Strontium-90	61.73	pCi/g		146773.92	569206.65	7	
	DPT Well C8662 - 8	Strontium-90	6173	pCi/g		146773.92	569206.65	8	
	DPT Well C8662 - 9	Strontium-90	432110	pCi/g		146773.92	569206.65	9	
	DPT Well C8662 - 10	Strontium-90	6173	pCi/g		146773.92	569206.65	10	
	DPT Well C8662 - 11	Strontium-90	617.3	pCi/g		146773.92	569206.65	11	
	DPT Well C8662 - 12	Strontium-90	493.84	pCi/g		146773.92	569206.65	12	
	DPT Well C8662 - 13	Strontium-90	185.19	pCi/g		146773.92	569206.65	13	
	DPT Well C8662 - 14	Strontium-90	123.46	pCi/g		146773.92	569206.65	14	
B26WR3	116-KE-3 - 27ft	Strontium-90	44,000	pCi/g		146747.56	569133.32	27.0	
	116-KE-3 - 40 ft	Strontium-90	10,000	pCi/g		146747.56	569133.32	40	

Table A2. Carbon-14 Data

Sample Number	Sample Location	Contaminant	Result	Units	Northing (m)	Easting (m)	Depth Below Grade (ft)
B2C3K9-A	116-KE-1	Carbon-14	1760.00	pCi/g	146737.82	569256.61	33
B2C3K7-A	116-KE-1	Carbon-14	6.38	pCi/g	146746.85	569253.45	33
B2C3K8-A	116-KE-1	Carbon-14	7.11	pCi/g	146756.54	569256.7	33
J017D9	116-KE-1 - A4	Carbon-14	2.95	pCi/g	146737.65	569254.71	10
J017D6	116-KE-1 - A1	Carbon-14	2.67	pCi/g	146758.42	569247.13	10
J017D8	116-KE-1 - A3	Carbon-14	1.27	pCi/g	146763.07	569263.05	10
J017F2	116-KE-1 - A1	Carbon-14	7600.00	pCi/g	146753.83	569526.59	30
J017F3	116-KE-1 - A2	Carbon-14	1880.00	pCi/g	146754.32	569258.32	30
J017F4	116-KE-1 - A3	Carbon-14	5.25	pCi/g	146755.67	569260.3	30

Table A3. Tritium Data

Sample Number	Sample Location	Contaminant	Result	Units	Northing (m)	Easting (m)	Depth Below Grade (ft)
J017D9	116-KE-1 - A4	Tritium	-0.02	pCi/g	146737.65	569254.71	10
J017D6	116-KE-1 - A1	Tritium	-0.06	pCi/g	146758.42	569247.13	10
J017D8	116-KE-1 - A3	Tritium	0.30	pCi/g	146763.07	569263.05	10
J017F2	116-KE-1 - A1	Tritium	851.00	pCi/g	146753.83	569526.59	30
J017F3	116-KE-1 - A2	Tritium	845.00	pCi/g	146754.32	569258.32	30
J017F4	116-KE-1 - A3	Tritium	465.00	pCi/g	146755.67	569260.3	30

Table A4. Carbon-14 Leach Test Data

Sample	Soil Mass (g)	Carbon-14 Soil Concentration (pCi/g)	Leachate Volume (L)	Leachate Concentration (pCi/L)	K_d (L/g)	Initial pCi in Soil	pCi in Leachate	Final pCi in Soil	% Leached	Note
B2C3K7-A	100	6.38	0.100	117	0.05353	638	11.70	626.30	1.83%	
B2C3K7-B	100	6.38	0.150	93.3	0.06688	638	14.00	624.01	2.19%	
B2C3K7-C	100	6.38	0.250	70.6	0.08787	638	17.65	620.35	2.77%	
B2C3K7-D	100	6.38	0.500	27.0	0.23130	638	13.50	624.50	2.12%	
B2C3K7-E	100	6.38	0.500	17.3	0.36379	638	8.65	629.35	1.36%	Dup
B2C3K8-A	100	7.11	0.100	429	0.01557	711	42.90	668.10	6.03%	
B2C3K8-B	100	7.11	0.150	309	0.02151	711	46.35	664.65	6.52%	
B2C3K8-C	100	7.11	0.250	200	0.03305	711	50.00	661.00	7.03%	
B2C3K8-E	100	7.11	0.250	192	0.03453	711	48.00	663.00	6.75%	Dup
B2C3K8-D	100	7.11	0.500	83.0	0.08066	711	41.50	669.50	5.84%	
B2C3K9-A	100	1760	0.100	91000	0.01834	176000	9100	166900	5.17%	
B2C3K9-E	100	1760	0.100	78800	0.02134	176000	7880	168120	4.48%	Dup
B2C3K9-B	100	1760	0.150	44000	0.03850	176000	6600	169400	3.75%	
B2C3K9-C	100	1760	0.250	27300	0.06197	176000	6825	169175	3.88%	
B2C3K9-D	100	1760	0.500	12900	0.13143	176000	6450	169550	3.66%	
B2C3L0-A	100	1550	0.100	108000	0.01335	155000	10800	144200	6.97%	

Table A4. Carbon-14 Leach Test Data

Sample	Soil Mass (g)	Carbon-14 Soil Concentration (pCi/g)	Leachate Volume (L)	Leachate Concentration (pCi/L)	K_d (L/g)	Initial pCi in Soil	pCi in Leachate	Final pCi in Soil	% Leached	Note
B2C3L0-B	100	1550	0.150	51300	0.02871	155000	7695	147305	4.96%	
B2C3L0-C	100	1550	0.250	32300	0.04549	155000	8075	146925	5.21%	
B2C3L0-D	100	1550	0.500	16300	0.09009	155000	8150	146850	5.26%	

Attachment B

STOMP Software Checkout and Installation Form

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM

Software Owner Instructions:

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

Software Subject Matter Expert Instructions:

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

GENERAL INFORMATION:

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

EXECUTABLE INFORMATION:

2. Executable Name (include path):

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

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

COMPILATION INFORMATION:

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

   RANSAC Linux Cluster (WD56054)

5. Operating System (include version number):

   Redhat Enterprise Linux WS3 (Taroon Update)

INSTALLATION AND CHECKOUT INFORMATION:

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

   INTERA GREEN Linux File Server (INTERA-00469)

7. Operating System (include version number):

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

8. Open Problem Report? ◉ No ○ Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

   /srv/samba/saved_data/test/stomp/build-02

10. Procedure(s):

    CHPRC-00211 Rev. 1, STOMP Software Test Plan

11. Libraries:

    N/A (static linking)

12. Input Files:

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

13. Output Files:

    plot.* files produced by STOMP executables

14. Test Cases:

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

15. Test Case Results:

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CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

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

PASS (diff all plot files showed no numerical differences)

16. Test Performed By: WE Nichols

17. Test Results: ◉ Satisfactory, Accepted for Use ○ Unsatisfactory

18. Disposition (include HISI update):

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

Prepared By: William E. Nichols

19. _____ WE Nichols _____ _____
Software Owner (Signature) Print Date

20. Test Personnel: William E. Nichols

_____ WE Nichols _____ _____
Sign Print Date

_____ _____ _____
Sign Print Date

_____ _____ _____
Sign Print Date

Approved By:

21. _____ N/R _____ _____
Software SME (Signature) Print Date

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