

Lysimeter and groundwater sample results do not corroborate Ra-226 presence in the vadose zone core. Of more than 150 lysimeter samples, Ra-226 was detected only twice, both times from the 0- to 35-ft interval, with no detections in the deeper lysimeter or perched water wells. Of the 191 groundwater samples, Ra-226 was detected three times. One of the detections was upgradient of the SDA and another was about 1 mile south of the SDA. The third detection was from a well within the SDA boundary. The detection rates for Ra-226 are shown in Table 4-84. The distribution of Ra-226 detections at the various depth intervals is shown in Figure 4-40.

Table 4-84. Detection rates for radium-226 in all media.

Media	Detection Rate (%)	Range of Detected Concentrations	Number of Detections > Risk-Based Concentration <sup>a</sup> or MCL <sup>b</sup>	Wells with Concentrations > Risk-Based Concentration or MCL
Vadose zone (0 to 35 ft)				
Cores	7.7	1.7 pCi/g	0	None
Soil moisture	2	34 to 46 pCi/L	2	PA01, 98-5
Vadose zone (35 to 140 ft)				
Cores	14.6	2.10 to 8 pCi/g	0	None
Soil moisture	0	Not applicable	0	None
Vadose zone (140 to 250 ft)				
Cores	21.1	2.60 to 7.9 pCi/g	0	None
Soil moisture	0	Not applicable	0	None
Vadose zone (>250 ft)				
Cores	0	Not applicable	0	None
Aquifer	1.6	4.0 to 5.4 pCi/L	3	M11S, M17S, OW-2

MCL = maximum contaminant level

a. For vadose zone cores, the 1E-05 risk-based concentration is 10.87 pCi/g.

b. For lysimeter, perched water, and aquifer samples, the MCL is 5 pCi/L.

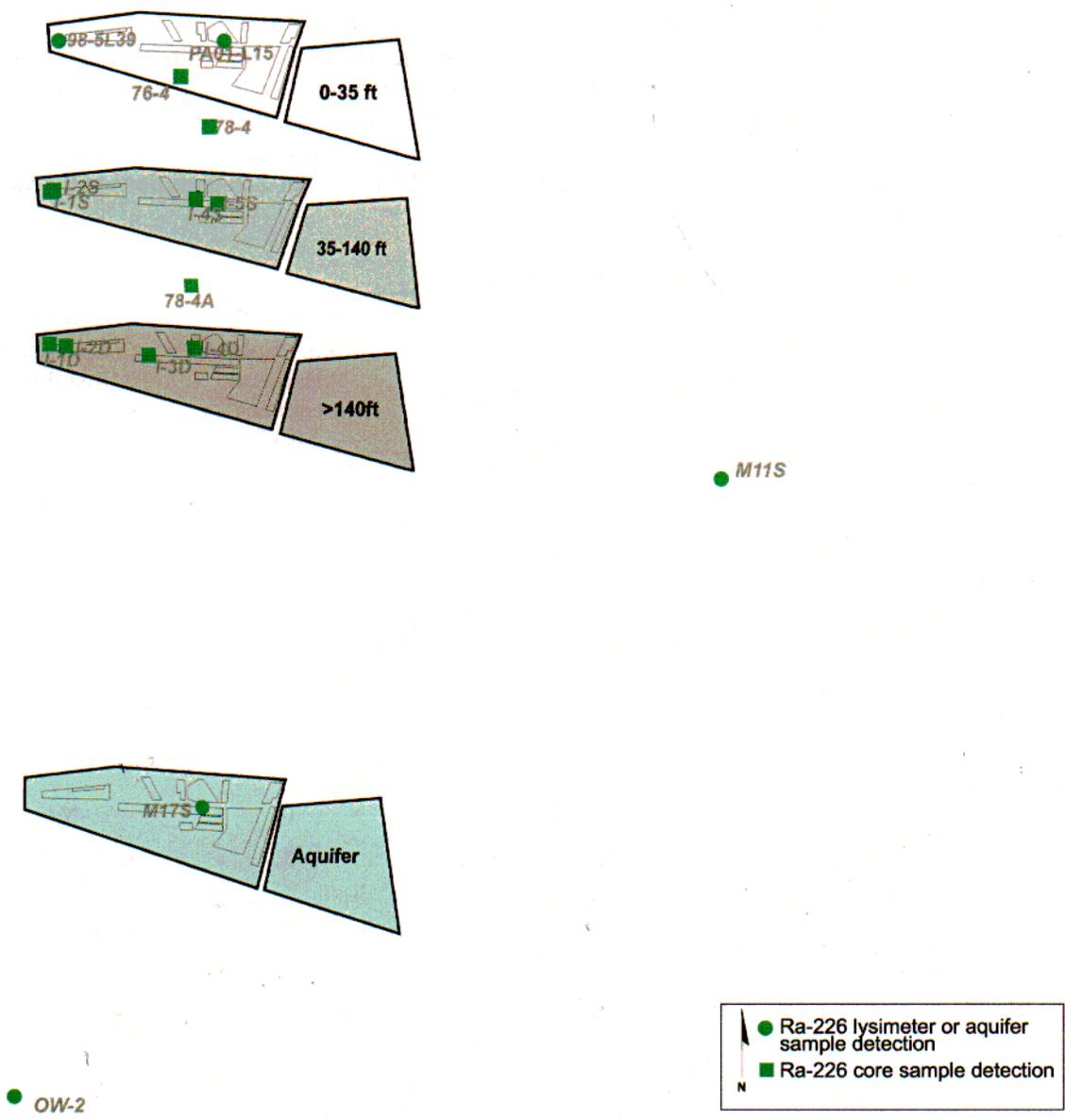


Figure 4-40. Locations of vadose zone core, lysimeter and aquifer samples with detectable concentrations of radium-226, by depth interval.

Whether the Ra-226 measured in the vadose zone core samples is attributable to Ra-226 or to interference from U-235 is uncertain. Therefore, the sample data are “J” flagged, indicating the uncertainty and bias associated with the results, and the influence of the U-235 on the Ra-226 data is indeterminate.

The INEEL is implementing modifications for analyzing Ra-226 to improve confidence in the analytical results. The accuracy of Ra-226 analysis is improved by use of alpha spectrometry or by measuring the equilibrated daughters with gamma spectrometry.

#### 4.6.17 Strontium-90

Strontium-90 is a radioisotope that is generated by nuclear reactor operations. Strontium-90 is a fission product that decays by the emission of beta particles with a 28.8-year half-life. It was identified in the IRA as a COPC, primarily from the crop ingestion exposure pathway (Becker et al. 1998). Available information about the presence of Sr-90-bearing waste in the SDA and available Sr-90 monitoring data for all media were reviewed for this report and are summarized below. The sampling data in this section were evaluated against the comparison concentrations in Table 4-85. The presence of Sr-90 below a depth of about 10 ft is not relevant to the crop ingestion pathway; however, the data for all depths were evaluated.

Table 4-85. Comparison concentrations for strontium-90.

Surface Soil Background Concentration <sup>a</sup> (pCi/g)	Risk-Based Soil Concentration <sup>b</sup> (pCi/g)	Aquifer Background Concentration <sup>c</sup>	Maximum Contaminant Level (pCi/L)	Risk-Based Aquifer Concentration <sup>b</sup> (pCi/L)
0.49	55.11	0	8	6.44

a. The value shown is the upper 95% tolerance limit with 95% confidence for composited surface soil (Rood, Harris, and White 1996).

b. The calculated risk-based concentration is equivalent to an increased cancer risk of 1E-05.

c. Knobel, Orr, and Cecil (1992).

**4.6.17.1 Waste Zone.** About 6.44E+05 Ci of Sr-90 was disposed of in the SDA. The waste streams containing the Sr-90 activity are identified in Table 4-86. Spectral gamma logging data provided no information about Sr-90.

Table 4-86. Waste streams containing strontium-90.

Waste Stream Code or Waste Generator	Waste Stream Description	Activity (Ci)	Proportion of Total Activity (%)
INEEL	INEEL reactor operations waste	3.89E+05	60.3
ANL-765-2H	Subassembly hardware	1.39E+05	21.6
ANL-785-1H	Subassembly hardware	6.60E+04	10.1
Miscellaneous	Miscellaneous minor streams	2.19E+04	3.4
ANL-765-1H	Dry active waste	1.48E+04	2.3
CPP-601-1H	Leached vycor glass	9.85E+03	1.5
CPP-601-3H	Dissolved fuel specimens	4.00E+03	1.0
<b>Total Disposals</b>		6.44E+05	100

INEEL = Idaho National Engineering and Environmental Laboratory

**4.6.17.2 Surface.** In total, 186 soil samples were collected between 1994 and 2000 from in and around the RWMC with 53 positive detections. The positive results ranged from  $(6.80 \pm 0.22)$  E-02 pCi/g (INEEL 2001) to  $1.56 \pm 0.12$  pCi/g (LMITCO 1997a). All detected soil concentrations are less than the 1E-05 surface soil risk-based concentration.

A total of 124 vegetation samples were collected between 1990 and 2000 from the RWMC and control locations yielding 10 positive detections. Detections ranged from  $(8.61 \pm 0.27)$  E-03 pCi/g (INEEL 2000) to  $2.01 \pm 0.12$  pCi/g (LMITCO 1998).

A total of 210 surface run-off water samples were collected between 1991 and 2000 from the RWMC and control locations yielding four positive detections. The positive results ranged from  $(4.05 \pm 1.17)$  E-01 pCi/L (LMITCO 1999) to  $(9.0 \pm 1.3)$  E-01 pCi/L (LMITCO 1996).

**4.6.17.3 Vadose Zone.** The distributions of Sr-90 in vadose zone core, soil moisture, and perched water in the various depth intervals are discussed below.

**4.6.17.3.1 Vadose Zone Core Samples—**A total of 352 vadose zone core samples were analyzed for Sr-90 between 1971 and 2000, yielding 24 positive detections. Twelve of the 24 detections were from the 1971 to 1973 timeframe, when there were known cross-contamination problems in the core sampling method (see Section 4.5.5). Table 4-87 shows positive detections of Sr-90 from vadose zone core samples. The detection rates for the various depth intervals are shown in Table 4-88.

Table 4-87. Positive detections of strontium-90 from vadose zone core samples.

Borehole Identification	Sample Depth (ft)	Concentration $\pm 1\sigma$ (pCi/g)	Date
76-1	221.0	$0.49 \pm 0.06$	1976
	221.2	$0.42 \pm 0.05$	1976
USGS-87	231.2 to 233.0	$0.46 \pm 0.05^a$	1971
USGS-88	521.0 to 522.0	$0.40 \pm 0.09^a$	1971
USGS-89	241.6 to 243.2	$0.64 \pm 0.07^a$	1971
	540.0 to 545.0	$0.30 \pm 0.09^a$	1972
USGS-91	233.8 to 236.3	$1.20 \pm 0.10^a$	1972
	243.2 to 245.1	$0.50 \pm 0.09^a$	1972
USGS-92	5.0 to 7.5	$0.24 \pm 0.07^a$	1972
	88.5 to 90.0	$0.30 \pm 0.09^a$	1972
	223.0 to 225.5	$0.30 \pm 0.09^a$	1972
USGS-93	13.8 to 14.0	$0.40 \pm 0.09^a$	1972
	101.0 to 103.0	$0.69 \pm 0.11^a$	1972
	103.0 to 105.0	$0.40 \pm 0.10^a$	1972
D02	1.2 to 1.7	$0.19 \pm 0.03$	1987
	15.5 to 16.0	$0.13 \pm 0.03$	1987
4E	10.0 to 22.5	$0.92 \pm 0.10$	1994
5E	18 to 21	$0.75 \pm 0.09$	1994
	98 to 104	$0.25 \pm 0.07$	1994
3V	100 to 104	$0.41 \pm 0.08$	1994
4V	105 to 118	$0.19 \pm 0.06$	1994
8V	100 to 125	$0.53 \pm 0.09$	1994
10V	7 to 10	$0.35 \pm 0.05$	1994
	98 to 124	$0.26 \pm 0.06$	1994

a. The 1971 and 1972 data are questionable because of cross-contamination concerns (see Section 4.5.5).

Table 4-88. Summary of strontium-90 occurrences in vadose zone core samples.

Depth Interval (ft)	Number of Detections/ Number of Samples (%)	Range (pCi/g)	Wells or Boreholes with Detections
0 to 35	7/46 (15.2)	0.13 to 0.92	4E, 5E, 10V, D02
35 to 140	8/145 (5.5)	0.19 to 0.69	5E, 3V, 4V, 8V, 10V
140 to 250	7/148 (4.7)	0.30 to 1.2	USGS-92, USGS-91
More than 250	2/13 (15.4)	0.30 to 0.40	USGS-89, USGS-88

All of the detections from cores located outside the SDA are questionable because they are from the early 1970s, when coring and sampling techniques may have introduced contamination into the boreholes (see Section 4.5.5; Barraclough et al. 1976; DOE-ID 1983). Results from cores USGS-91, USGS-92, and USGS-93 inside the SDA also are in that questionable data set.

Strontium-90 is present in surface soils from nuclear fallout at concentrations of about  $0.4 \pm 0.2$  pCi/g (Rood, Harris, and White 1996). Most Sr-90 results are approximately the same as background levels, with the exception of USGS-91 at 1.2 pCi/g, which is slightly higher but comes from the 1970s data set. All sample concentrations were less than the  $1E-05$  risk-based soil concentration of 55.11 pCi/g.

**4.6.17.3.2 Lysimeter Well Samples at Depths of 0 to 35 ft**—A total of 72 shallow lysimeter well samples were analyzed for Sr-90 between 1997 and May 2001, with seven positive detections (see Table 4-89). Two of the samples were above the MCL for the aquifer.

The positive sample results were not confirmed by reanalysis of the original sample. The occurrence of the positive detections relative to the samples that had nondetectable Sr-90 is shown in Figure 4-41. The 52.1 pCi/L result obtained in Well W06-L27 was not confirmed by reanalysis, and Sr-90 was not detected in that lysimeter in the five sampling events subsequent to that detection.

Table 4-89. Detections of strontium-90 in shallow lysimeter samples.

Lysimeter	Depth (ft)	Concentration $\pm 1\sigma$ (pCi/L)	Confirmation Flag <sup>a</sup>	Date
W23-L08	11.8	$3.8 \pm 1.1$	A	June 2000
PA02-L16	8.7	<b><math>9 \pm 2</math></b>	A	September 2000
W06-L27	11.8	<b><math>52 \pm 4</math></b>	A	August 1997
PA03-L33	10.0	$3.8 \pm 1.0$	A	March 2000
98-1L35	16.5	$2.2 \pm 0.7$	A	November 1999
(SDA-01)		$3.5 \pm 1.0$		March 2000
98-4L-38	17.0	$3.5 \pm 0.9$	A	March 2000
(SDA-08)				

Confirmation flag:

A = No second sample collected, no reanalysis performed.

Note: Concentrations in red bold exceed the maximum contaminant level of 8 pCi/L.

Year	Quarter	98-1 L35	98-4 L38	98-5 L39	PA01- L15	PA02- L16	PA03- L33	W06- L27	W08- L13	W08- L14	W23- L08	W23- L09	W25- L28
1997	1												
	2												
	3							52					
	4												
1998	1												
	2												
	3												
	4												
1999	1												
	2												
	3												
	4	2.2											
2000	1	3.5	3.5				3.8						
	2										3.8		
	3					9							
	4												
2001	1												
	2												
	3												
	4												
Key		Sr-90 was analyzed for, but not detected.											
		Sr-90 was detected (pCi/L).											
		If more than one detection occurred in a well in a single quarter, only the highest concentration is listed.											

Figure 4-41. Occurrence of strontium-90 in shallow lysimeter samples.

**4.6.17.3.3 Lysimeter Samples at Depths of 35 to 140 ft**—In total, 14 samples were collected from eight lysimeter wells between 1997 and 2001 with one positive detection. The lysimeter wells that yielded sufficient sample volume for Sr-90 analysis were D06-DL01, D06-DL02, TW1-DL04, and D15-DL06. Five other lysimeters in this depth interval were not analyzed for Sr-90 because the volume of water collected was insufficient. The positive result was  $4.1 \pm 1.2$  pCi/L in lysimeter TW1 DL04 from November 1998. The detection could not be confirmed by reanalysis because of the limited sample volume available. The detected lysimeter concentration did not exceed the MCL of 8 pCi/L.

**4.6.17.3.4 Perched Water Samples at Depths Greater than 140 ft**—A total of 42 perched water well samples and 10 filtered sediment samples were analyzed for Sr-90 by the USGS and the INEEL between 1972 and March 2000. The results included one positive detection and that detection exceeded the aquifer MCL of 8 pCi/L (see Table 4-90).

Subsequent water samples collected from lysimeter and perched water Well USGS-92 through March 2000 have not tested positive for Sr-90 detections. The positive water sample result obtained in April 1980 was not confirmed by reanalysis of the original sample. No data are available from lysimeters at depths greater than 140 ft because the volume of water collected was insufficient to perform the analysis.

Table 4-90. Positive detections of strontium-90 from lysimeter wells and perched water wells.

Lysimeter or Perched Water Well	Depth (ft)	Concentration $\pm 1\sigma$ (pCi/L) Water	Confirmation Flag <sup>a</sup>	Concentration $\pm 1\sigma$ (pCi/g) Filtered Sediments	Date
USGS-92	214	<b>9 <math>\pm</math> 2</b>	A	Not analyzed	April 1980

a. Confirmation flag:

A = No second sample collected, no reanalysis performed.

Note: Concentrations in red bold exceed the maximum contaminant level of 8 pCi/L.

**4.6.17.4 Aquifer.** A total of 283 RWMC aquifer well samples were screened for Sr-90 between 1992 and April 2001 by means of gross beta analysis, with 97 of the samples above the gross beta-screening limit of 5 pCi/L. Those 97 samples were analyzed specifically for Sr-90, and three contained detectable amounts of Sr-90 (Table 4-91).

Table 4-91. Aquifer samples with detectable concentrations of strontium-90.

Aquifer Well	Concentration $\pm 1\sigma$ (pCi/L)	Confirmation Flag <sup>a</sup>	Date
M4D	0.12 $\pm$ 0.02	D	April 1997
	0.17 $\pm$ 0.03	D	April 1997
M6S	2.5 $\pm$ 0.6	A	April 1996

a. Confirmation flag:

A = No second sample collected, no reanalysis performed.

D = Detection confirmed by reanalysis.

Note: Highlighted values and confirmation flag "D" indicate that positive detection was confirmed.

Subsequent samples collected from M4D and M6S through April 2001 have not tested positive for Sr-90. The distributions of Sr-90 detections and nondetections in the aquifer between 1992 and 2001 are shown in Figure 4-42 for the USGS and INEEL wells.

Samples from INEEL aquifer Wells M3S and M7S were split with the USGS and compared. None of the samples split with the USGS between 1993 and July 2000 yielded positive detections for Sr-90.

Besides the 15 RWMC monitoring aquifer wells routinely sampled by the INEEL, the USGS manages, controls, and routinely samples eight other wells in the vicinity of the RWMC. A total of 669 USGS aquifer well samples in the vicinity of the RWMC were analyzed for Sr-90 between 1972 and January 2001 with 11 detections. Detectable concentrations measured in the USGS wells are shown in Table 4-92. The USGS detections and nondetections between 1972 and 1991 are shown in Figure 4-43.

Six of the 11 detections associated with the USGS aquifer wells occurred between 1972 and 1974, shortly after the wells were drilled and installed. The 1972 to 1974 results are questionable because of cross-contamination problems (Barraclough, Robertson, and Janzer 1976). Subsequent samples collected from the USGS aquifer wells from 1975 through 1995 yielded five Sr-90 detections. Concentrations in USGS-87 exceeded the aquifer 1E-05 risk-based concentration of 6.44 pCi/L and the EPA primary drinking water MCL for Sr-90 of 8 pCi/L, but no detectable concentrations have been measured in USGS-87 since 1987.

Year	Quarter	USGS-87	USGS-88	USGS-89	USGS-90	RWMC Prod	USGS-117	USGS-119	USGS-120	M1S	M3S	M4D	M6S	M7S	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	A11A31	OW-2	
1992	1	Green	Green	Green	Green		Green	Green	Green																
	2	Green	Green	Green	Green		Green	Green	Green																
	3	Green	Green	Green	Green		Green	Green	Green																
	4	Green	Green	Green	Green		Green	Green	Green																
1993	1	Green	Green	Green	Green		Green	Green	Green																
	2	Green	Green	Green	Green		Green	Green	Green																
	3	Green	Green	Green	Green		Green	Green	Green																
	4	Green	Green	Green	Green		Green	Green	Green																
1994	1	Green	Green	Green	Green		Green	Green	Green																
	2	Green	Green	Green	Green		Green	Green	Green																
	3	Green	Green	Green	Green		Green	Green	Green																
	4	Green	Green	Green	Green		Green	Green	Green																
1995	1	Green	Green	Green	Green		Green	Green	Green																
	2	Green	Green	Green	Green		Green	Green	Green																
	3	Green	Green	Green	Green		Green	Green	Green																
	4	Green	Green	Green	Green		Green	Green	Green	2.5															
1996	1	Green	Green	Green	Green		Green	Green	Green																
	2	Green	Green	Green	Green		Green	Green	Green				2.5												
	3	Green	Green	Green	Green		Green	Green	Green																
	4	Green	Green	Green	Green		Green	Green	Green																
1997	1	Green	Green	Green	Green		Green	Green	Green																
	2	Green	Green	Green	Green		Green	Green	Green																
	3	Green	Green	Green	Green		Green	Green	Green			0.17													
	4	Green	Green	Green	Green		Green	Green	Green																
1998	1	Green	Green	Green	Green		Green	Green	Green																
	2	Green	Green	Green	Green		Green	Green	Green																
	3	Green	Green	Green	Green		Green	Green	Green																
	4	Green	Green	Green	Green		Green	Green	Green																
1999	1	Green	Green	Green	Green		Green	Green	Green																
	2	Green	Green	Green	Green		Green	Green	Green																
	3	Green	Green	Green	Green		Green	Green	Green																
	4	Green	Green	Green	Green		Green	Green	Green																
2000	1	Green	Green	Green	Green		Green	Green	Green																
	2	Green	Green	Green	Green		Green	Green	Green																
	3	Green	Green	Green	Green		Green	Green	Green																
	4	Green	Green	Green	Green		Green	Green	Green																
2001	1	Green	Green	Green	Green		Green	Green	Green																
	2	Green	Green	Green	Green		Green	Green	Green																
	3	Green	Green	Green	Green		Green	Green	Green																
	4	Green	Green	Green	Green		Green	Green	Green																
Key		Green	Sr-90 was analyzed for, but not detected.																						
		Yellow	Sr-90 was detected (pCi/L).																						
		Red	If more than one detection occurred in a well in a single quarter, only the highest concentration is listed.																						

Figure 4-42. Occurrence of detectable concentrations of strontium-90 in aquifer samples, 1992 through April 2001.

Figure 4-43. Occurrence of detectable concentrations of strontium-90 from 1972 through 1991 in the U.S. Geological Survey aquifer samples.

Year	Quarter	USGS-87	USGS-88	USGS-89	USGS-90	RWMC Prod	USGS-117	USGS-119	USGS-120
1972	1								
	2								
	3								
	4								
1973	1		58						
	2								
	3		28						
	4								
1974	1		7						
	2		8	9	7				
	3		15						
	4								
1975	1								
	2								
	3								
	4								
1976	1								
	2								
	3								
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1977	1								
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1986	1								
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	4								
1987	1								
	2								
	3		23						
	4								
1988	1								
	2							6.4	
	3								
	4								
1989	1								
	2								
	3								
	4								
1990	1								
	2								
	3								
	4								
1991	1								
	2								
	3								
	4								
Key									
Sr-90 was analyzed for, but not detected.									
Sr-90 was detected (pCi/L).									
If more than one detection occurred in a well in a single quarter, only the highest concentration is listed.									

Table 4-92. Detectable concentrations of strontium-90 in U.S. Geological Survey aquifer wells.

Aquifer Well	Concentration $\pm 1\sigma$ (pCi/L)	Date
USGS-87	7 $\pm$ 2 <sup>a</sup>	October 1973
	<b>8 <math>\pm</math> 2<sup>a</sup></b>	May 1974
	<b>15 <math>\pm</math> 2<sup>a</sup></b>	August 1974
	<b>22 <math>\pm</math> 3</b>	July 1987
	<b>23 <math>\pm</math> 4</b>	September 1987
	7 $\pm$ 2	September 1987
USGS-88	<b>58 <math>\pm</math> 4<sup>a</sup></b>	March 1973
	<b>28 <math>\pm</math> 3<sup>a</sup></b>	August 1973
	<b>9 <math>\pm</math> 2<sup>a</sup></b>	May 1974
USGS-90	7 $\pm$ 2 <sup>a</sup>	May 1974
USGS-120	6.4 $\pm$ 1.6	June 1988
	2.5 $\pm$ 0.8	October 1995

Note: Concentrations in red bold exceed the maximum contaminant level of 8 pCi/L.

a. The 1972 to 1974 data are questionable because of cross-contamination concerns.

**4.6.17.5 Summary of Strontium-90.** Data from the surface soil, vadose zone cores, and lysimeter, perched water, and aquifer well samples do not indicate the widespread presence of Sr-90 in the environment of the RWMC at levels exceeding background concentrations. Strontium-90 detection rates, shown in Table 4-93, decrease with depth, with 9.7% in the shallow lysimeter wells to 1.0% in the aquifer wells. No trends are apparent. No spatial distribution pattern to the detections in the vadose zone or the aquifer wells is evident, and no detectable concentration of Sr-90 has been found in the aquifer wells since 1997. The locations of vadose zone core, lysimeter, and aquifer samples with detectable concentrations of Sr-90, by depth interval is shown in Figure 4-44.

#### 4.6.18 Technetium-99

Technetium-99 is a radioisotope that is generated by nuclear reactor operations. Technetium-99 is a fission product that decays by the emission of beta particles and low-energy gamma rays with a half-life of 2.13E+05 years. It was identified in the IRA as a COPC, primarily from the groundwater and crop ingestion exposure pathways (Becker et al. 1998). Available information about the presence of Tc-99-bearing waste in the SDA and the available Tc-99 monitoring data for all media were reviewed for this report and are summarized below. The sampling data in this section are evaluated against the comparison concentrations for Tc-99 in Table 4-94.

**4.6.18.1 Waste Zone.** About 61 Ci of Tc-99 was disposed of in the SDA. The waste streams containing the Tc-99 activity are identified in Table 4-95. Spectral gamma logging data provided no information about Tc-99.

**4.6.18.2 Surface.** Technetium-99 is not on the target analyte list for the surface samples; therefore, no surface data are available for Tc-99.

Table 4-93. Strontium-90 detection rates in sampled media.

Sampled Depth or Media	Detection Rate (%)	Range	Number of Detections >Risk-Based Concentration or MCL <sup>a</sup>	Wells with Detections >MCL
Vadose zone (0 to 35 ft):				
Core	15.2	0.13 to 0.92 pCi/g	0	None
Lysimeter	9.7	2.18 to 52.1 pCi/L	2	PA02, W06
Vadose zone (35 to 140 ft):				
Core	5.5	0.19 to 0.69 pCi/g	0	None
Lysimeter	7.1	4.12 pCi/L	0	None
Vadose zone (140 to 250 ft):				
Core	4.7	0.19 to 1.2 pCi/g	0	None
Lysimeter	2.3	9 pCi/L	1	USGS-92
Aquifer (INEEL)	1.0	0.12 to 2.5 pCi/L	0	M4D, M6S
Aquifer (USGS)	1.6	2.5 to 58 pCi/L	7 <sup>b</sup>	USGS-87, USGS-88

MCL = maximum contaminant level

INEEL = Idaho National Engineering and Environmental Laboratory

USGS = U.S. Geological Survey

a. For vadose zone cores and surface soil samples, the calculated 1E-05 risk-based concentration is 55.11 pCi/g. For lysimeter, perched water and aquifer samples, the aquifer MCL of 8 pCi/L is used for comparison only.

b. The number shown includes questionable detections from 1971 to 1972.

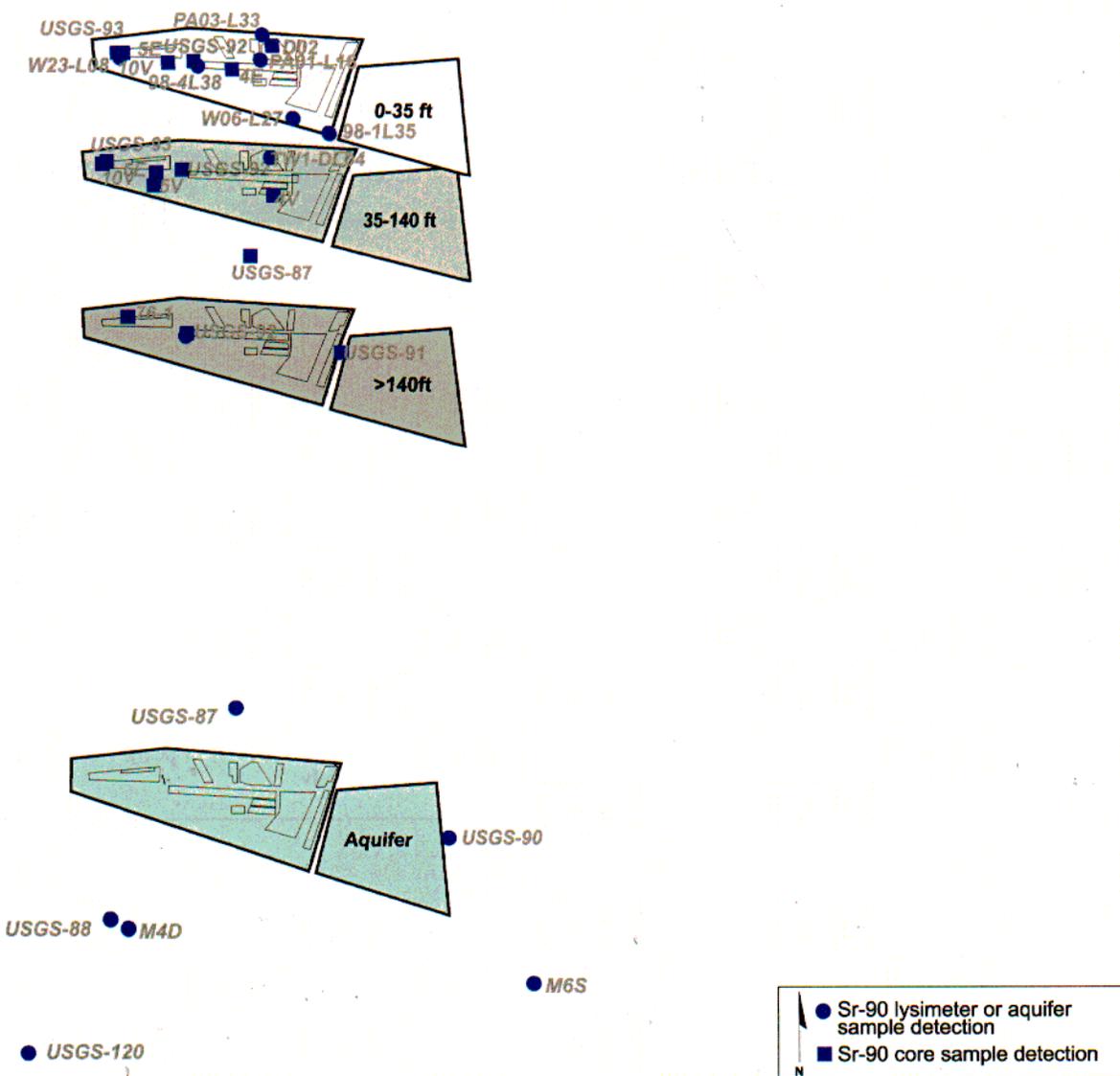


Figure 4-44. Locations of vadose zone core, lysimeter and aquifer samples with detectable concentrations of strontium-90, by depth interval.

Table 4-94. Comparison concentrations for technetium-99.

Surface Soil Background Concentration <sup>a</sup> (pCi/g)	Risk-Based Soil Concentration <sup>b</sup> (pCi/g)	Aquifer Background Concentration	Maximum Contaminant Level (pCi/L)	Risk-Based Aquifer Concentration <sup>b</sup> (pCi/L)
Not established	1,036	Not established	900	173

a. The value in this column represents the upper 95% tolerance limit with 95% confidence for composited surface soil (Rood, Harris, and White 1996).

b. Calculated risk-based concentration is equivalent to an increased cancer risk of 1E-05.

Table 4-95. Waste streams containing technetium-99.

Waste Stream Code or Waste Generator	Waste Stream Description	Activity (Ci)	Proportion of Total Activity (%)
Idaho National Engineering and Environmental Laboratory (INEEL)	INEEL reactor operations waste	5.44E+01	89.9
Miscellaneous	Miscellaneous minor streams	2.12E+00	3.5
Argonne National Laboratory metal	Subassembly hardware	1.75E+00	2.9
Naval Reactors Facility	Test specimens	1.56E+00	2.6
D&D-ARA-1	Low-level waste from the decontamination and demolition of the Auxiliary Reactor Area facilities (primarily contaminated metal and debris)	6.42E-01	1.1
<b>Total Disposals</b>		<b>6.05E+01</b>	<b>100</b>

#### 4.6.18.3 Vadose Zone

**4.6.18.3.1 Vadose Zone Core Samples**—A total of 52 vadose zone core samples were analyzed for Tc-99 between 1994 and 2000, yielding 19 positive detections (see Table 4-96). The Tc-99 detection rates per depth interval are indicated in Table 4-97. Earlier core samples collected from 1971 to 1993 were not analyzed for Tc-99.

Positive detections of Tc-99 were obtained from all “I” wells (inside the SDA) near the B-C and C-D interbeds. None of the “O” wells (outside the SDA), which were also collected in the 1999 to 2000 timeframe, had positive detections. Detection rates increased with depth down to 250 ft, though the number of samples is too few to draw conclusions about trends. Fifteen of the 19 positive Tc-99 results were qualified as questionable (“J” flagged) because the laboratory method blank also contained about 0.3 pCi/g of Tc-99, which biased the affected results approximately 12%. Therefore, Tc-99 may be present at these sample locations in low concentrations, or may not be present at all.

Table 4-96. Positive detections of technetium-99 from vadose zone core samples.

Borehole Identification	Sample Depth (ft)	Concentration $\pm 1\sigma$ (pCi/g)	Date
I-1S	101.6 to 102.0	$1.49 \pm 0.18J^a$	1999 and 2000
	105.5	$4.2 \pm 0.4$	1999 and 2000
	110.6 to 111.0	$4.2 \pm 0.4$	1999 and 2000
I-1D	224.5 to 225.0	$1.46 \pm 0.19J$	1999 and 2000
	237.6 to 238.0	$2.5 \pm 0.3J$	1999 and 2000
	242.7 to 243.0	$1.7 \pm 0.2J$	1999 and 2000
I-2S	99.0 to 100.0	$2.4 \pm 0.3J$	1999 and 2000
	111.0	$3.3 \pm 0.3$	1999 and 2000
	112.5 to 113.0	$1.8 \pm 0.2J$	1999 and 2000
I-2D	223.5 to 224.0	$2.1 \pm 0.2J$	1999 and 2000
I-3S	99.0 to 101.0	$1.08 \pm 0.17J$	1999 and 2000
I-3D	228.5 to 229.0	$2.0 \pm 0.3J$	1999 and 2000
	231.5 to 232.0	$2.9 \pm 0.3J$	1999 and 2000
I-4S	98.2 to 98.8	$2.3 \pm 0.3J$	1999 and 2000
I-4D	223.0 to 223.6	$2.9 \pm 0.3J$	1999 and 2000
	229.6 to 230.0	$3.1 \pm 0.3J$	1999 and 2000
	237.0 to 237.5	$3.0 \pm 0.3J$	1999 and 2000
	237.5 to 238.0	$3.4 \pm 0.3$	1999 and 2000
I-5S	103.5 to 104.0	$1.8 \pm 0.2J$	1999 and 2000

a. Some of the data were "J" flagged because of low concentrations detected in the sample blank. See text for discussion.

Table 4-97. Summary of technetium-99 occurrences in the vadose zone core samples.

Depth Interval (ft)	Number of Detections/ Number of Samples (%)	Range (pCi/g)	Wells or Borehole with Detection
0 to 35	0/11 (0)	Not applicable	Not applicable
35 to 140	9/25 (36.0)	1.08 to 4.2	I-1S, I-2S, I-3S, I-4S, I-5S
140 to 250	10/16 (62.5)	1.46 to 3.4	I-1D, I-2D, I-3D, I-4D
More than 250	0/0	Not applicable	Not applicable

**4.6.18.3.2 Lysimeter Samples at Depths of 0 to 35 ft**—A total of 82 shallow lysimeter samples were analyzed for Tc-99 between 1997 and May 2001, resulting in 16 detections (see Table 4-98).

The positive detections were not confirmed by reanalysis of the original sample. The occurrence of the detections relative to the nondetections is shown in Figure 4-45.

Five out of six results from Lysimeter W23-L09 (8 ft deep) contained detectable amounts of Tc-99, and the June 2000 sample from Lysimeter W23-L08 (12 ft deep) in the same borehole also contained detectable Tc-99, suggesting movement in the vadose zone may be occurring. In addition, three out of

Table 4-98. Detected concentrations of technetium-99 in shallow lysimeters.

Lysimeter	Depth (ft)	Concentration $\pm 1\sigma$ (pCi/L)	Confirmation Flag <sup>a</sup>	Date
W23-L08	11.8	39 $\pm$ 6	A	June 2000
		46 $\pm$ 7	A	May 2001
W23-L09	14.8	17 $\pm$ 4	A	April 1997
		30 $\pm$ 5	A	August 1997
		20 $\pm$ 2	B	August 1998
		20 $\pm$ 4	A	March 2000
		33 $\pm$ 5	A	June 2000
W08-L13	11.3	15 $\pm$ 5	A	June 2000
PA01-L15	14.3	17 $\pm$ 5	A	June 2000
		27 $\pm$ 4	B	September 2000
PA02-L16	8.7	13 $\pm$ 3	B	December 1998
PA03-L33	10.0	36 $\pm$ 5	A	December 1998
		21 $\pm$ 3	A	November 1999
		17 $\pm$ 4	A	March 2000
98-1L35 (SDA-01)	16.5	16 $\pm$ 4	A	June 2000
98-5L39 (SDA-10)	10.5	21 $\pm$ 5	A	June 2000

a. Confirmation flag:

A = No second sample collected, no reanalysis performed.

B = Reanalysis performed, no confirmation.

Year	Quarter	98-1 L35	98-4 L38	98-5 L39	PA01- L15	PA02- L16	PA03- L33	W06- L27	W08- L13	W08- L14	W23- L08	W23- L09	W25- L28
1997	1												
	2											17	
	3											30	
	4												
1998	1												
	2												
	3											20	
	4						36						
1999	1												
	2												
	3												
	4						21						
2000	1						17					20	
	2	16		21	17				15		39	33	
	3				27								
	4												
2001	1												
	2										46		
	3												
	4												
Key		Tc-99 was analyzed for, but not detected.											
		Tc-99 was detected (pCi/L).											
		If more than one detection occurred in a well in a single quarter, only the highest concentration is listed.											

Figure 4-45. Occurrence of technetium-99 detections in shallow lysimeters.

four samples from Lysimeter PA03-L33 have contained detectable amounts of Tc-99. The presence of Tc-99 is corroborated by numerous positive detections of Tc-99 in the vadose zone core samples from the "T" wells, which are inside the SDA boundary. Soil moisture with elevated Tc-99 concentrations and noticeable trends are primarily isolated to two distinct locations, the west end and the north-central portion, of the SDA.

None of the positive results exceeded the MCL of 900 pCi/L used for comparison. Though the Tc-99 results and trend data imply some release may be occurring, the data do not support a clear conclusion.

**4.6.18.3.3 Lysimeter Samples at Depths of 35 to 140 ft**—A total of 22 lysimeter samples were analyzed for Tc-99 between 1996 and May 2001, with four positive detections (see Table 4-99).

Table 4-99. Detected concentrations of technetium-99 in the 35 to 140-ft interval of the vadose zone.

Lysimeter	Depth (ft)	Concentration $\pm 1\sigma$ (pCi/L)	Confirmation Flag <sup>a</sup>	Date
D06-DL01	88	11 $\pm$ 2	A	August 1998
D06-DL02	44	33 $\pm$ 3	A	August 1998
D15-DL06	98	5.8 $\pm$ 1.3 21 $\pm$ 7	A A	April 1996 June 2000

a. Confirmation flag:

A = No second sample collected, no reanalysis performed.

The positive sample results could not be confirmed by reanalysis because of the limited sample volumes available. Subsequent samples collected from these three wells through May 2001 have not shown Tc-99 detections. Of the eight other lysimeter wells sampled, none had detectable amounts of Tc-99. None of the detected concentrations exceed the MCL used for comparison.

**4.6.18.3.4 Lysimeter and Perched Water Samples at Depths Greater than 140 ft**—A total of 15 water samples and eight filtered sediment samples from perched water and lysimeter wells were analyzed for Tc-99 between 1997 and December 2000. There were three positive detections, two of the filtered sediments and one of the liquid. The sediment samples did not exceed the 1E-05 risk-based concentration for soil, and the liquid sample did not exceed the MCL of 900 pCi/L (see Table 4-100).

The September 2000 water sample result was not confirmed by reanalysis of the original sample. The one subsequent water sample from Well USGS-92 in December 2000 did not contain detectable Tc-99. The USGS does not analyze samples from perched water Well USGS-92 for Tc-99. Though the concentration in the liquid fraction was relatively high, the result was not confirmed via reanalysis.

Table 4-100. Positive detections of technetium-99 from lysimeters and perched water wells.

Lysimeter or Perched Water Well	Concentration $\pm 1\sigma$ (pCi/L) Water	Confirmation Flag	Concentration $\pm 1\sigma$ (pCi/g) Filtered Sediments	Confirmation Flag <sup>a</sup>	Date
USGS-92	Not applicable	Not applicable	1.25 $\pm$ 0.17	A	December 1998
	280 $\pm$ 37	A	3.1 $\pm$ 0.4	A	September 2000

a. Confirmation flag:

A = No second sample collected, no reanalysis performed.

**4.6.18.4 Aquifer.** A total of 240 aquifer well samples from four RWMC area aquifer wells were collected and analyzed for Tc-99 between 1994 and April 2001. There were five positive detections of Tc-99 (see Table 4-101). None of the positive results exceeded the MCL.

Table 4-101. Detected concentrations of technetium-99 in aquifer samples around the Radioactive Waste Management Complex.

Aquifer Well	Concentration $\pm 1\sigma$ (pCi/L)	Confirmation Flag <sup>a</sup>	Date
M3S	1.4 $\pm$ 0.3	A	April 1997
M4D	9.0 $\pm$ 2.5	B	April 1996
M6S	1.0 $\pm$ 0.3	A	April 1997
M17S	1.5 $\pm$ 0.4 35 $\pm$ 5	D D	May 2000 May 2000

a. Confirmation flag:

A = No second sample collected, no reanalysis performed.

B = Reanalysis performed, no confirmation.

D = Detection confirmed by reanalysis.

Note: Highlighted values and the "D" confirmation flag indicate that the positive detection was confirmed.

Only the May 2000 Tc-99 detection for Well M17S was confirmed by reanalysis of the original sample, but the positive result did not agree with the original analysis. As shown in Figure 4-46, subsequent samples collected from the four aquifer wells have not yielded positive detections.

The USGS does not analyze for Tc-99 in the eight RWMC wells they manage, control, and routinely sample.

**4.6.18.4.1 Summary of Technetium-99**—Vadose zone core samples were collected inside and outside of the SDA to determine whether Tc-99 and other radionuclides were present. All of the vadose zone cores taken within the SDA contained detectable amounts of Tc-99 at some depth, while none of the cores outside the SDA boundary contained detectable Tc-99. The Tc-99 detection rates for all sampled media are indicated in Table 4-102.

Technetium-99 has been detected in the aquifer, but no trends are evident. However, Tc-99 is a mobile contaminant and has been detected in some of the lysimeter and perched water well samples from the SDA. As shown in Table 4-102, the detection rates remain relatively constant over depth in the vadose zone but drop dramatically to 2.1% in the aquifer wells. Locations of the detections of Tc-99 in the vadose zone cores, lysimeters, and aquifer samples are shown in Figure 4-47.



Table 4-102. Technetium-99 detection rates in all sampled media.

Media or Depth Interval	Detection Rate (%)	Range	Total Number of Samples >Risk-Based Concentration or MCL <sup>a</sup>	Location of Samples >Risk-Based Concentration or MCL
Vadose zone (0 to 35 ft)				
Core	0	Not applicable	0	None
Lysimeter	19.5	13 to 46 pCi/L	0	None
Vadose zone (35 to 140 ft)				
Core	36.0	1.08 to 4.2 pCi/g	0	None
Lysimeter	18.2	5.8 to 33 pCi/L	0	None
Vadose zone (140 to 250 ft)				
Core	62.5	1.46 to 3.4 pCi/g	0	None
Lysimeter/Well	13.0	280	0	
Vadose zone (>250 ft)				
Core	Not applicable	Not applicable	Not applicable	Not applicable
Lysimeter	Not applicable	Not applicable	Not applicable	Not applicable
Aquifer (INEEL)	2.1	1.0 to 35 pCi/L	0	0

MCL = maximum contaminant level

INEEL = Idaho National Engineering and Environmental Laboratory

a. Vadose zone cores are compared with the E-05 risk-based concentration for soil (1,036 pCi/L); soil moisture, perched water, and aquifer samples compared to the maximum contaminant level of 900 pCi/L.

#### 4.6.19 Uranium

Uranium is a radioactive element that occurs naturally in the environment as three principal isotopes (U-234, U-235, and U-238). Uranium-238 and U-235 are the parent isotopes of two independent decay series, while U-234 is a decay product of the U-238 decay series. Uranium also is processed and handled by human beings for use in nuclear weapons and nuclear reactors and contains four principal isotopes (U-234, U-235, U-236, and U-238). Uranium-234, U-235, U-236, and U-238 decay by the emission of alpha particles and gamma rays, with half-lives of 2.46E+05, 7.04E+08, 2.34E+07, and 4.47E+09 years, respectively. Uranium-233 is an isotope that does not occur naturally and is not produced during the enrichment process. It is produced in small quantities from the decay of Am-241 and in significant quantities in nuclear reactors that use thorium fuel. The properties of the natural uranium isotopes are shown in Table 4-103. Uranium isotopes are identified in the IRA as COPCs, primarily for the groundwater ingestion exposure pathway (Becker et al. 1998). Available information about the presence of uranium in the SDA and available uranium monitoring data for all media were reviewed for this report and are summarized below.

Because uranium is naturally occurring, identifying background concentrations was necessary to determine whether the INEEL samples contained contamination. Recognizing this, studies have been conducted to identify uranium background concentrations of U-234 and U-238 in soil (Rood, Harris, and White 1996) and of total uranium in the aquifer (Knobel, Orr, and Cecil 1992).

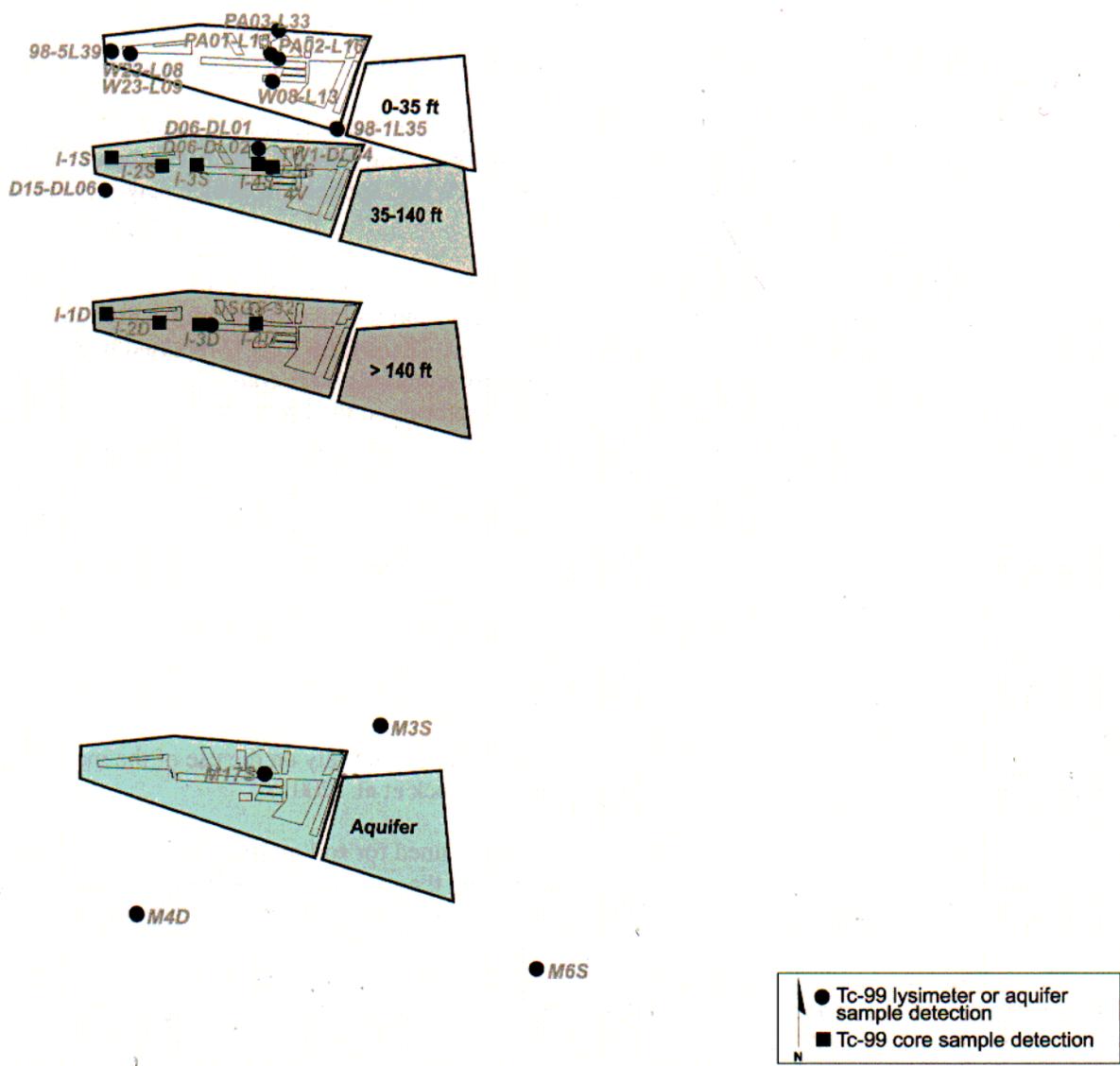


Figure 4-47. Locations of vadose zone core, lysimeter and aquifer samples with detectable concentrations of technetium-99, by depth interval.

Table 4-103. Properties of the natural uranium isotopes.

Property	U-234	U-235	U-238
Half-life (years)	2.46E+05	7.04E+08	4.47E+09
Specific Activity (pCi/g of isotope)	6.19E+09	2.13E+06	3.36E+05
Activity in 1 g uranium <sub>nat</sub> (pCi)	3.40E+05	1.55E+04	3.34E+05
Natural abundance (activity %)	49.3	2.3	48.4

The USGS established background concentrations of total uranium in the SRPA (Knobel, Orr, and Cecil 1992) using 72 samples from wells in the Magic Valley (i.e., in the vicinity of Twin Falls, Idaho). According to the USGS study, the background for total uranium in the Snake River Plain Aquifer is about

0 to 3.35  $\mu\text{g/L}$ , which equates to about 0 to 1.1 pCi/L for U-234 and U-238, and about 0.05 for U-235, after adjusting for specific activity and the relative abundance of each isotope in the earth's crust.

Background uranium concentrations identified in Knobel, Orr, and Cecil (1992) may not be applicable to the INEEL background aquifer concentrations for several reasons. The background concentrations for U-234 appear to be too low for INEEL or RWMC application, which may be caused by the following:

- The method of converting and estimating uranium isotopic concentrations from the total uranium concentrations reported by the USGS. The U-234, U-235, and U-238 concentrations used in this document were calculated from the mean value of  $3.35 \pm 0.18 \mu\text{g/L}$  for total U reported by the USGS (Knobel, Orr, and Cecil 1992). The isotopic concentrations were converted from total uranium ( $\mu\text{g/L}$ ) by using the specific activity of each isotope and the known natural abundance of each uranium isotope in the earth's crust. The concentrations were based on the assumption that U-234 abundance is 0.0058%. Deviation from this proportion would affect the U-234 concentration.
- The isotopic components of uranium in the aquifer in the Magic Valley differ from the composition of the aquifer beneath the INEEL. Roback et al. (September 2001) determined that U-234 and U-238 vary considerably in the SRPA in the vicinity of the INEEL, and natural U-234:U-238 ratios may vary by a factor of two or more in the aquifer. Results of the Magic Valley samples are based on total uranium and do not account for varying concentrations of U-234 and U-238.

Future examination of uranium contamination in the SRPA could rely on the use of the more recent uranium isotopic background concentrations developed by Roback et al. (2001).

Because no background concentrations have been determined for soil moisture or perched water samples, a local background concentration was estimated using the mean of sample concentrations from wells just outside the SDA (i.e., the "O" wells) and from Well D15, a designated local background site.

The vadose zone core data from background locations around the RWMC correlate well with the relative abundance of the various uranium isotopes in the earth's crust. Obtaining precise numbers for U-235 is difficult because U-235 background is relatively low and the analytical techniques used on routine samples measure near the detection limit. To obtain low-level analytical data for U-235 and U-236 to help identify uranium sources as natural, depleted, or enriched, a set of lysimeter samples was submitted for TIMS analysis to achieve ultra low-level detection limits and uncertainties. The U-235 and U-236 results were used to calculate precise uranium isotopic ratios for U-234:U-238, U-236:U-238, and U-238:U-235.

The typical isotopic composition associated with enriched, depleted, and natural uranium is shown in Table 4-104, and typical ratios are shown in Table 4-105. Enriched uranium refers to natural uranium (ore) that has been processed to increase the concentration of U-235. The enrichment process (gaseous diffusion technology most commonly used in the United States) removes the U-238, which increases the concentration of both U-234 and U-235 (DOE-STD-1136-2000). The by-product of the enrichment process (U-238) is referred to as depleted uranium.

Table 4-104. Typical isotopic composition of anthropic uranium (% by weight).

Form	U-234	U-235	U-236	U-238
Enriched (high)	1.0%	93.1%	0.4%	5.5%
Enriched (low)	0.03%	2.97%	0.00%	97.00%
Depleted	0.001%	0.22%	0.000%	99.78%

Table 4-105. Uranium ratio guideline for estimating potential uranium sources.

		Atomic Mass Guideline Ratios			Radioactivity Guideline Ratios	
		U-234/238	U-234/238	U-238/235	U-234/238	U-238/235
Category		(INEEL Groundwater) <sup>a</sup>				
Depleted	(0.2%)	<<8.60E-05	<<5.5E-05	~500	~ 0.1	~ 77
Depleted	(0.4%)	<8.60E-05	<5.5E-05	~250	Not established	~ 39
Natural	(0.7%)	8.60E-05 to 1.66E-04	5.5E-05	~138	~ 1	~ 22
					~ 1.5 to 3 <sup>a</sup>	~ 22
Enriched	(2%)	>1.66E-04	>5.5E-05	~50	Not established	~ 8
Enriched	(93%)	>>1.66E-04	>>5.5E-05	~0.08	~ 3,000	~ 0.01

INEEL = Idaho National Engineering and Environmental Laboratory

a. Uranium-234/238 are not in secular equilibrium in groundwater beneath the Idaho National Engineering and Environmental Laboratory (Johnson et al. 1998).

The U-238 and U-235 ratio could not be calculated on routine environmental samples because the concentrations of U-235 are generally too low for reliable measurement with routine radioanalytical techniques. However, the concentrations of U-233/234 and U-238 are typically high enough for consistent detection and precision. Therefore, the U-234:U-238 ratio is the only ratio that is routinely assessed in WAG 7 investigations. When measurable concentrations of U-235 are present, the U-238:U-235 ratios are assessed.

All of the uranium isotopes were identified as COPCs in the IRA, primarily from the groundwater ingestion exposure pathway (Becker et al. 1998).

The sampling results reported by the laboratory generally are combined for U-233/234 and U-235/236. These pairs of isotopes are combined because they cannot be chemically separated and they have alpha particle energies that are nearly identical. Therefore, they are nearly impossible to differentiate in environmental level samples using routine alpha spectroscopy. If obtaining results for each separate radionuclide becomes necessary, analysis by a nonradiochemical methodology (i.e., mass spectrometry) would be required.

The sampling data in this section are evaluated against the comparison concentrations in Table 4-106.

Table 4-106. Comparison concentrations for uranium.

Contaminant	Soil 1E-05 Risk-Based Concentration (pCi/g)	Background INEEL Soil <sup>a</sup> (pCi/g)	Local Soil Moisture Background <sup>b</sup> (pCi/L)	Background Aquifer <sup>c</sup> (pCi/L)	Aquifer 1E-05 Risk-Based Concentration (pCi/L)	Maximum Contaminant Level (pCi/L)
U-233	49.60	Not established	Not established	Not established	6.63	27 (total naturally occurring uranium)
U-234	50.23	1.44	3	1.1	6.74	
U-235	48.69	0.103 <sup>d</sup>	0.5	0.05	6.63	
U-236	53.27	Not established	Not established	Not established	7.11	
U-238	37.79	1.4	1.5	1.1	5.47	

INEEL = Idaho National Engineering and Environmental Laboratory

a. Upper 95%/95% tolerance limit with 95% confidence for composite surface soils on the INEEL (Rood, Harris, and White 1996).

b. Local soil moisture background is the mean of the concentrations in the "O" wells (outside of the SDA) and of Well D15, a designated background location.

c. Calculated from the mean uranium concentration of 3.35 ug/L from Knobel, Orr and Cecil 1992.

d. Background U-235 concentration in soil is based on the Radiological and Environmental Sciences Laboratory maximum background soil concentration cited in Rood, Harris, and White (1996, Table 4).

#### 4.6.19.1 Waste Zone

**4.6.19.1.1 Inventory**—The following estimated quantities of uranium isotopes were disposed of at the SDA:

- 1.51 Ci of U-233
- 67.4 Ci of U-234
- 5.54 Ci of U-235
- 2.86 Ci of U-236
- 117 Ci of U-238.

Additional quantities of uranium are generated over time by ingrowth (see Section 4.1.2). Tables 4-107 through 4-111 show the waste streams containing uranium disposals. Also included is the amount of uranium that would be produced if all of the parent were allowed to decay. Percentages of the total uranium from parent isotopes are not given because the amount of uranium present is dependant on the timeframe assessed. In addition, many of the uranium isotopes decay into other isotopes of interest. Specifically, U-233 is generated by the decay of Pu-241, Am-241 and Np-237 and U-233 decays into Th-229. Uranium-234 is generated by the decay of U-238 and Pu-238 and U-234 decays into Th-230, Ra-226, and Pb-210. Uranium-235 is generated by the decay of Am-243 and Pu-239 and decays into Pa-231 and Ac-227. Uranium-236 is generated by the decay of Pu-240 and decays into Th-232 and Ra-228.

Table 4-107. Waste streams containing U-233.

Waste Stream Code or Waste Generator	Waste Stream Description	Activity (Ci)	Proportion of Total Activity (%)
ARA-626-1H	Fuel scrap, waste from disassembly of facilities and hot cell waste	6.00E-01	39.8
RFO-DOW-19H	Miscellaneous scrap	5.4E-01	35.9
SMC-628-2	Unsolidified slag	3.01E-01	19.9
SMC-990-1	Depleted uranium-contaminated material (e.g., metals, glass, and gravel)	2.74E-02	1.8
SMC-628-1	Nonacidic evaporator sludge	2.21E-02	1.5
Miscellaneous	Miscellaneous minor streams	1.66E-02	1.1
<b>Total Disposals</b>		1.51E+00	100
Pu-241 ingrowth	Half-life equals 14.4 years. See Section 4.6.13	8.82E+01	NA
Am-241 ingrowth	Half-life equals 432 years. See Section 4.6.2	4.97E+02	NA
Np-237 ingrowth	Half-life equals 2.14E+06 years. See Section 4.6.10	3.56E+01	NA

**4.6.19.1.2 Gamma Logging**—The spectral gamma-logging tool provides no information about U-234.

The spectral gamma-logging tool detected U-235 based on the 186-keV gamma, and U-238 based on the 1,001-keV gamma emitted by its progeny Pa-234m. The detection rates above the noise level for probeholes and individual samples, and other detection data are shown in Table 4-112.

Table 4-108. Waste streams containing uranium-234.

Waste Stream Code or Waste Generator	Waste Stream Description	Activity (Ci)	Proportion of Total Activity (%)
RFO-DOW-18H	Enriched uranium	2.15E+01	31.9
RFO-DOW-16H	Depleted uranium	1.45E+01	21.5
CPP-601-3H	Dissolved fuel specimens	4.70E+00	7.0
Miscellaneous	Miscellaneous minor streams	4.65E+00	6.9
PDA-RFO-1A	Inorganic salts, depleted uranium, and sewage sludge	4.64E+00	6.9
OFF-ATI-1H	Irradiated fuel from research	3.64E+00	5.4
ANL-EBRI-1H	Miscellaneous combustibles and core, vessel, and loop components	3.36E+00	5.0
OFF-GEC-1H	Core, vessel, and loop components	2.95E+00	4.4
TAN-607-2	Test Area North Hot Shop noncompactable waste	1.83E+00	2.7
ANL-752-1R	Contact-handled waste	1.33E+00	2.0
OFF-CSM-1H	Magnesium fluoride slag and miscellaneous laboratory waste	1.30E+00	1.9
ANL-704-1R	Contact-handled fuel fabrication waste	1.21E+00	1.8
TRA-603-15H	Metal	1.11E+00	1.6
ALE-317-2R	Combustibles	7.10E-01	1.1
<b>Total Disposals</b>		67.43	100
U-238 ingrowth	Half-life equals 4.47E+09 years. See Section 4.6.19	2.14E+06	NA
Pu-238 ingrowth	Half-life equals 8.78E+01 years. See Section 4.6.13	6.13E+00	NA

**4.6.19.1.3 Uranium-235/236**—A total of 186 soil samples were collected between 1994 and 2000 from in and around the RWMC. Based on gamma spectrometric analytic results, 76 were selected for U-235 analysis. Fourteen positive detections of U-235 were documented. The positive results ranged from  $(4.4 \pm 0.9)$  E-02 pCi/g at Pad A to  $(6.2 \pm 1.4)$  E-02 pCi/g at the active area (LMITCO 1995c).

A total of 124 vegetation samples were collected between 1990 and 2000 from the RWMC and control locations. Based on gamma spectrometric analytic results, about 30 samples were selected for U-235 analysis. No positive detections of U-235 were documented.

A total of 210 surface run-off water samples were collected between 1991 and 2000 from the RWMC and control locations. Based on gamma spectrometric analytic results, about 93 samples were selected for U-235 analysis. No positive detections of U-235 were documented.

**4.6.19.1.4 Uranium-238**—A total of 186 soil samples were collected between 1994 and 2000 from the RWMC area. Based on gamma spectrometric analytic results, 76 were selected for U-238 analysis. The 19 positive detections ranged in concentration from  $(1.1 \pm 0.2)$  E-01 pCi/g (active area) to  $1.61 \pm 0.27$  pCi/g (north of the administrative area) (LMITCO 1997). None of the samples exceeded the 1E-05 risk-based concentration for soil.

Table 4-109. Waste streams containing uranium-235.

Waste Stream Code or Waste Generator	Waste Stream Description	Activity (Ci)	Proportion of Total Activity (%)
RFO-DOW-16H	Depleted uranium	1.08E+00	19.5
TRA-603-16H	Combustibles	7.80E-01	14.1
RFO-DOW-18H	Enriched uranium	7.44E-01	13.4
Miscellaneous	Miscellaneous minor streams	6.26E-01	11.3
TRA-603-15H	Metal	5.35E-01	9.7
TRA-603-6H	Core, vessel, and loop components	4.02E-01	7.3
PDA-RFO-1A	Inorganic salts, depleted uranium and sewage sludge	3.25E-01	5.9
WAG-WG7-02	Acid Pit in situ stabilization treatability study waste	1.80E-01	3.3
OFF-GEC-1H	Core, vessel, and loop components	1.57E-01	2.8
CPP-601-3H	Dissolved fuel specimens	1.50E-01	2.7
INEEL	INEEL reactor operations waste	1.28E-01	2.3
OFF-ATI-1H	Irradiated fuel from research	1.14E-01	2.1
ANL-EBRI-1H	Miscellaneous combustibles and core, vessel, and loop components	1.10E-01	2.0
OFF-CSM-1H	Magnesium fluoride slag and miscellaneous laboratory waste	8.00E-02	1.4
OFF-GDA-1H	Fuel fabrication item, laboratory equipment, activated metal and irradiated fuel	7.00E-02	1.3
ANL-752-1R	Contact-handled waste	5.60E-02	1.0
<b>Total Disposals</b>		5.54E+00	100
Am-243 ingrowth	Half-life equals 7.83E+03 years. See Section 4.6.3.	1.41E-03	NA
Pu-239 ingrowth	Half-life equals 2.41E+04 years. See Section 4.6.13.	2.22E+00	NA

INEEL = Idaho National Engineering and Environmental Laboratory

Table 4-110. Waste streams containing uranium-236.

Waste Stream Code or Waste Generator	Waste Stream Description	Activity (Ci)	Proportion of Total (%)
RFO-DOW-16H	Depleted uranium	9.03E-01	31.5
INEEL	INEEL reactor operations waste	5.83E-01	20.4
TRA-603-15H	Metal	4.22E-01	14.7
TRA-603-1H	Resins	2.7E-01	9.4
TRA-642-6H	Core, vessel, and loop components	2.44E-01	8.5
TRA-603-4H	Core and loop components	1.07E-01	3.7
TRA-603-9H	Expended fuel and ceramic fuel	8.11E-02	2.8
RFO-DOW-18H	Enriched uranium	8.04E-02	2.8
Miscellaneous	Miscellaneous minor streams	7.44E-02	2.6
NRF	Test specimens	5.29E-02	1.8
SMC-628-2	Unsolidified slag	4.37E-02	1.5
<b>Total Disposals</b>		<b>2.86E+00</b>	<b>100</b>
Pu-240 ingrowth	Half-life equals 6.57E+03 years	4.80E-00	NA

INEEL = Idaho National Engineering and Environmental Laboratory

Table 4-111. Waste streams containing uranium-238.

Waste Stream Code or Waste Generator	Waste Stream Description	Activity (Ci)	Proportion of Total Activity (%)
RFO-DOW-16H	Depleted uranium	7.62E+01	65.0
PDA-RFO-1A	Inorganic salts, depleted uranium, and sewage sludge	2.49E+01	21.2
Miscellaneous	Miscellaneous minor streams	8.20E+00	7.0
SMC-628-2	Unsolidified slag	2.31E+00	2.0
ARA-627-1H	Fuel scrap, waste from disassembly of facilities, and hot cell waste	1.64E+00	1.4
OFF-CSM-1H	Magnesium fluoride slag and miscellaneous laboratory waste	1.32E+00	1.1
ALE-ALE-1H	Building rubble, electric wires, piping, machinery, tracers and sources, glass, gloves, paper, filters, and vermiculite	1.32E+00	1.1
INEEL	INEEL reactor operations waste	1.30E+00	1.1
<b>Total Disposals</b>		<b>117.19</b>	<b>100</b>

INEEL = Idaho National Engineering and Environmental Laboratory

Table 4-112. Detection rates for uranium-235 and uranium-238 from the gamma logging tool.

Isotope	Probehole Detection Rate (%)	Measurement Detection Rate (%)	Detection Limit (pCi/g)	Number Above E-05 Risk-Based Concentration	Number Above Background	Maximum Concentration (pCi/g)	Average Concentration (pCi/g)	Median (pCi/g)
U-235	44/135 (33%)	261/4863 (5%)	2	25	Not applicable	345	22	8
U-238	70/135 (52%)	862/4863 (18%)	25	640	862	220,894	2,300	109

A total of 124 vegetation samples were collected between 1990 and 2000 from the RWMC and control locations. Based on gamma spectrometric analytic results, about 30 samples were selected for U-238 analysis. The nine positive detections of U-238 ranged in concentration from (1.98 ± 0.44) E-03 pCi/g (TSA) (INEEL 2000) to (2.79 ± 0.51) E-02 pCi/g (active area) (LMITCO 1998).

A total of 210 surface run-off water samples were collected between 1991 and 2000 from the RWMC and control locations. Based on gamma spectrometric analytic results, about 93 samples were selected for U-238 analysis. The six positive detections ranged in concentration from (2.61 ± 0.86) E-02 pCi/L (TSA-3) (LMITCO 1998) to (3.69 ± 0.82) E-01 pCi/L (Control T-12) (LMITCO 1998).

#### 4.6.19.2 Vadose Zone

**4.6.19.2.1 Uranium in Vadose Zone Core Samples**—Vadose zone core samples have been collected around the RWMC during several sampling campaigns. Core samples identified as sedimentary interbed have U-234 and U-238 concentrations that are near 1 pCi/L, which is typical of naturally occurring uranium in soils and sediments. However, core samples identified as massive basalt, fractured basalt, and rubble zone have U-234 and U-238 concentrations at much lower concentrations (0.1 to 0.2 pCi/g).

**4.6.19.2.1.1 Uranium-233/234**—A total of 87 vadose zone core samples were analyzed for U-233/234 between 1971 and 2000, with 47 positive detections. These 87 included 32 samples from 1999 to 2000, and 55 from the earlier campaigns, when reported values were unusually low (see Section 4.6.16.3.1). Only one of the 87 samples exceeded a background concentration of 1.44 pCi/g (Table 4-113), and none exceeded the soil risk-based concentration of 50.23 pCi/g for U-234.

Table 4-113. Summary of uranium-233/234 occurrences greater than background in the vadose zone core samples.

Depth Interval (ft)	Number Detections/Number of Samples (%)	Number of Detections >Background <sup>a</sup> /Number of Samples (%)	Range of concentrations >Background (1.44 pCi/g)	Wells and Boreholes with Detections >Background
0 to 35	3/11 (27.0)	0/11 (0)	Not applicable	Not applicable
35 to 140	22/40 (55.0)	1/40 (2.5)	1.7	76-4
140 to 250	22/36 (61.1)	0/36 (0)	Not applicable	Not applicable
More than 250	0/0	0/0 (NA)	Not applicable	Not applicable

a. Background U-233/234 for Idaho National Engineering and Environmental Laboratory surface soil is 1.44 pCi/g (Rood, Harris, and White 1996).

**4.6.19.2.1.2 Uranium-235/236**—A total of 86 vadose zone core samples were analyzed for U-235/236, with 12 detections. One slightly exceeded a background of 0.103 pCi/g, and none exceeded the 1E-05 soil risk-based concentration of 48.7 pCi/g for U-235. The detection rates for the various depth intervals are shown in Table 4-114.

Table 4-114. Summary of U-235/236 detections above background concentrations in vadose zone core samples.

Depth Interval (ft)	Number of Detections/ Number of Samples (%)	Number of Detections Above Background <sup>a</sup> / Number of Samples (%)	Range of Concentrations > Background (0.103 pCi/g)	Wells and Boreholes with Detections > Background
0 to 35	0/9 (0)	0/9 (0)	Not applicable	None
35 to 140	5/41 (12.2)	0/41 (0)	Not applicable	None
140 to 250	7/36 (19.4)	1/36 (2.8)	0.120	I-3D
More than 250	0/0 (0)	0/0 (0)	Not applicable	None

a. Background U-235 for Idaho National Engineering and Environmental Laboratory surface soil is 0.103 pCi/g (Rood, Harris, and White 1996).

**4.6.19.2.1.3 Uranium-238**—A total of 96 vadose zone core samples were analyzed for U-238, with 62 detections. Thirty-two of the samples were analyzed in 1999 and 2000 (all had detected concentrations of U-238). The other 64 samples were analyzed between 1971 and 1993. Of those, 53 were analyzed in 1993 and were all qualified as questionable (“J” flagged) because the laboratory method blank contained detectable (0.2 pCi/g) U-238. Of the 53 samples from 1993, 17 of them were documented as positive detections after adjusting for the contamination in the laboratory method blank (0.2 pCi/g). Positive results are presented here even though the laboratory method blank contained detectable U-238 because the concentration of the blank was minimal (0.2 pCi/g) compared to the sample results.

Six of the 62 positive detections were above the INEEL surface soil background of 1.40 pCi/g established by Rood, Harris, and White (1996) (Table 4-115). The background exceedance rates for the various depth intervals are shown in Table 4-116. All of the results above background were among the “J” flagged data set.

**4.6.19.2.1.4 Uranium Ratios in the Vadose Zone Core Samples**—The concentration or activity ratio of U-233/234:U-238 can be used to evaluate whether the uranium in a sample is natural uranium or uranium from waste, and whether the uranium from waste is enriched (higher U-233/234:U-238 ratio) or depleted (lower ratio) (see Section 4.6.16). Uranium-233/234:U-238 activity ratios were between 0.8 and 1.1 for the 1999 and 2000 vadose zone core data, which is expected for samples that contain only natural uranium. Ratios were not calculated on the data that were collected prior to 1999 because many of the samples were identified as massive basalt, fractured basalt and rubble, and many of the concentrations in those data sets were too low to provide reliable detections.

Table 4-115. Uranium-238 concentrations above background from vadose zone core samples.

Borehole Identification	Sample Depth (ft)	Concentration <sup>a</sup> ± 1σ (pCi/g)	Date
76-4	99.9	1.7 ± 0.10 <sup>b</sup>	1993
USGS-91	23.4 to 25.0	5.4 ± 0.2 <sup>b</sup>	1993
8802D	95.0 to 96.0	2.70 ± 0.10 <sup>b</sup>	1993
USGS-94	116.3 to 118.0	5.9 ± 0.2 <sup>b</sup>	1993
	217.0 to 220.2	7.5 ± 0.2 <sup>b</sup>	1993
USGS-93	222.5 to 236.0	2.80 ± 0.10 <sup>b</sup>	1993

a. Background is 1.40 pCi/g (Rood, Harris, and White 1996).

b. Data are questionable because of method blank contamination.

Table 4-116. Summary of U-238 occurrences greater than background in the vadose zone core samples.

Depth Interval (ft)	Number of U-238 Detections/Total Number of Samples (%)	Number of U-238 Concentrations >Background <sup>a</sup> /Total Number of Samples (%)	Range of Concentrations >Background (1.40 pCi/g)	Wells and Boreholes with Detections >Background
0 to 35	8/13 (61.5)	1/13 (7.7)	5.40	USGS-91
35 to 140	27/44 (61.4)	3/44 (6.8)	1.7 to 5.9	8802D, USGS-94, 76-4
140 to 250	27/39 (69.2)	2/39 (5.1)	2.8 to 7.5	USGS-93, USGS-94
More than 250	0/0	0/0	—	—

a. Background is 1.40 pCi/g (Rood, Harris, and White 1996).

**4.6.19.2.1.5 Vadose Zone Core Summary**—Uranium-233/234, U-235 and U-238 concentrations appear to be at background levels in core samples. Uranium-233/234:U-238 ratios on the 1999 to 2000 data were representative of natural uranium.

#### 4.6.19.2.2 Lysimeter Samples at Depths of 0 to 35 ft

**4.6.19.2.2.1 Uranium-233/234**—A total of 122 lysimeter samples collected from the shallow vadose zone were analyzed for U-233/234 between 1997 (beginning of uranium monitoring) and May 2001. Of those, 120 samples contained detectable concentrations of U-233/234 and two samples were assigned data qualifier flags. The results are shown for the shallow lysimeters in Figure 4-48. A total of 91 analyses exceeded the aquifer 1E-05 risk-based concentration for U-234 (6.74 pCi/L) used for comparison. The highest U-233/234 concentrations came from lysimeter samples taken from Wells PA01-L15, PA02-L16, and PA03-L33 (near Pad A), and W23-L08 and W23-L09 (on the west end of the SDA) and W08-L13 (near the Acid Pit). Prominent increasing U-233/234 trends were observed in the west end of the SDA (W23), and near Pad A (PA03). Figure 4-49 shows the occurrence of U-233/234 nondetections, detections above background, and detections greater than 1E-05 aquifer risk-based concentration (6.7 pCi/L) in shallow lysimeters.

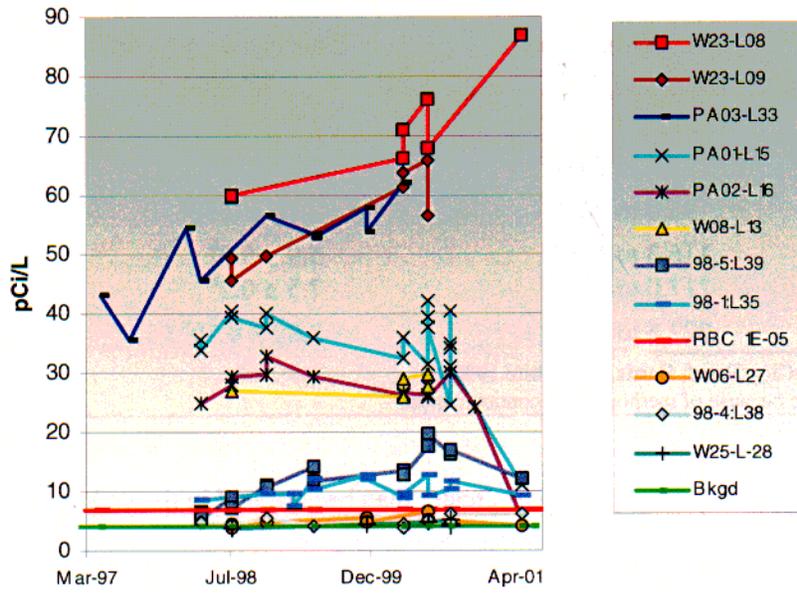


Figure 4-48. Soil moisture sample concentrations of uranium-233/234 in shallow lysimeters.

Year	Quarter	98-1 L35	98-4 L38	98-5 L39	PA01- L15	PA02- L16	PA03- L33	W06-L27	W08-L13	W23-L08	W23-L09	W25-L28
1997	1											
	2						43.2					
	3						35.4					
	4											
1998	1						54.5					
	2	8.7	4.8	6.4	35.6	24.9	45.6					
	3		4.4	8.9	39.2	29.4		4.6	26.8	60.1	49.2	3.8
	4	9.6	5.7	11.1	40.0	32.8	56.5	4.9			49.7	
1999	1	9.7										
	2	12.2	4.3	14.0	35.7	29.4	53.4					
	3											
	4	12.9					57.9	5.6				4.6
2000	1	9.5	4.5	13.6	35.9	26.4	61.9		29.1	71.1	63.9	
	2	12.6	5.2	19.8	41.9	27.5		6.7	29.5	76.1	65.7	4.8
	3	11.7	6.1	16.9	40.3	29.9						5.2
	4					24.3						
2001	1											
	2	9.2	6.2	12.2	11.0	5.2		4.1		87.0		
	3											
	4											
Key			U-233/234 was analyzed for, but not detected.									
		x.xx	U-233/234 was detected at soil moisture background levels (3 pCi/L).									
			U-233/234 was detected above soil moisture background, but less than the risk-based concentration (6.7 pCi/L).									
			U-233/234 was detected above the risk-based concentration.									
			If more than one detection occurred in a well in a single quarter, only the highest concentration is listed.									

Figure 4-49. Occurrence of uranium-233/234 detections at or near background (3 pCi/L), and detections greater than 1E-05 aquifer risk-based concentration (6.7 pCi/L) in shallow lysimeters.

**4.6.19.2.2.2 Uranium-235/236**—A total of 122 lysimeter samples from shallow lysimeters in the SDA were analyzed for U-235/236, with 42 positive detections. Routine lysimeter monitoring began in 1997 in Well PA03; however, routine monitoring did not begin in the other lysimeter wells until 1998. The concentration trends are shown for each lysimeter in Figure 4-50. The occurrence of soil moisture detections of U-235/236 above background concentration in shallow lysimeters is depicted in Figure 4-51.

None of the detected concentrations in any of the shallow lysimeters exceeds the 1E-05 aquifer risk-based concentration for U-235 (6.63 pCi/L) or U-236 (7.11 pCi/L). Detected concentrations of U-235/236 ranged from 0.35 pCi/L (PA01-L15) to 4.40 pCi/L (W23-L09), with the majority of values between 1.0 and 2.6 pCi/L. In Well W23, U-235/236 was first detected just recently, with the last two sampling events yielding detectable U-235/236. The wells with the highest U-235/236 concentrations (Wells W23 and PA03) also show elevated concentrations and emerging trends of U-233/234; however, the data are insufficient to identify a significant correlation.

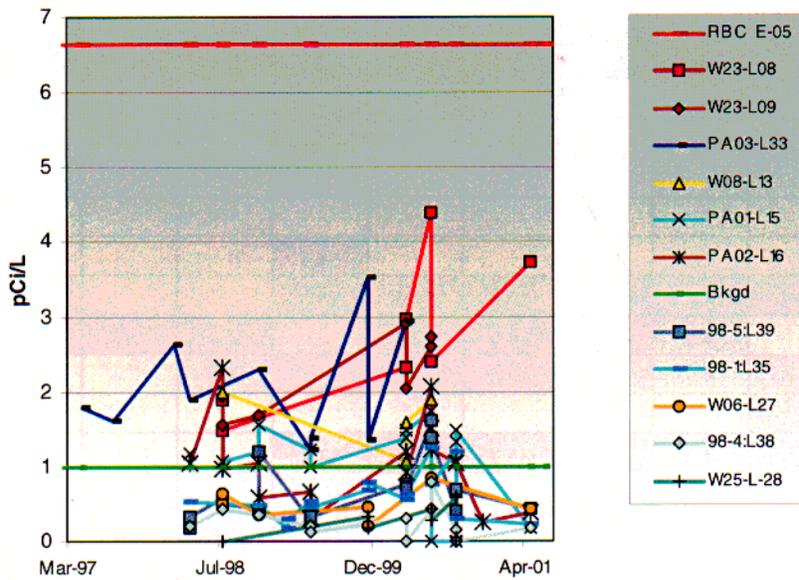


Figure 4-50. Soil moisture sample concentrations of uranium-235/236 in shallow lysimeters. (Note: Nondetected concentrations also are shown. Also see Figure 4-51, in which detected concentrations are identified for each well.)

Lysimeters W08-L13 (near Acid Pit), W23-L08 and -L09 (west end of SDA), and PA03-L33 (near Pad A) show concentrations that are consistently greater than subsurface background levels. The last two sampling events out of W23-L08 yielded samples with concentrations that were about four times higher than concentrations in other lysimeters. Uranium-233/234 was also elevated in W23 and PA03.

**4.6.19.2.2.3 Uranium-238**—A total of 122 shallow lysimeter samples were analyzed for U-238 between 1997 (beginning of uranium monitoring) and May 2001. 121 results contained detectable levels of U-238, ranging from  $0.26 \pm 0.06$  pCi/L (98-4L38) to  $53 \pm 5$  pCi/L (W23-L08), with the majority of values between about 3 and 28 pCi/L (Figure 4-52). One result contained a data qualifier flag. Results from PA03-L09, W23-L08, and W23-L09 are 10 pCi/L or more higher than all other samples in the latest round of sampling, and all three of these lysimeters exhibit increasing U-238 trends. The occurrence of the detections greater than the local soil moisture background and the detections above the risk-based concentrations are shown in Figure 4-53.

Year	Quarter	98-1 L35	98-4 L38	98-5 L39	PA01- L15	PA02- L16	PA03- L33	W06- L27	W08- L13	W23- L08	W23- L09	W25- L28
1997	1											
	2						1.8					
	3						1.6					
	4											
1998	1						2.6					
	2						1.9					
	3				1.1	2.3			2.0			
	4	0.48	0.37	1.2	1.6	1.1	2.3	0.35			1.7	
1999	1											
	2				1.2							
	3											
	4						3.5					
2000	1											
	2	1.3	0.79	1.6	1.7	2.1			1.9	4.4	2.6	
	3											
	4											
2001	1											
	2									3.7		
	3											
	4											
Key		U-235/236 was analyzed for, but not detected.										
	x.xx	U-235/236 was detected at local soil moisture background levels (0.5 pCi/L).										
		U-235/236 was detected above local soil moisture background, but less than the risk-based concentration (6.6 pCi/L).										
		U-235/236 was detected above the risk-based concentration.										
		If more than one detection occurred in a well in a single quarter, only the highest concentration is listed.										

Figure 4-51. Occurrence of uranium-235/236 nondetections, detections at or above background (0.5 pCi/L), and detections greater than 1E-05 aquifer risk-based concentration (6.6 pCi/L) in shallow lysimeters.

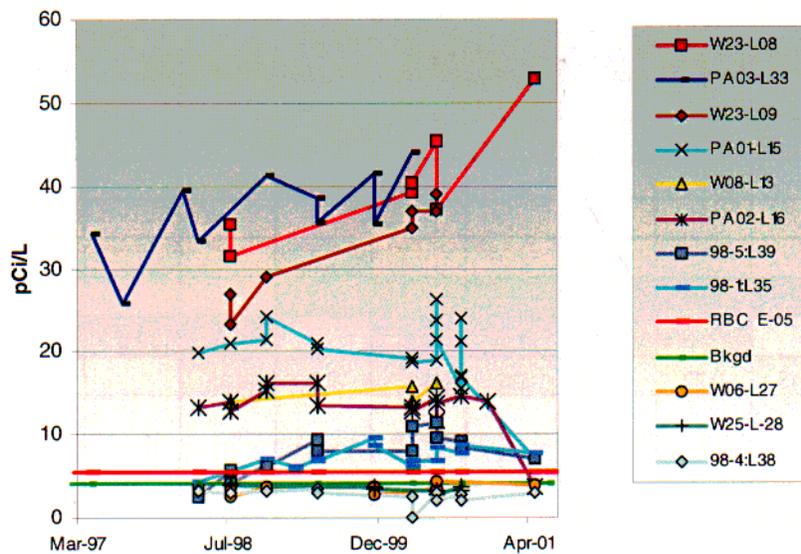


Figure 4-52. Soil moisture sample concentrations of uranium-238 in shallow lysimeters.

The wells with elevated uranium concentrations and noticeable trends are located at the west end of the SDA (W23) and near Pad A (PA03). As will be discussed later, the deeper lysimeter well samples (between 35 and 140 ft) also show elevated uranium concentrations and trends in these two locations.

Most of the samples consistently exceed the  $1E-05$  aquifer risk-based concentration for U-238 (5.47 pCi/L). The uranium data readily identify increasing uranium concentrations, but the source of uranium cannot be determined without additional data and further investigation.

**4.6.19.2.2.4 Uranium Ratios in Shallow Lysimeter Samples**—The atomic mass or activity ratios of U-234:U-238 can be used to evaluate whether it is likely that the uranium in a sample is natural uranium or uranium from waste, and whether the uranium from waste is enriched (higher U-233/234:U-238 ratio) or depleted (lower ratio) (see Section 4.6.16).

Uranium-233/234:U-238 ratios were evaluated for the routine shallow lysimeter well samples. All but one of the U-233/234:U-238 atomic mass ratios were between  $5.31E-05$  and  $1.30E-04$  (normal range), with the one outlier being  $7.96E-04$ , attributable to a low concentration of U-238 (0.26 pCi/L).

The U-233/234:U-238 ratios for the W23-L09 and W23-L08 lysimeters decrease over time, suggesting the appearance of depleted uranium at both depth intervals in the soil moisture at the west end of the SDA (see Table 4-104). The U-233/234:U-238 atomic mass ratios associated with Lysimeter 98-5L39 also decreased from 1998 through March 2000, though, the June 2000 ratio increased.

Aside from the emerging trend toward depleted uranium in shallow lysimeter samples from Well W23, the current ratios for the shallow lysimeters are contradictory or unclear.

Year	Quarter	98-1 L35	98-4 L38	98-5 L39	PA01- L15	PA02- L16	PA03- L33	W06-L27	W08-L13	W23-L08	W23-L09	W25-L28
1997	1											
	2						34.2					
	3						25.7					
	4											
1998	1						39.5					
	2	4.4	3.3	3.5	19.9	13.2	33.4					
	3		2.9	5.6	21.1	13.9		3.3	14.0	35.4	26.9	3.9
	4	7.0	3.2	6.3	24.2	16.1	41.2	3.6			29.0	
1999	1	6.1										
	2	7.1	3.5	9.4	21.0	16.1	38.5					
	3											
	4	9.7					41.5	3.7				3.5
2000	1	6.9	2.6	11.0	19.1	13.3	44.0		15.7	40.4	37.0	
	2	8.4	3.0	11.5	26.3	14.3		4.3	16.2	45.5	39.0	3.3
	3	8.8	2.8	9.1	24.0	14.5						3.7
	4					13.9						
2001	1											
	2	7.7		7.2	7.1	3.6		3.9		53.0		
	3											
	4											
Key		U-238 was analyzed for, but not detected.										
	x.xx	U-238 was detected at local soil moisture background levels (1.5 pCi/L).										
		U-238 was detected above local soil moisture background, but less than the risk-based concentration (RBC) (5.5 pCi/L).										
		U-238 was detected above the RBC.										
		If more than one detection occurred in a well in a single quarter, only the highest concentration is listed.										

Figure 4-53. Occurrence of uranium-238 nondetections, detections at or above background (1.5 pCi/L), and detections greater than 1E-05 aquifer risk-based concentration (5.5 pCi/L) in shallow lysimeters.

In 1999, seven shallow lysimeter water samples were collected and sent for TIMS analysis. With the low-level analysis, it is possible to also evaluate the U-236 data, which is unique to anthropic uranium, and U-238:U-235 ratios. The samples were collected from the PA01-L15, PA02-L16, PA03-L33, W23-L08, 98-4L38, 98-5L39, and W25-L28 lysimeters. The water samples were filtered and both the filtrate and filtered material were analyzed for isotopic U-234, U-235, U-236, and U-238. None of the seven shallow lysimeters contained detectable U-236 (unique to man-made uranium) or had uranium ratios that confirmed the presence of anthropic uranium (Roback et al. 2000). However, the TIMS results suggested that the ratios for both water and filter samples from W23-L08 (11 ft deep) and the water sample from 98-5L39 (10 ft deep) deviated somewhat from natural uranium.

#### 4.6.19.2.3 Lysimeter Samples at Depths of 35 to 140 ft

**4.6.19.2.3.1 Uranium-233/234**—A total of 48 lysimeter samples collected from the B and C basalt flows and B-C interbed were analyzed for U-233/234 between 1997 (beginning of

uranium monitoring) and May 2001, with 37 detections. The U-233/234 soil moisture results ranged from  $1.7 \pm 0.3$  pCi/L (D15-DL06) to  $111 \pm 10$  pCi/L (D06-DL01). Concentration trends for each intermediate depth lysimeter are shown in Figure 4-54. The U-233/234 detections above the local soil moisture background (3 pCi/L) and above the  $1E-05$  aquifer risk-based concentration (6.7 pCi/L) are shown in Figure 4-55.

Uranium-233/234 results from D06 and TW1 consistently exceed the  $1E-05$  aquifer risk-based concentration for U-233 and U-234. Results from Well D06 near Pad A suggest that U-233/234 is leaching because there is a prominent increasing trend in the 88-ft lysimeter, and a constant, but high concentration in the 44-ft lysimeter. Concentrations in Well TW1 (located within the Pit 5 boundary) have always been relatively high (about 85 to 90 pCi/L), although the most recent sample contained a low concentration of U-233/234 (about 5 pCi/L), which is likely an unidentifiable sampling or analytical anomaly.

Lysimeter Well I-1S-DL09 (on the west end of the SDA) appears to have somewhat elevated concentrations of U-233/234, although not nearly as high as those from TW1 and D06.

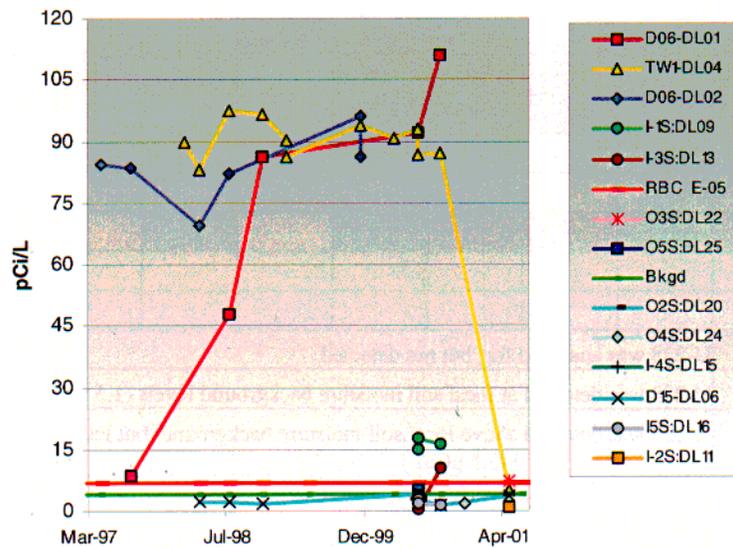


Figure 4-54. Soil moisture sample concentrations of uranium-233/234 in mid-depth lysimeters.

Year	Quarter	D06-DL01	D06-DL02	D15-DL06	I-1S	I-2S	I-3S	I-4S	I-5S	O-2S	O-3S	O-4S	O-5S	TW1-DL04
1997	1													
	2		84.4											
	3	8.5	83.5											
	4													
1998	1													90.0
	2		69.6	2.0										82.8
	3	47.9	82.3	2.4										97.4
	4	86.3		1.7										96.7
1999	1													90.2
	2													
	3													
	4		96.1											93.7
2000	1													90.6
	2	92.1		2.5	17.7				1.7				4.9	92.9
	3	111			16.1		10.4							87.0
	4										1.8			
2001	1													
	2			3.8							7.3			5.2
	3													
	4													
Key			U-233/234 was analyzed for, but not detected.											
		x.xx	U-233/234 was detected at local soil moisture background levels (3 pCi/L).											
			U-233/234 was detected above local soil moisture background, but less than the risk-based concentration (RBC) (6.7 pCi/L).											
			U-233/234 was detected above the RBC.											
			If more than one detection occurred in a well in a single quarter, only the highest concentration is listed.											

Figure 4-55. Occurrence of uranium-233/234 nondetections, detections at or above background (3 pCi/L), and detections greater than 1E-05 aquifer risk-based concentration (6.7 pCi/L) in mid-depth lysimeters.

**4.6.19.2.3.2 Uranium-235/236**—A total of 48 U-235/236 analyses were performed on lysimeter samples from the 35- to 140-ft depth interval within the SDA between 1997 (beginning of uranium monitoring) and May 2001, with 25 positive detections. One of the results (TW1-DL04) exceeded the E-05 risk-based concentration for the aquifer, used for comparison. Figure 4-56 shows the concentration trends in each of the intermediate depth lysimeters. Figure 4-57 shows the occurrence of the positive U-235/236 detections greater than local soil moisture background and greater than the 1E-05 aquifer risk-based concentration.

Though soil moisture results can be highly variable, a t-test shows that the U-235/236 concentrations from Lysimeter TW1-DL04 are significantly higher ( $p < 0.01$ ) than that in other lysimeters. Nine of 19 samples from TW1-DL04 yielded positive U-235/236 concentrations, and the TIMS analysis confirmed the presence of enriched uranium in TW1-DL04 samples.

There is a possible U-235/236 temporal trend in Lysimeter D06-DL01, which has relatively high concentrations, though the most recent data show a decline in the U-235/236 concentration, which may be attributable to natural variability, or an unidentifiable sampling or analytical anomaly.

Supporting TIMS data from Los Alamos confirm that anthropic uranium was present in a sample from TW1-DL04. Lysimeter D06-DL01 shows a possible trend of increasing U-235/236 over time, though the most recent data from that well suggest that the trend may be reversing or that the apparent trend could be attributable to natural variability.

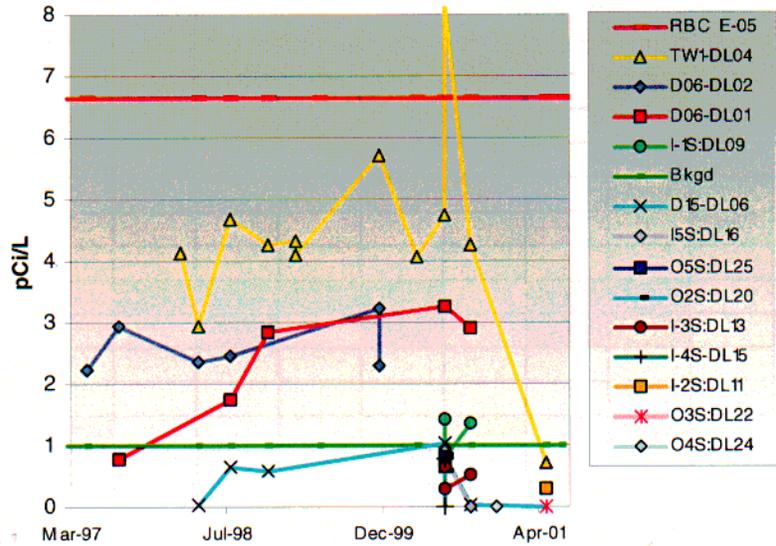


Figure 4-56. Soil moisture sample concentrations of uranium-235/236 measured in mid-depth lysimeters.

Year	Quarter	D06-DL01	D06-DL02	D15-DL06	I-1S	I-2S	I-3S	I-4S	I-5S	O-2S	O-3S	O-4S	O-5S	TW1-DL04
1997	1													
	2		2.2											
	3		2.9											
	4													
1998	1													4.1
	2		2.4											2.9
	3	1.7	2.5											4.7
	4	2.8		0.59										4.3
1999	1													4.3
	2													
	3													
	4		3.2											5.7
2000	1													
	2	3.3		1.0	1.4			0.78	0.90				0.65	8.2
	3	2.9												4.3
	4													
2001	1													
	2													
	3													
	4													
Key			U-235/236 was analyzed for, but not detected.											
			U-235/236 was detected at local soil moisture background levels (0.5 pCi/L).											
			U-235/236 was detected above local soil moisture background, but less than the risk-based concentration (RBC) (6.6 pCi/L).											
			U-235/236 was detected above the RBC.											
			If more than one detection occurred in a well in a single quarter, only the highest concentration is listed.											

Figure 4-57. Occurrence of uranium-235/236 nondetections, detections at or above background (0.5 pCi/L), and detections greater than the 1E-05 aquifer risk-based concentration of 6.6 pCi/L in mid-depth lysimeters.

**4.6.19.2.3.3 Uranium-238**—A total of 48 lysimeter U-238 analyses were performed on samples collected from the B and C basalt flows and B-C interbed between 1997 (beginning of uranium monitoring) and May 2001. Most of the lysimeters sampled have detectable levels of U-238. The positive results ranged from  $0.7 \pm 0.2$  pCi/L (D15-DL06) to  $52.6 \pm 4.8$  pCi/L (D06-DL01), with the majority of values between approximately 2 and 35 pCi/L. Figure 4-58 shows the U-238 concentration trends in each of the intermediate depth lysimeters. Figure 4-59 shows the occurrence of U-238 above background and above the 1E-05 risk-based concentration for U-238.

Samples from lysimeters D06-DL01 and D06-DL02 consistently contain U-238 above the 1E-05 risk-based concentration for U-238 used for comparison (Figure 4-58). There is a prominent trend in U-238 in D06-DL01 and a relatively stable but elevated concentration in D06-DL02, which is located in the same well (Figure 4-58). Lysimeter TW1-DL04 concentrations are considerably lower than the

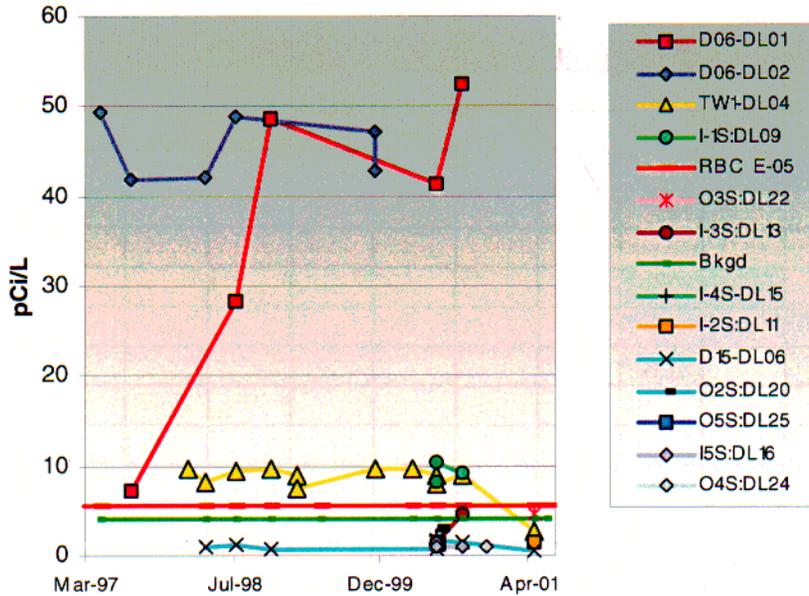


Figure 4-58. Soil moisture sample concentrations of uranium-238 measured in mid-depth lysimeters.

concentrations in the D06 lysimeters, but the uranium ratios U-233/234:U-238 and U-238:U-235/236 suggest the presence of enriched uranium (anthropic) in samples from that well.

**4.6.19.2.4 Uranium Ratios in Mid-Depth Lysimeter Samples**—Four lysimeter water samples (D06-DL01, D06-DL02, TW1-DL04, and D15-DL06) were collected from the B and C basalt flows and B-C interbed in 1999 and sent for TIMS analysis. The water samples were filtered and both the filtrate and filtered material were analyzed for isotopic U-234, U-235, U-236, and U-238. The filter sample from TW1-DL04 contained U-236 and had uranium isotopic ratios (i.e., U-234:U-238 and U-238:U-235) indicative of enriched uranium (Roback et al. 2000).

The INEEL routine monitoring data for U-235/236 from the lysimeters at this depth range are consistent with the TIMS results. The uranium data suggest increasing uranium concentrations, though the source of uranium in some cases cannot be determined without additional data and further investigation. The uranium atomic mass ratios for U-233/234:U-238 and U-238:U-235/236 in Lysimeter TW1-DL04 indicate anthropic uranium. The elevated U-234 results on the other three lysimeters and the trend data on D06-DL01 are inconclusive.

**4.6.19.2.5 Deep Lysimeter and Perched Water Samples at Depths Greater than 140 ft**

**4.6.19.2.5.1 Uranium-233/234**—A total of 21 water samples (four lysimeter and 17 perched water) were analyzed for U-233/234 between 1998 and December 2000. There were nine positive detections of U-233/234, all from the perched water wells. Three of the positive detections met or exceeded the 1E-05 aquifer risk-based concentration of 6.7 pCi/L, used for comparison (Table 4-117).

Year	Quarter	D06-DL01	D06-DL02	D15-DL06	I-1S	I-2S	I-3S	I-4S	I-5S	O-2S	O-3S	O-4S	O-5S	TW1-DL04
1997	1													
	2		49.4											
	3	7.2	41.9											
	4													
1998	1													9.8
	2		42.1											8.2
	3	28.4	48.9	1.2										9.5
	4	48.6		0.68										9.6
1999	1													9.1
	2													
	3													
	4		47.2											9.6
2000	1													9.6
	2	41.4		1.6	10.3		1.5	2.1		3.1				9.1
	3	52.6			9.3		4.5							8.9
	4										0.87			
2001	1													
	2										4.7			2.6
	3													
	4													
Key			U-238 was analyzed for, but not detected.											
		x.xx	U-238 was detected at local soil moisture background levels (1.5 pCi/L).											
			U-238 was detected above local soil moisture background, but less than the risk-based concentration (RBC) (5.5 pCi/L).											
			U-238 was analyzed detected above the RBC (5.5 pCi/L).											
			If more than one detection occurred in a well in a single quarter, only the highest concentration is listed.											

Figure 4-59. Occurrence of uranium-238 nondetections, detections at or above background, and detections greater than the 1E-05 aquifer risk-based concentration in mid-depth lysimeter samples.

Table 4-117. Positive detections of uranium-233/234 from perched water wells greater than 140 ft deep.

Perched Water Well	Concentration $\pm 1\sigma$ (pCi/L) Water	Confirmation Flag	Concentration $\pm 1\sigma$ (pCi/g) Filtered Sediments	Confirmation Flag <sup>a</sup>	Date
USGS-92	<b>6.9 <math>\pm 1.9</math></b>	A	0.47 $\pm 0.05$	A	April 1998
	<b>7.5 <math>\pm 0.6</math></b>	A	0.35 $\pm 0.03$	A	December 1998
	2.2 $\pm 0.4$	D	0.66 $\pm 0.08$	A	March 1999
	2.5 $\pm 0.7$	D	—	—	March 1999
	3.0 $\pm 0.7$	D	0.75 $\pm 0.13$	D	November 1999
	2.3 $\pm 0.7$	D	0.90 $\pm 0.14$	D	November 1999
	<b>6.7 <math>\pm 0.7</math></b>	A	0.76 $\pm 0.07$	A	March 2000
8802D	0.53 $\pm 0.17$	A	—	—	December 1998
	1.3 $\pm 0.4$	A	—	—	March 2000

a. Confirmation flag:

A = No second sample collected, no reanalysis performed.

D = Detection confirmed by reanalysis.

Note: Highlighted values and the "D" confirmation flag indicate a confirmed detection.

Note: Concentrations in red bold exceed the 1E-05 risk-based concentration for aquifer.

**4.6.19.2.5.2 Uranium-235/236**—A total of 21 water samples and six filtered sediment samples from the perched water wells and deep suction lysimeters were analyzed for U-235/236 between 1998 and December 2000. There were no positive detections identified. The USGS does not analyze perched water Well USGS-92 for U-235/236.

**4.6.19.2.5.3 Uranium-238**—A total of 21 water samples and six filtered sediment samples from the perched water wells and deep suction lysimeters were analyzed for U-238 between 1998 and December 2000, with 13 positive detections (see Table 4-118). None of the results exceed the 1E-05 aquifer risk-based concentration for U-238 (5.47 pCi/L), and none of the results in the 140<sup>+</sup>-ft region of the vadose zone are suspiciously high.

Table 4-118. Positive detections of uranium-238 from perched water Wells USGS-92 and USGS-8802D.

Perched Water Well	Concentration $\pm 1\sigma$ (pCi/L) Water	Confirmation Flag	Concentration $\pm 1\sigma$ (pCi/g) Filtered Sediments	Confirmation Flag <sup>a</sup>	Date
USGS-92	3.6 $\pm 1.1$	A	0.53 $\pm 0.05$	A	April 1998
	4.7 $\pm 0.4$	A	0.40 $\pm 0.04$	A	December 1998
	1.2 $\pm 0.3$	B	0.71 $\pm 0.08$	D	March 1999
	1.3 $\pm 0.4$	B	0.68 $\pm 0.12$	D	November 1999
	Not detected	—	0.88 $\pm 0.14$	—	November 1999
	3.2 $\pm 0.4$	A	0.72 $\pm 0.07$	A	March 2000
8802D	0.37 $\pm 0.11$	D	Not applicable	—	March 2000
	0.89 $\pm 0.26$	D	Not applicable	—	March 2000

a. Confirmation flag:

A = No second sample collected, no reanalysis performed.

D = Detection confirmed by reanalysis.

Note: Highlighted values and the "D" confirmation flags indicate a confirmed detection.

**4.6.19.2.5.4 Uranium Ratios**—Two perched water samples from the greater than 140-ft-depth interval of the vadose zone were sent to Los Alamos for TIMS analysis. The samples were filtered and both the filtrate and filtered material were analyzed for isotopic U-235, as well as

U-234, U-236, and U-238. The 8802D water sample results showed uranium isotopic ratios indicative of depleted uranium (Roback et al. 2000). This sample also contained U-236, which is indicative of anthropic uranium.

#### **4.6.19.3 Aquifer**

**4.6.19.3.1 Uranium-233/234**—A total of 162 aquifer samples in the vicinity of the RWMC were analyzed for U-233/234 between 1998 (beginning of uranium monitoring) and April 2001. All the wells sampled around the RWMC have detectable levels of U-233/234 at concentrations typical of background (1.1 pCi/L) uranium in aquifer. The U-233/234 results varied from  $0.40 \pm 0.04$  pCi/L (M4D) to  $1.84 \pm 0.15$  pCi/L (OW-2), with the majority of values between 0.82 and 1.54 pCi/L. The occurrence of U-233/234 detections in aquifer samples is shown in Figure 4-60.

The USGS does not analyze for U-233/234 in their eight RWMC wells they manage, control, and routinely sample.

The concentrations of U-233/234 detected are at background concentrations, and below the  $1E-05$  aquifer risk-based concentration (6.63 to 6.74 pCi/L). Ninety-three of the samples slightly exceeded 1.1 pCi/L, but did not appear to be elevated above background concentration.

Some INEEL aquifer well samples were analyzed using the TIMS method with an ultra-low detection limit and computed uranium ratios. The results suggest that the uranium in the aquifer beneath the RWMC is naturally occurring (i.e., U-234) and that the aquifer has not been impacted by anthropic uranium.

**4.6.19.3.2 Uranium-235/236**—A total of 161 RWMC aquifer well samples were analyzed for U-235/236 between 1998 (beginning of uranium monitoring) and April 2001. All the wells sampled around the RWMC have sporadic detections of U-235/236 at concentrations near the detection sensitivity of the radioanalytical method. The U-235/236 detections varied from  $0.020 \pm 0.006$  pCi/L (M15S) to  $0.18 \pm 0.02$  pCi/L (OW-2), with the majority of values between 0.03 and 0.10 pCi/L. Figure 4-61 identifies the detected concentrations of U-235/236 in the aquifer. The USGS does not analyze for U-235/236 in their eight RWMC wells.

**4.6.19.3.3 Uranium-238**—A total of 162 RWMC aquifer well samples in the vicinity of the RWMC were analyzed for U-238 between 1998 (beginning of uranium monitoring) and April 2001, all with detectable levels of U-238 at concentrations typical of background uranium in the Snake River Plain Aquifer. The U-238 results varied from  $0.21 \pm 0.03$  pCi/L (M4D) to  $0.88 \pm 0.08$  pCi/L (OW-2), with the majority of values between 0.4 and 0.7 pCi/L. The USGS does not analyze for U-238 in the eight RWMC wells they manage, control, and routinely sample; thus, no USGS U-238 data are available for the RWMC aquifer. The concentrations of U-238 detected are below the  $1E-05$  risk-based concentration for the aquifer. Aquifer detections above background and nondetections for U-238 are illustrated in Figure 4-62.

Year	Quarter	M1S	M3S	M4D	M6S	M7S	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	A11 A31	OW-2
1998	1															
	2	0.78	1.44	0.49	1.12	1.36	0.73									
	3	1.00	1.65	0.61	1.30	1.54	0.93	1.33	1.43	1.38	1.29					
	4															
1999	1															
	2	0.93	1.37	0.42	1.22	1.33	0.66	1.37	1.54	1.36	1.51					
	3	0.87	1.40	0.42	1.21	1.09	0.71	1.26		1.48	1.24					
	4	0.87	1.27	1.49	1.23	1.31	0.79	1.24	1.38	1.21	1.43					
2000	1	0.89		0.40	1.20	1.28	0.57	1.27	1.31	1.32	1.47	1.07	1.38			
	2													1.15		
	3	0.89	1.44	0.42	1.31	1.40	0.63	1.20	1.44	1.28	1.56	1.23	1.31	1.31		
	4	1.14	1.32	0.52	1.05	1.32	0.84	1.16		1.21	1.69	0.84	1.28	1.23	0.90	1.84
2001	1	0.89	1.61		1.12	1.15		1.14	1.64	1.09	1.27	1.14	1.23	1.19	0.92	1.56
	2	0.85	1.37	0.56	1.12	1.32		1.13	1.38	1.25	1.27	1.22	1.19	1.20	1.19	1.46
	3															
	4															
Key			U-233/234 was analyzed for, but not detected.													
		x,xx	U-233/234 was detected at aquifer background levels (1.1 pCi/L).													
			U-233/234 was detected above aquifer background, but below the risk-based concentration (RBC) (6.7 pCi/L).													
			U-233/234 was detected above the RBC.													
			If more than one detection occurred in a well in a single quarter, only the highest concentration is listed.													

Figure 4-60. Occurrence of uranium-233/234 nondetections and detections at or above background in aquifer wells monitored by the Idaho National Engineering and Environmental Laboratory.

Year	Quarter	M1S	M3S	M4D	M6S	M7S	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	A11 A31	OW-2
1998	1															
	2															
	3	0.091		0.044	0.088	0.086		0.079	0.082	0.049						
	4															
1999	1		0.058						0.040	0.044	0.071					
	2	0.050				0.038		0.041	0.044		0.051					
	3		0.039					0.036								
	4		0.040		0.031	0.050			0.034		0.030					
2000	1															
	2													0.035		
	3		0.041		0.037				0.031		0.039		0.040			
	4	0.037	0.051			0.046	0.029	0.029		0.044	0.064	0.020		0.041	0.046	
2001	1															
	2		0.038		0.047	0.040		0.027	0.062	0.035	0.046	0.055	0.113	0.044		0.177
	3															
	4															
Key			U-235/236 was analyzed for, but not detected.													
		x.xx	U-235/236 was detected at aquifer background levels (0.05 pCi/L).													
			U-235/236 was detected above aquifer background, but below the risk-based concentration (RBC) (6.6 pCi/L).													
			U-235/236 was detected above the RBC.													
			If more than one detection occurred in a well in a single quarter, only the highest concentration is listed.													

Figure 4-61. Occurrence of uranium-235/236 nondetections and detections at or above background in aquifer wells monitored by the Idaho National Engineering and Environmental Laboratory.

Year	Quarter	M1S	M3S	M4D	M6S	M7S	M10S	M11S	M12S	M13S	M14S	M15S	M16S	M17S	A11A31	OW-2
1998	1															
	2	0.35	0.60	0.25	0.54	0.56	0.42									
	3	0.53	0.64	0.33	0.65	0.74	0.46	0.66	0.72	0.69	0.58					
	4															
1999	1	0.38	0.73	0.23	0.60	0.51	0.35	0.53	0.75	0.54	0.63					
	2	0.43	0.62	0.32	0.58	0.67	0.27	0.55	0.72	0.54	0.71					
	3	0.34	0.65	0.28	0.53	0.52	0.32	0.52		0.55	0.65					
	4	0.40	0.65	0.67	0.58	0.69	0.35	0.50	0.64	0.48	0.60					
2000	1	0.46	0.68	0.22	0.56	0.58	0.28	0.57	0.61	0.55	0.62	0.57	0.66			
	2													0.63		
	3	0.43	0.72	0.23	0.52	0.68	0.33	0.47	0.68	0.61	0.67	0.55	0.60	0.58		
	4	0.53	0.60	0.25	0.45	0.65	0.37	0.44		0.51	0.71	0.39	0.59	0.60	0.41	0.88
2001	1	0.41	0.77	0.25	0.45	0.45		0.49	0.58	0.54	0.58	0.51	0.63	0.63	0.48	0.85
	2	0.41	0.65	0.30	0.58	0.62		0.42	0.67	0.49	0.60	0.56	0.53	0.51	0.54	0.64
	3															
	4															
Key			U-238 was analyzed for, but not detected.													
		x.xx	U-238 was detected at aquifer background levels (1.1 pCi/L).													
		v	U-238 was detected above aquifer background (1.1 pCi/L), but below the risk-based concentration (RBC) (5.5 pCi/L).													
			U-238 was detected above the RBC.													
			If more than one detection occurred in a well in a single quarter, only the highest concentration is listed.													

Figure 4-62. Occurrence of uranium-238 nondetections and detections at or above background in aquifer wells monitored by the Idaho National Engineering and Environmental Laboratory.

**4.6.19.3.4 Uranium Ratios**—In 1999, aquifer samples were collected from Wells M1S, M3S, M7S, M10S, M14S, USGS-87, USGS-117, USGS-119, and USGS-120 and sent for TIMS analysis. The aquifer well water samples were filtered and both the filtrate and filtered material were analyzed for U-234, U-235, U-236, and U-238. Natural uranium has a U-238:U-235 atomic ratio of 137.88 and contains no U-236 (Roback et al. 2001). None of the aquifer well samples indicated the presence of anthropic uranium in the aquifer below the RWMC (Roback et al. 2001). The TIMS analysis of the filters and filtrate did not show the presence of U-236 and showed an average U-238:U-235 ratio of 137.82. Thus, the RWMC aquifer has not been impacted by anthropic uranium from the SDA or from upgradient sources. The INEEL routine monitoring program includes evaluating the U-234:U-238 and U-238:U-235 ratios. The U-234:U-238 atomic mass ratios associated with all the INEEL aquifer wells are typical of INEEL aquifer.

**4.6.19.4 Summary of Uranium.** Uranium was not detected above background levels in the soil and rock collected from vadose zone cores or in the aquifer. However, there are some potential trends developing in the soil moisture samples. The distribution of detected U-233/234, U-235/236, and U-238 above background in the various media are shown in Figures 4-63, 4-64, and 4-65, respectively. With the exception of the lysimeter and perched water samples, all the concentrations of all uranium isotopes are around background. Table 4-119 shows the detection rates and E-5 risk-based concentration exceedance rates in each of the media for each uranium isotope.

Uranium isotopes are elevated in some lysimeter samples. Routine monitoring results from the shallow lysimeters suggest that there is an emerging trend in anthropic uranium around the Pad A area and at the western end of the SDA. Samples from PA03 and W23 consistently have higher concentrations of all the uranium isotopes, and the low-level TIMS results suggest that uranium from Wells W23 and 98-5 on the west end of the SDA deviate from natural. The U-233/234:U-238 ratio in W23 suggests that there is depleted uranium in that well. Uranium-233/234 and U-238 were increasing in the lysimeter samples from PA03 and W23, and the U-235/236 was elevated. Many of the lysimeter samples exceeded the aquifer risk-based concentration for U-233/234 and U-238.

Uranium concentrations were elevated in intermediate depth lysimeters near Pit 5 and Pad A, and were slightly elevated in Well I-1S, a relatively new well on the west end of the SDA. Uranium ratios on the TIMS data confirm that enriched uranium (i.e., anthropic) is present in TW1. The TIMS results from the other lysimeters were inconclusive.

Uranium isotopes do not appear to be elevated in the deeper vadose zone. The TIMS data suggest the possibility of anthropic uranium in the perched water from Well 8802D at around 220 ft deep, but no conclusion can be drawn from one sample result.

Ratios calculated for the vadose zone core, lysimeter, perched water, and aquifer samples do not provide strong evidence that anthropic uranium is widespread throughout the vadose zone beneath the RWMC. Ratios for the vadose zone cores and the aquifer were indicative of natural uranium. Ratios for the soil moisture and perched water suggest anthropic uranium is present. Depleted uranium trends may be developing in the shallow lysimeter samples at the west end of the SDA, and depleted uranium has been detected in the perched water sampled around 214 ft deep. Ratios for the intermediate vadose zone (35 to 140 ft) indicate the presence of enriched uranium in the Pit 5 area.



Figure 4-63. The distribution of detected uranium-233/234 above background in the vadose zone core, lysimeter, perched water, and aquifer samples at the Radioactive Waste Management Complex.

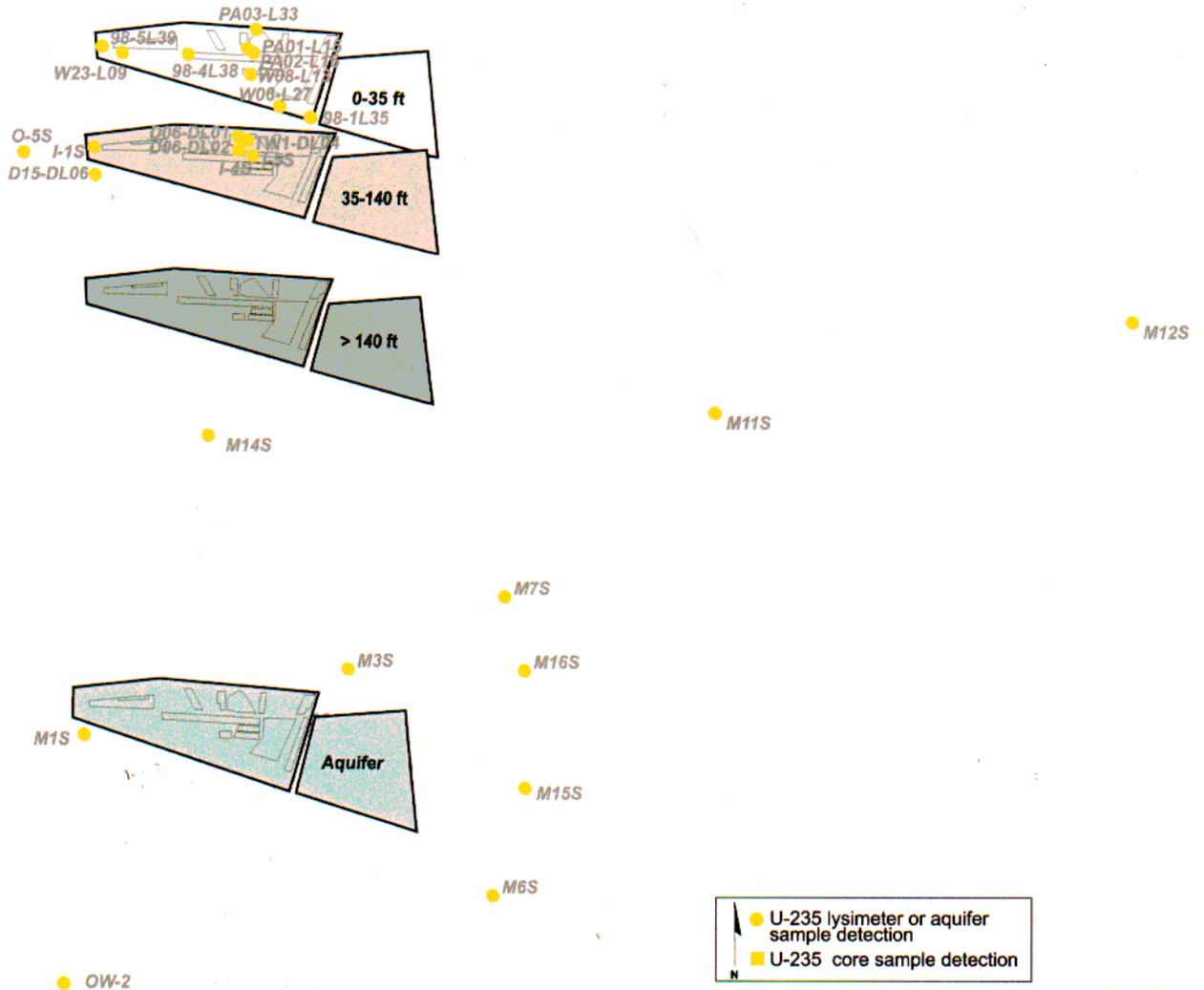


Figure 4-64. The distribution of uranium-235/236 positive detections greater than background levels in vadose zone cores, soil moisture, perched water and aquifer samples at the Radioactive Waste Management Complex.

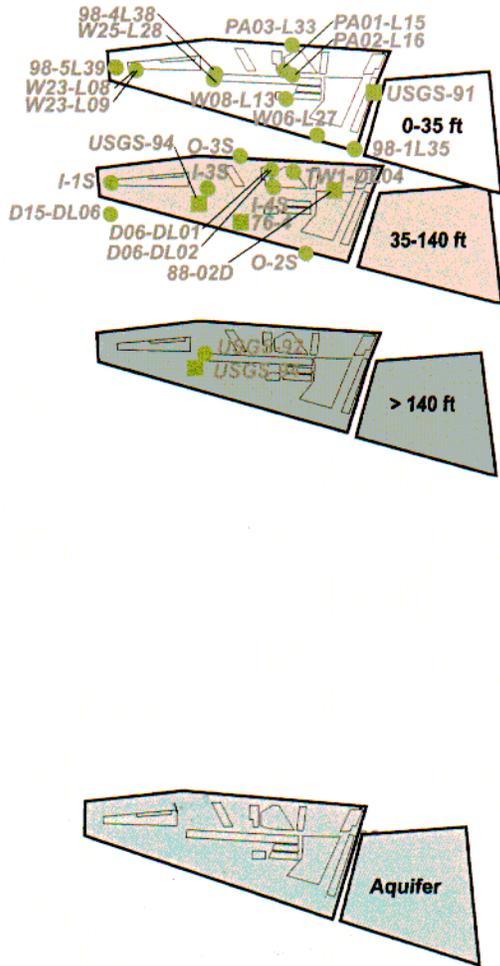


Figure 4-65. The distribution of uranium-238 positive detections greater than background levels in vadose zone cores, soil moisture; perched water, and aquifer samples at the Radioactive Waste Management Complex.

Table 4-119. Detection rates and 1E-05 risk-based concentration exceedance rates for uranium isotopes in all media.

Sampled Media	Detection Rate (%)	Range	Risk-Based Concentration Exceedance Rate (%)	Wells >Risk-Based Concentration
<b>U-233/234</b>				
Vadose zone 0 to 35 ft				
Cores	27	0.7 to 0.99 pCi/g	0	None
Soil moisture	98.3	3.69 to 87.0 pCi/L	75	98-1, 98-5, PA01, PA02, PA03, W06, W08, W23
Vadose zone 35 to 140 ft				
Cores	55.0	0.4 to 1.7 pCi/g	0	None
Soil moisture	77.0	1.68 to 111 pCi/L	56	D06, I-1S, I-3S, O-3S, TW1
Vadose zone 140 to 250 ft				
Cores	61.1	0.5 to 1.21 pCi/g	0	None
Soil moisture	42.96	0.5 to 7.47 pCi/L	14.3	USGS-92
Vadose zone more than 250 ft				
Cores	No data	No data	No data	No data
Soil moisture	No data	No data	No data	No data
Aquifer	84.8	0.4 to 1.84 pCi/L	0	None
<b>U235/236</b>				
Vadose zone 0 to 35 ft				
Cores	0	-	0	None
Soil moisture	34.4	0.35 to 4.4 pCi/L	0	None
Vadose zone 35 to 140 ft				
Cores	12.2	0.02 to 0.06 pCi/g	0	None
Soil moisture	52.0	0.59 to 8.2 pCi/L	2.1	TW1
Vadose zone 140 to 250 ft				
Cores	19.4	0.05 to 0.12 pCi/g	0	None
Soil moisture	0	-	0	None
Vadose zone more than 250 ft				
Cores	No data	No data	No data	No data
Soil moisture	No data	No data	No data	No data
Aquifer	38.0	0.020 to 0.177 pCi/L	0	None
<b>U-238</b>				
Vadose zone 0 to 35 ft				
Cores	61.5	0.6 to 5.4 pCi/g	0	None
Soil moisture	99.2	0.26 to 53 pCi/L	73.8	98-1, 98-5, PA01, PA02, PA03, W08, W23
Vadose zone 35 to 140 ft				
Cores	61.4	0.3 to 5.9 pCi/g	0	None
Soil moisture	79.2	0.68 to 52.6 pCi/L	52.1	D06, I-1S, TW1
Vadose zone 140 to 250 ft				
Cores	69.2	0.56 to 7.5 pCi/g	0	None
Soil moisture	33.3	0.37 to 4.7 pCi/L	0	None
Vadose zone more than 250 ft				
Cores	No data	No data	No data	No data
Soil moisture	No data	No data	No data	No data
Aquifer	93.0	0.21 to 0.88 pCi/L	0	None

## 4.7 Inorganic Contaminants

### 4.7.1 Nitrates

Nitrate ( $\text{NO}_3^-$ ) is an inorganic anion generally associated with nitrate-containing salts or fertilizers, or the aerobic decomposition of organic matter. Because it is an anion, it is readily transported through the vadose zone with migrating water. Nitrates exist in the SRPA at detectable concentrations of about 1 to 2 mg/L at background locations (Knobel, Orr, and Cecil 1992). Excess nitrate in groundwater is most commonly associated with large-scale farming operations or feedlots, from the addition of nitrogen-containing fertilizers, or from excessive manure in stockpiles or lagoons. Most of the nitrates in the SDA originate from nitrate salts used in weapons manufacturing. Nitrate was identified in the IRA as a COPC, primarily for the groundwater ingestion exposure pathway (Becker et al. 1998).

The nitrate sample data are presented in the following tables as they were reported in the limitations and validation or laboratory reports (see Section 4.5.3). Most of the data were reported as "nitrate" or "nitrate-N." The "nitrate-N" probably indicates that the concentration obtained by the analysis was reported on a nitrogen basis rather than as nitrate. Results in this section are compared to the MCL of 10 mg/L nitrates.

**4.7.1.1 Waste Zone.** About  $4.35\text{E}+08$  g of nitrates were disposed of in the SDA. Table 4-120 identifies the waste streams containing the nitrate inventory mass.

Table 4-120. Waste streams containing nitrates.

Waste Stream Code	Waste Stream Description	Mass (g)	Proportion of Total Mass (%)
PDA-RFO-1A	Nitrate salts RFO sludge	2.31E+08	53
RFO-DOW-17H	Nitrate salts in sludge	1.57E+08	36
CPP-601-4H	Acidic aqueous liquid	4.79E+07	11
<b>Total Disposals</b>		<b>4.35E+08</b>	<b>100</b>

**4.7.1.2 Surface.** Nitrates have not been measured in routine surface sampling.

**4.7.1.3 Vadose Zone.** The distributions of nitrate in vadose zone core, soil moisture, and perched water in the various depth intervals are discussed below.

**4.7.1.3.1 Core Samples—**A total of 27 nitrate and nitrite analyses were performed on core samples from the 1993 investigation, all of which were positive detections (see Table 4-121).

**4.7.1.4 Lysimeter Samples at Depths of 0 to 35 ft.** A total of 72 nitrate and nitrite analyses were performed on soil moisture samples collected from 10 shallow vadose zone lysimeters between 1994 and May 2001. Of these, there were 54 detections, 37 of which exceeded the MCL of 10 mg/L used for comparison (see Table 4-122).

Table 4-121. Detections of nitrates in Radioactive Waste Management Complex core samples.

Borehole Identification	Sample Depth (ft)	Name in Report <sup>a</sup>	Concentration (mg/kg)	Date
76-1	204.9 to 205.9	Nitrate + Nitrite-N	1.39	May 1993
76-2	78 to 79	Nitrate + Nitrite-N	1.72	May 1993
76-3	94 to 95	Nitrate-N	0.23	May 1993
	215 to 215.8	Nitrate-N	0.22	May 1993
76-5	45.1 to 46.0	Nitrate-N	0.29	May 1993
	48.0 to 49.0	Nitrate-N	0.53	May 1993
77-2	72.6 to 73.5	Nitrate-N	0.47	May 1993
	199.5 to 200.3	Nitrate-N	0.57	May 1993
78-2	126.5 to 127.8	Nitrate-N	0.24	May 1993
	226.3 to 230.1	Nitrate-N	0.38	May 1993
78-5	130.6 to 132.0	Nitrate-N	0.34	May 1993
	172.9 to 173.7	Nitrate-N	0.25	May 1993
79-2	27.0 to 29.0	Nitrate-N	0.38	May 1993
	70.0 to 70.6	Nitrate-N	0.37	May 1993
	221.5 to 222.5	Nitrate-N	0.33	May 1993
79-3	53.9 to 55.0	Nitrate-N	0.23	May 1993
	100.6 to 101.8	Nitrate-N	0.26	May 1993
8801D	43.2 to 44.7	Nitrate-N	0.91	May 1993
	87.0 to 89.0	Nitrate-N	0.91	May 1993
	170.3 to 171.3	Nitrate-N	2.94	May 1993
USGS-91	23.4 to 25.0	Nitrate-N	2.00	May 1993
	106.0 to 108.0	Nitrate-N	1.86	May 1993
USGS-93	14.0 to 16.0	Nitrate-N	0.57	May 1993
	222.5 to 236.0	Nitrate-N	0.75	May 1993
USGS-94	26.1 to 28.0	Nitrate-N	0.21	May 1993
USGS-95	76.0 to 114.4	Nitrate-N	0.29	May 1993
	235.2 to 239.0	Nitrate-N	0.25	May 1993

a. Compound name is presented as reported in Loehr, Einerson, and Jorgensen (1993). It is unknown whether the data represent nitrate or nitrogen concentrations in the samples.

Table 4-122. Detections of nitrates and nitrites from shallow lysimeters at depths of 0 to 35 ft.

Lysimeter	Depth (ft)	Name in Database <sup>a</sup>	Concentration (mg/L)	Date
W23-L08	11.8	Nitrate/Nitrite-N	30.8	April 1997
		Nitrate/Nitrite-N	27.7	August 1997
		Nitrate	102	August 1998
		Nitrate	0.12	March 2000
W23-L09	7.7	Nitrate/Nitrite-N	18.3	April 1997
		Nitrate/Nitrite-N	16.2	August 1997
		Nitrate/Nitrite-N	31.4	August 1997
		Nitrate	48.8	August 1998
		Nitrate-N	0.42	June 2000
W08-L13	11.3	Nitrate/Nitrite-N	34.1	April 1997
		Nitrate/Nitrite-N	5.6	August 1997
		Nitrate/Nitrite-N	16.7	August 1997
		Nitrate+Nitrite-N	30.7	June 2000
W08-L14	6.2	Nitrate/Nitrite-N	44.3	April 1997
		Nitrate/Nitrite-N	71.3	August 1997
		Nitrate/Nitrite-N	70.8	August 1997
PA01-L15	14.3	Nitrate/Nitrite-N	6.79	June 1994
		Nitrate/Nitrite-N	6.82	May 1995
		Nitrate	16.9	April 1996
		Nitrate/Nitrite-N	5.65	April 1997
		Nitrate/Nitrite-N	6.38	August 1997
		Nitrate	26.3	August 1998
		Nitrate	29.9	December 1998
PA02-L16	8.7	Nitrate/Nitrite-N	47.5	June 1994
		Nitrate-N	42.8	April 1995
		Nitrate	242	April 1996
		Nitrate/Nitrite-N	48.5	April 1997
		Nitrate	47.3	August 1997
		Nitrate/Nitrite-N	44.8	August 1997
		Nitrate/Nitrite-N	55.6	February 1998
		Nitrate	45.9	April 1998
		Nitrate	205	August 1998
		Nitrate	232	December 1998
		Nitrate	47.0	March 2000
Nitrate-N	30.3	May 2001		
W06-L27	11.8	Nitrate/Nitrite-N	3.67	April 1997
		Nitrate/Nitrite-N	2.90	August 1997
		Nitrate/Nitrite-N	3.68	August 1997
		Nitrate/Nitrite-N	6.02	February 1998
		Nitrate	9.30	August 1998
		Nitrate	11.2	December 1998
		Nitrate-N	7.89	May 2001

Table 4-122. (continued).

Lysimeter	Depth (ft)	Name in Database <sup>a</sup>	Concentration (mg/L)	Date
W25-L28	15.5	Nitrate/Nitrite-N	<b>21.3</b>	April 1997
		Nitrate/Nitrite-N	<b>10.2</b>	August 1997
		Nitrate/Nitrite-N	<b>21.2</b>	August 1997
		Nitrate+Nitrite-N	<b>26.2</b>	November 1999
		Nitrate-N	<b>26.7</b>	June 2000
PA03-L33	10	Nitrate	8.93	August 1997
		Nitrate/Nitrite-N	<b>10.6</b>	February 1998
		Nitrate	9.97	April 1998
		Nitrate	8.0	March 2000
98-5L39 (SDA10)	10.5	Nitrate	4.63	April 1998
		Nitrate	<b>27.0</b>	August 1998
		Nitrate	<b>16.8</b>	December 1998

a. Compound name is presented as reported by the laboratory. It is unknown whether the data represent nitrate or nitrogen concentrations in the sample.

Values in **red bold** exceed the maximum contaminant level of 10 mg/L. **Highlighted data** are the original and confirmation results.

**4.7.1.4.1 Lysimeter Samples at Depths of 35 to 140 ft**—A total of 29 nitrate and nitrite analyses were performed by the INEEL on soil moisture samples collected from seven lysimeters between 1995 and May 2001. Of these there were 18 detections, 12 of which exceed the MCL of 10 mg/L used for comparison (see Table 4-123).

Table 4-123. Detected nitrates in lysimeter samples at depths of 35 to 140 ft.

Lysimeter	Depth (ft)	Name in Database <sup>a</sup>	Concentration (mg/L)	Date
D06-DL01	88	Nitrate	<b>17.2</b>	August 1997
		Nitrate	9.03	April 1998
D06-DL02	44	Nitrate + Nitrite-N	<b>32.3</b>	April 1995
		Nitrate	<b>24.0</b>	August 1997
		Nitrate	<b>23.7</b>	April 1998
		Nitrate	<b>14.0</b>	March 2000
TW1-DL04	101.7	Nitrate + Nitrite-N	<b>2.02</b>	April 1995
		Nitrate + Nitrite-N	<b>2.73</b>	April 1995
		Nitrate	<b>41.9</b>	April 1996
		Nitrate	<b>42.0</b>	April 1996
		Nitrate/Nitrite-N	<b>13.1</b>	February 1998
		Nitrate	<b>14.2</b>	April 1998
		Nitrate	<b>13.0</b>	March 2000
D15-DL06	98	Nitrate-N	7.8	May 2001
		Nitrate/Nitrite-N	<b>13.3</b>	April 1997
I-2S DL11	92	Nitrate/Nitrite-N	0.76	August 1997
		Nitrate + Nitrite-N	<b>48.9</b>	May 2001
I-3S DL13	93	Nitrate + Nitrite-N	1.41	May 2001

a. Results are presented as reported by the laboratory. It is unknown whether the data represent nitrate or nitrogen concentrations in the sample.

Note: Values in **red bold** exceed the maximum contaminant level of 10 mg/L. **Highlighted data** are the original and confirmation results.

**4.7.1.4.2 Perched Water Samples at Depths Greater than 140 ft**—A total of five nitrate and nitrite analyses were performed by the INEEL on perched water samples collected from two wells between 1997 and May 2001. All samples contained detectable concentrations of nitrates, but none of the concentrations exceeded the MCL of 10 mg/L used for comparison (see Table 4-124).

Table 4-124. Detections of nitrates in the vadose zone soil moisture at depths greater than 140 ft.

Perched Water Well	Depth (ft)	Name in Database	Concentration (mg/L)	Date
USGS-92	214	Nitrate/Nitrite-N	4.07	April 1997
		Nitrate/Nitrite-N	0.58	August 1997
		Nitrate/Nitrite-N	1.96	February 1998
		NO <sub>2</sub> +NO <sub>3</sub> -N	1.05	October 1999
8802D	220	Nitrate/Nitrite-N	3.81	February 1998

a. Results are presented as reported by the laboratory. It is unknown whether the data represent nitrate or nitrogen concentrations in the sample.

**4.7.1.5 Aquifer.** Low levels of nitrates have been detected in the aquifer-monitoring wells in the vicinity of the RWMC. All 16 of the RWMC INEEL wells sampled from 1992 to May 2001 had nitrate concentrations below the MCLs and were typical of levels normally detected in the aquifer. The reported levels of nitrates typically found in the SRPA are 1 to 2 mg/L, with concentrations that range from 0.4 to 5 mg/L (Knobel, Orr, and Cecil 1992). The range of concentrations associated with the RWMC aquifer monitoring wells from 1992 to April 2001 (273 measurements) varied from a minimum of 0.28 mg/L to a maximum of 2.9 g/L, with the majority of values between 0.5 and 1.3 mg/L. Well M6S shows an increasing nitrate trend (see Figure 4-66).

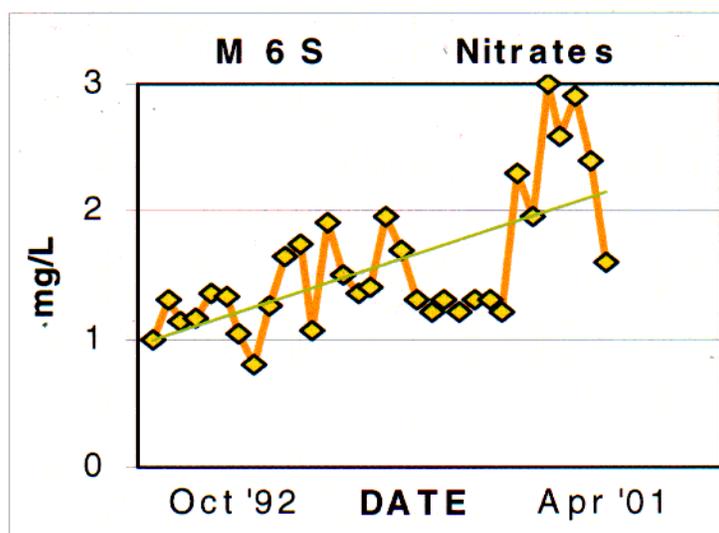


Figure 4-66. Nitrate concentrations in Well M6S from 1992 to 2001.

The trend observed in Well M6S began shortly after the well was installed in 1992. The cause of the trend is unknown. Well M6S was cleaned out in February 2001 as part of routine well maintenance

and various types of corrosion products and other debris were removed from the bottom of the well.<sup>a</sup> Nitrate concentrations since the well cleaning have declined; however, it will require several more sampling events before a decreasing trend can be substantiated.

Besides the wells routinely sampled by the INEEL, the USGS manages and regularly samples eight other wells in the vicinity of the RWMC. Most of these wells have been monitored by the USGS for nitrates since 1981; however, the RWMC Production Well was first monitored for nitrates in 1974. All of the RWMC USGS wells sampled from 1974 to April 2001 had nitrate concentrations around background (i.e., 1 to 2 mg/L). None of the USGS results exceeded the MCL (10 mg/L). The range of concentrations associated with the USGS aquifer monitoring wells from 1974 to April 2001 (139 measurements) varied from a minimum of 0 mg/L to a maximum of 2.1 mg/L, with the majority of values between 0.6 and 1.4 mg/L.

The concentrations of nitrates detected in the RWMC aquifer monitoring wells are below 58.4 mg/L, which is the concentration associated with the hazard index of one. There are no risk-based concentrations associated with nitrates because nitrates are not carcinogenic.

## 4.8 Volatile Organic Compounds

Carbon tetrachloride, PCE, and methylene chloride have been identified as COPCs, primarily for the groundwater ingestion exposure pathway. Information about the disposal inventories and the detections of these compounds in environmental media is presented in the following subsections.

### 4.8.1 Carbon Tetrachloride

Carbon tetrachloride is a chlorinated aliphatic hydrocarbon that can exist in multiple phases including: (a) a non-aqueous phase liquid, (b) a vapor phase in the soil gas, (c) an aqueous phase dissolved in soil water, and (d) a solid phase sorbed onto soil particles. In the vadose zone, CCl<sub>4</sub> will partition into all the phases, seeking an equilibrium condition. At the SDA, however, a liquid phase is unlikely because of the high viscosity of the treated 743-series waste.

Many investigations have been conducted to determine the extent of CCl<sub>4</sub> contamination and other VOCs at the SDA. These investigations have detected CCl<sub>4</sub> in surficial sediments, vadose zone soil gas, vadose zone soil water (perched water and lysimeters), and the aquifer beneath and surrounding the SDA. Carbon tetrachloride vapor has also been detected emanating from the soil surface by surface isolation flux chambers. Sources of CCl<sub>4</sub> information and data include, but are not limited to, Mann and Knobel (1987), Mann (1990), Liszewski and Mann (1993), Duncan, Troutman, and Sondrup (1993), Sondrup and Martian (1995), Greene and Tucker (1998), Rodriguez (2000), Miller and Varvel (2001), Housley (2002), the USGS Aquifer Quality Database, and results from routine monitoring.

Careful attention should be paid to the different concentration units for CCl<sub>4</sub> in the gaseous-phase and aqueous-phase. Aqueous-phase concentrations are often given in µg/L (mass of contaminant/volume of aqueous solution). For low concentrations, this is the same as parts per billion, which is a mass/mass ratio (e.g., µg of contaminant per kg of solution). Gaseous-phase concentrations on the other hand are given as parts per million by volume (ppmv), or parts per billion by volume (ppbv), both of which are a volume-to-volume ratio.

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a. Dooley, Kirk, personal conversation, September 25, 2001, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

#### 4.8.1.1 Waste Zone

**4.8.1.1.1 Inventory and Distribution**—The primary source of CCl<sub>4</sub> at the SDA is 743-series waste drums shipped from DOE's Rocky Flats Plant between 1966 and 1970 (Miller and Varvel 2001). Initially 9,691 743-series waste drums were buried in multiple pits in the SDA, including Pits 4, 5, 6, 9, 10, 11, and 12. Of these, 1,015 drums were subsequently retrieved from Pits 11 and 12 in the 1970s, leaving 8,676 drums of 743-series waste drums in the SDA. The estimated mass of CCl<sub>4</sub> contained in these 8,676 drums is 8.2E+05 kg (Table 4-125) with a standard deviation of 1.4E+05 kg (Miller and Varvel 2001). Figure 4-67 displays a drum density burial map for 743-series waste drums. Based on information reported in Miller and Varvel (2001), 6,225 (about 72%) of the 8,676 743-series drums buried in the SDA were buried in Pits 4 and 6. Table 4-126 displays the distribution of 743-series drums within the SDA.

Table 4-125. Waste streams containing carbon tetrachloride.

Waste Stream Code	Waste Stream Description	Mass (kg)	Proportion of Total Mass (%)
RFO-DOW-15H	Organic sludge	7.94E+05	96.8
RFO-DOW-4H	Paper, rags, and plastic	2.05E+04	2.5
Miscellaneous	Miscellaneous minor streams	5.74E+03	0.7
<b>Total Disposals</b>		<b>8.20E+05</b>	<b>100</b>

Table 4-126. Post-retrieval distribution of 743-series waste drums.

Pit	Number of Drums (% of total)
Pit 4	3,701 (42.6%)
Pit 5	49 (0.6%)
Pit 6	2,524 (29.1%)
Pit 9	1,144 (13.2%)
Pit 10	1,258 (14.5%)
<b>Total</b>	<b>8,676 (100%)</b>

Though a considerable amount of VOCs have been released from the 743-series waste into the vadose zone, a significant portion may still yet reside in sludge in the pits. Estimating the mass of VOCs remaining in source pits and trenches in the SDA is important in supporting decisions relating to SDA remediation.

# 743 Series Drum Burial Locations



Figure 4-67. Map of the Subsurface Disposal Area showing relative drum burial densities for 743-series waste drums.

A study was recently conducted that provides a preliminary estimate of the mass of CCl<sub>4</sub> and total VOCs remaining in the SDA pits.<sup>a</sup> The estimate is based on calculations of CCl<sub>4</sub> and total VOC mass originally buried in the SDA (Miller and Varvel 2001) and the results of recent chlorine logging in the waste. The chlorine logging was performed in probeholes along the 743-series transect in Pit 4 and provides the basis for estimating the current mass of CCl<sub>4</sub> and total VOCs at select locations within the SDA. The study attempted to quantify and propagate random errors in both data sets to provide an estimate of the uncertainty in the final VOC mass estimate.

The results of the study estimate that 51% ( $\pm 20\%$ ) of the initial chlorine mass buried in the SDA still remains. If it is assumed that the VOCs have not undergone chemical transformation since burial, and that the relative mass fractions of each VOC in 743-series waste has remained constant, the mass of CCl<sub>4</sub> remaining in the pits is estimated to be 4.1E+05 kg with a standard error of 1.5E+05 kg. The mass of total VOCs remaining is estimated to be 5.5E+05 kg with a standard error of 2.0E+05 kg. The study points out that additional work is needed to determine the adequacy of the assumptions and the presence of any bias errors in the supporting analysis, both of which influence the accuracy of the remaining mass estimates.

**4.8.1.1.2 Waste Zone Soil Gas Data from Type B Probes**—In 2001, 16 Type B vapor probes were installed within the waste zone in the 743 and DU Focus Areas. Eight of the 16 probes are functional and the other eight probes will not currently yield a sample. The probes that will not yield a sample may be clogged, possibly by the sludge from some of the buried waste. Of the 16 probes, nine have been installed in the organic sludge focus area and only three of the nine will yield a sample. The remaining seven waste zone vapor probes have been installed in the depleted uranium focus area where there is less 743-series waste, and five of the seven have yielded a sample.

Two of the functioning vapor ports (DU-08-VP2 and DU-10-VP3) have had vapor samples analyzed by an offsite laboratory and have yielded what is believed to be acceptable results; however, the data have not yet been validated. Table 4-127 lists the names, depths, and preliminary CCl<sub>4</sub> gas concentrations for samples collected from these locations. The 13,000-ppmv concentration measured in DU-08-VP2 is the highest vapor concentration measured at the SDA. This should not be surprising since it is the first sample ever collected from the waste zone. Samples from the remaining functioning vapor ports have been analyzed with a field instrument that has not been reliable. Problems with this instrument are being corrected and additional data will be collected during the next round of vapor port sampling.

Table 4-127. Unvalidated carbon tetrachloride vapor concentrations from Type B vapor probes.

Vapor Port	Port Depth (ft)	CCl <sub>4</sub> Concentration (ppmv)	Date
743-03-VP1	18.0	No sample can be obtained	Not applicable
743-03-VP2	13.3	No sample can be obtained	Not applicable
743-03-VP3	4.8	No sample can be obtained	Not applicable
743-08-VP1	20.2	Not sampled	Not applicable
743-08-VP2	13.4	Not sampled	Not applicable
743-08-VP3	4.9	No sample can be obtained	Not applicable
743-18-VP1	20.0	No sample can be obtained	Not applicable

a. Miller, Eric C., A. Jeffrey Sondrup, and Nicholas E. Josten, 2002, "Preliminary Estimate of Carbon Tetrachloride and Total Volatile Organic Compound Mass Remaining in SDA Pits (Draft)," INEEL/EXT-02-00140, Rev. A, draft, Idaho National Engineering and Environmental Laboratory, Bechtel BWXT Idaho, LLC, Idaho Falls, Idaho.

Table 4-127. (continued).

Vapor Port	Port Depth (ft)	CCl <sub>4</sub> Concentration (ppmv)	Date
743-18-VP3	7.6	No sample can be obtained	Not applicable
743-18-VP4	14.6	Not sampled	Not applicable
DU-08-VP2	15.8	13,000	November 2001
DU-10-VP1	11.6	No sample can be obtained	Not applicable
DU-10-VP2	10.0	Not sampled	Not applicable
DU-10-VP3	6.2	610	November 2001
DU-14-VP1	16.1	No sample can be obtained	Not applicable
DU-14-VP2	11.7	Not sampled	Not applicable
DU-14-VP3	4.9	Not sampled	Not applicable

**4.8.1.2 Surface.** Gaseous emissions from the soil surface of the SDA were collected in December 1992 and July 1993 using a surface isolation flux chamber. Measurements were made in the 12 locations indicated in Figure 4-68. The results for CCl<sub>4</sub>, in terms of concentration within the sample canisters and emission rates, are shown in Table 4-128. Emissions of CCl<sub>4</sub> were detected in 10 of the 12 locations. The maximum emission rate for CCl<sub>4</sub> was 56 µg/m<sup>2</sup>/min at location FC-5 between Pits 4 and 10. The complete results of these studies can be found in Duncan, Troutman, and Sondrup (1993) and Schmidt (1993).

Table 4-128. Summary of carbon tetrachloride data collected from 1992 and 1993 surface flux chamber measurements.

Sample Location	December 1992		July 1993	
	Concentration in Canister (ppbv)	Emission Rate (µg/m <sup>2</sup> /minute)	Concentration in Canister	Emission Rate
FC-1	3.3 (3.9) <sup>a</sup>	0.87	4.5 (5.0) <sup>a</sup>	Not detected
FC-2	8.3	2.0	Not detected	Not detected
FC-3	<1	Not detected	Not detected	Not detected
FC-4	8.7	2.1	Not detected	Not detected
FC-5	85	20	240 <sup>b</sup>	56
FC-6	21	5.0	46	10
FC-7	11	2.6	Not detected	Not detected
FC-8	3.2	0.77	Not detected	Not detected
FC-9	2.9	0.70	14	2.1
FC-10	160	38	2.4	Not detected
FC-11	23	5.5	200	46
FC-12	<1	Not detected	Not detected	Not detected

a. Replicate analysis.

b. Reported value is an average of multiple results.

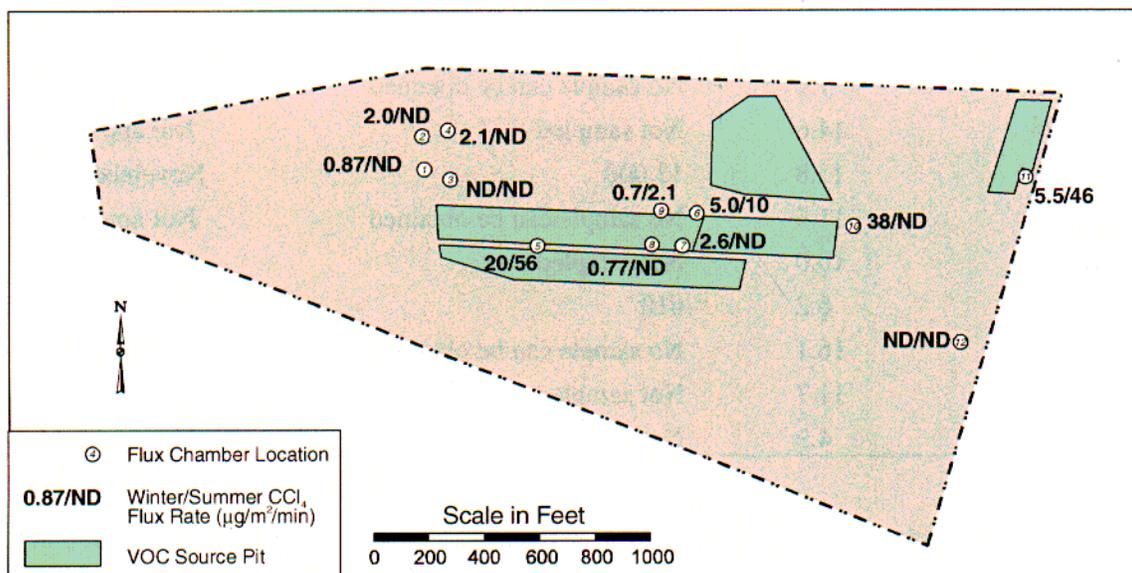


Figure 4-68. Surface flux chamber measurement locations.

**4.8.1.3 Vadose Zone.** Carbon tetrachloride is ubiquitous in the vadose zone in the vicinity of the SDA, as shown by hundreds of gas and water sample analyses. This section discusses the vadose zone sample results, including (a) shallow soil gas survey data, (b) shallow well soil gas data, (c) deep soil gas data, (d) perched water data, and (e) lysimeter data.

**4.8.1.3.1 Shallow Soil Gas Survey Data**—Four shallow soil gas surveys have been performed at the SDA. The first two surveys were conducted in 1987 and 1992 and covered large areas using a relatively coarse grid spacing. These surveys analyzed samples using portable gas chromatographs and produced respective CCl<sub>4</sub> concentration ranges of 0 to 427 ppmv and 0 to 255 ppmv. The most recent surveys, conducted in 1999 and 2000, used a finer spacing and were focused in areas over Pits 4, 5, 6, and 10, identified by the previous surveys as 743-waste burial locations. These surveys analyzed samples using a Brüel and Kjaer portable photoacoustic gas analyzer. The CCl<sub>4</sub> concentration ranges for the 1999 and 2000 surveys are 2 to 7,260 ppmv and 0 to 6,330 ppmv, respectively. Because the 1999 and 2000 surveys were focused over specific pits where 743-series drums are buried, it is not surprising that the maximum measured concentrations are much greater than the first two surveys.

The results of the four surveys generally agree with one another in terms of identifying burial locations of VOCs contained in 743-series waste. Figure 4-69 shows an isopleth of CCl<sub>4</sub> concentrations from the 2000 shallow soil gas survey. To a large degree, this information validates the 743-series waste burial locations shown in Figure 4-67. A summary of all four shallow soil gas surveys can be found in Housley, Sondrup, and Varvel (2001).

# Shallow Soil Gas Survey Overview

Year 2000 - CCl<sub>4</sub> Sampling Results

WAG 7 OU 7 - 08 Pit 4, 5, 6, and 10

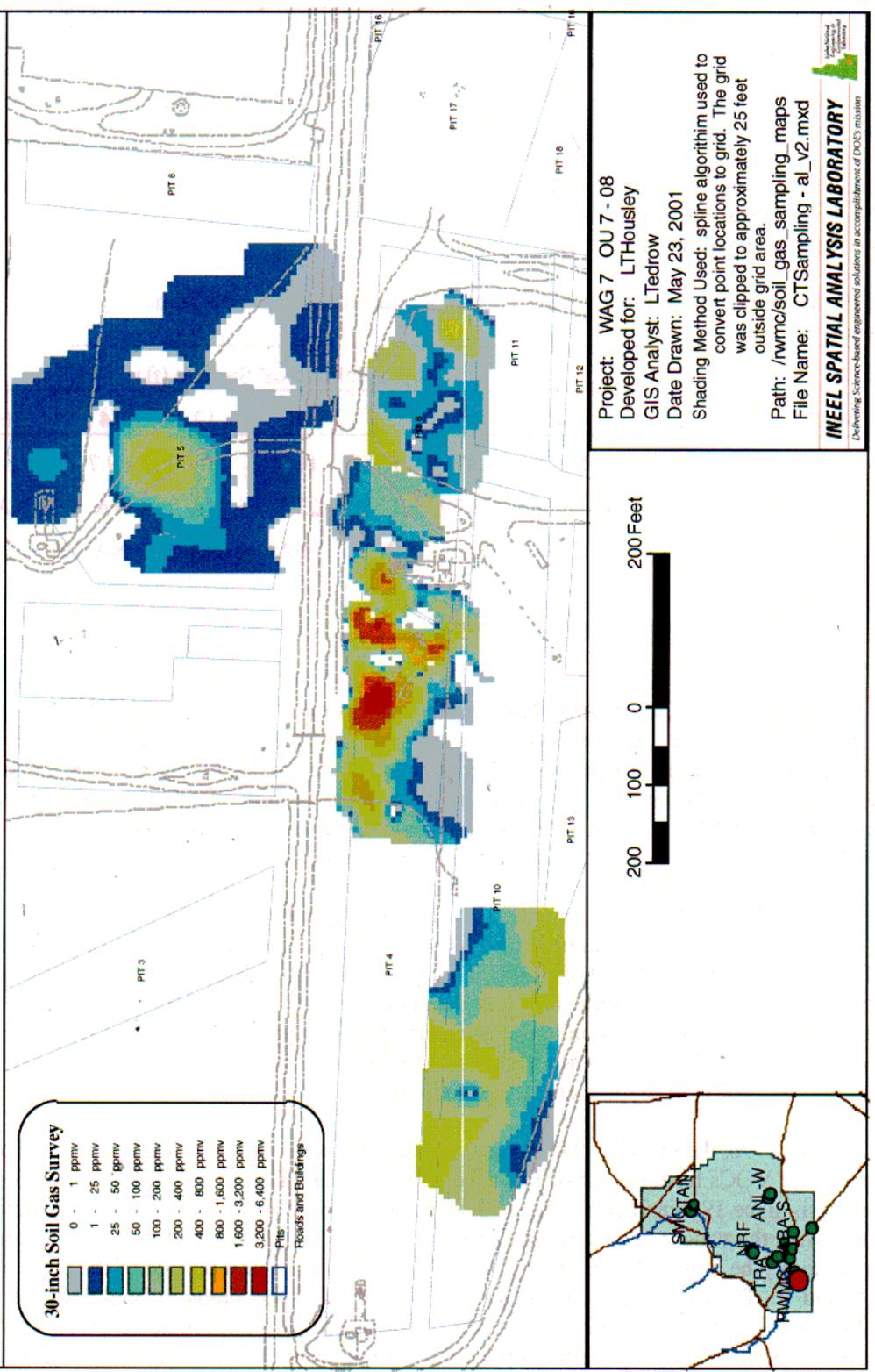


Figure 4-69. Carbon tetrachloride concentrations (ppmv) in shallow soil gas measured during the 2000 shallow soil gas survey.

**4.8.1.3.2 Shallow Well Soil Gas Sampling**—In August 1992, gas samples were collected from gas sampling ports in Wells TEM1A, TEM2A, and TEM3A (see Figure 4-70 for well locations). The sampling ports are located in the surficial sediments at 2-ft depth intervals down to basalt. Samples were analyzed on-site with a Sentex Scentograph portable gas chromatograph. Results for CCl<sub>4</sub> from these analyses are summarized in Table 4-129. The maximum concentration measured was 103 ppmv in Well TEM-1A at a depth of 4.9 m (16 ft). The vertical profile in each well shows an increase with depth in CCl<sub>4</sub> concentrations. For additional details, see Duncan, Troutman, and Sondrup (1993).

Later in the same year, other shallow well gas samples were collected and analyzed from locations around the Acid Pit and Pit 9. The results of these samples were consistent with TEM-series well sample results and the 1992 shallow gas survey.

Table 4-129. Summary of carbon tetrachloride vapor concentration results from August 1992 TEM-series well samples.

Well	Depth Below Soil Surface (ft)								
	2	4	6	8	10	12	14	16	18
TEM1A	8.79	13.9	13.7	13.6	16.7	20.0	89.7	103	NA
TEM2A	ND	2.49	3.39	17.1	23.8	NA	NA	NA	NA
TEM3A	8.62	13.6	24.0	NA	NA	NA	NA	69.8	147

NA = not applicable  
 ND = not detected at 0.1 ppm  
 Note: All values are reported as mean concentration in ppmv.

**4.8.1.3.3 Deep Soil Gas Data**—Soil gas monitoring in the vadose zone is accomplished using an extensive system of permanent soil gas sampling ports inside and outside the SDA boundary. The ports are made of stainless tubing attached to the outside of well casings. Figure 4-70 shows the location of wells with soil gas-sampling ports in the vicinity of the SDA and Figure 4-71 shows the depths of the ports. Note the port depths range from a minimum depth of 4.6 m (15 ft) in Well WWW-1 to a maximum depth of 180.1 m (591 ft), just above the water table, in Well M13S.

Soil gas data for the SDA are contained in three primary references. The first is Sondrup and Martian (1995) who compiled and summarized VOC soil gas data in the vicinity of the SDA from 1991 through 1995 for the IRA (Becker et al. 1998). Though Sondrup and Martian (1995) contains soil gas data prior to 1992, Izbicki (1992) recommended that data collected prior to 1992 be used only for identification of contaminants and qualitative analysis because of quality and reliability concerns. The other two soil gas data references are Rodriguez (2000), which contains soil gas data from 1992 through 1999; and Housley (2001), a supplement to the Rodriguez (2000) report.

In January 1996, the OCVZ project began operation of a multi-well VVE system inside the SDA to remove gas phase VOCs from the subsurface (see Section 3.2.8). This system has operated on a nearly continuous basis since 1996 and greatly altered deep soil gas concentrations. Figure 4-72 shows conceptually what the vadose zone soil gas concentrations before operation of the vapor-vacuum extraction system. The highest levels of CCl<sub>4</sub> were located in the central portion of the SDA between Pits 4, 5, 6, and 10. The maximum concentration measured was 4,864 ppmv in Well 9302 Port 6, at a depth of 23.5 m (77 ft) in January 1995. Data from wells outside the SDA indicate CCl<sub>4</sub> has migrated more than 1 km (3,281 ft) beyond the SDA boundary, but concentrations decrease significantly with

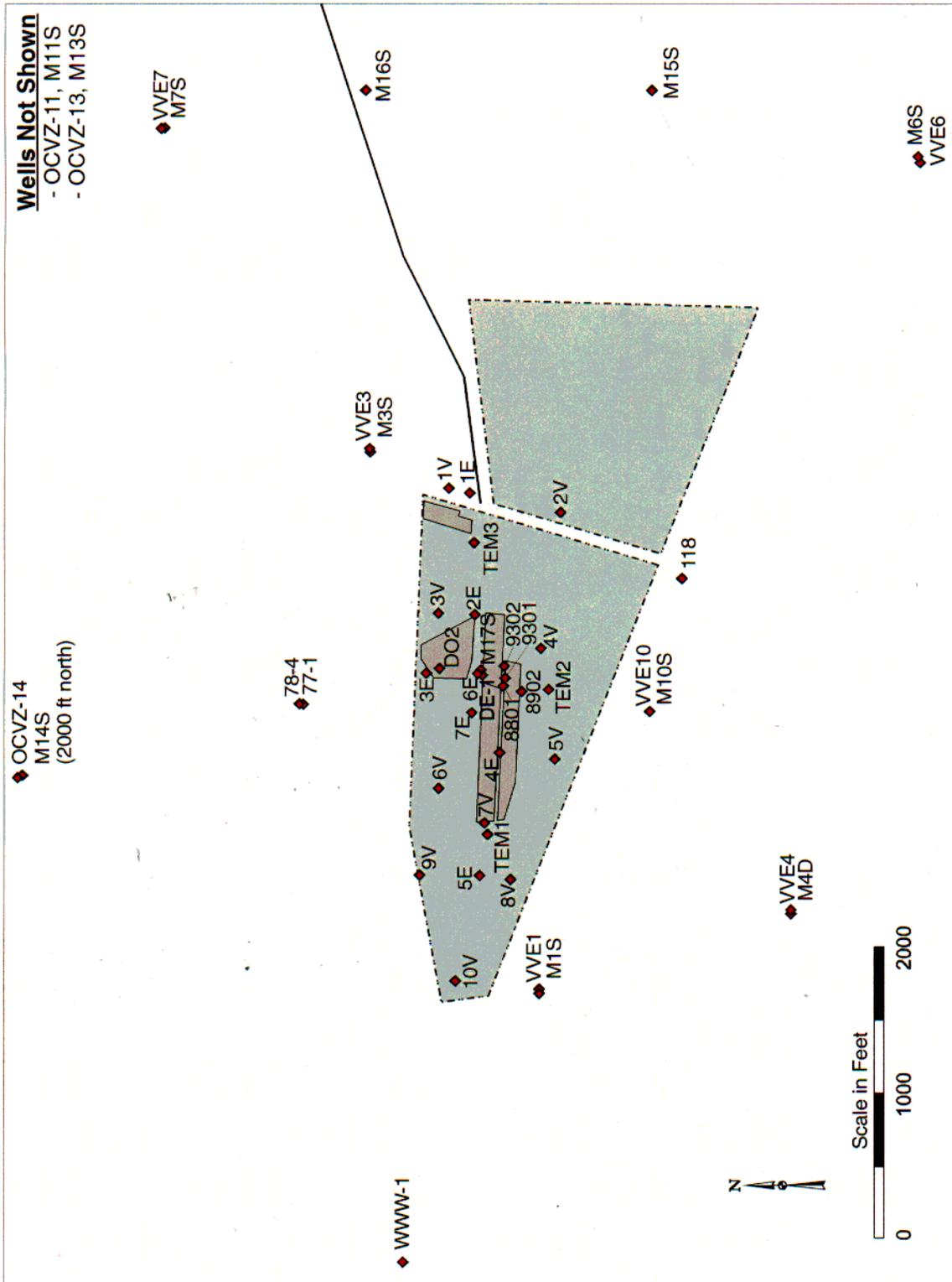


Figure 4-70. Locations of wells in the vicinity of the Subsurface Disposal Area with permanent vapor sampling ports.

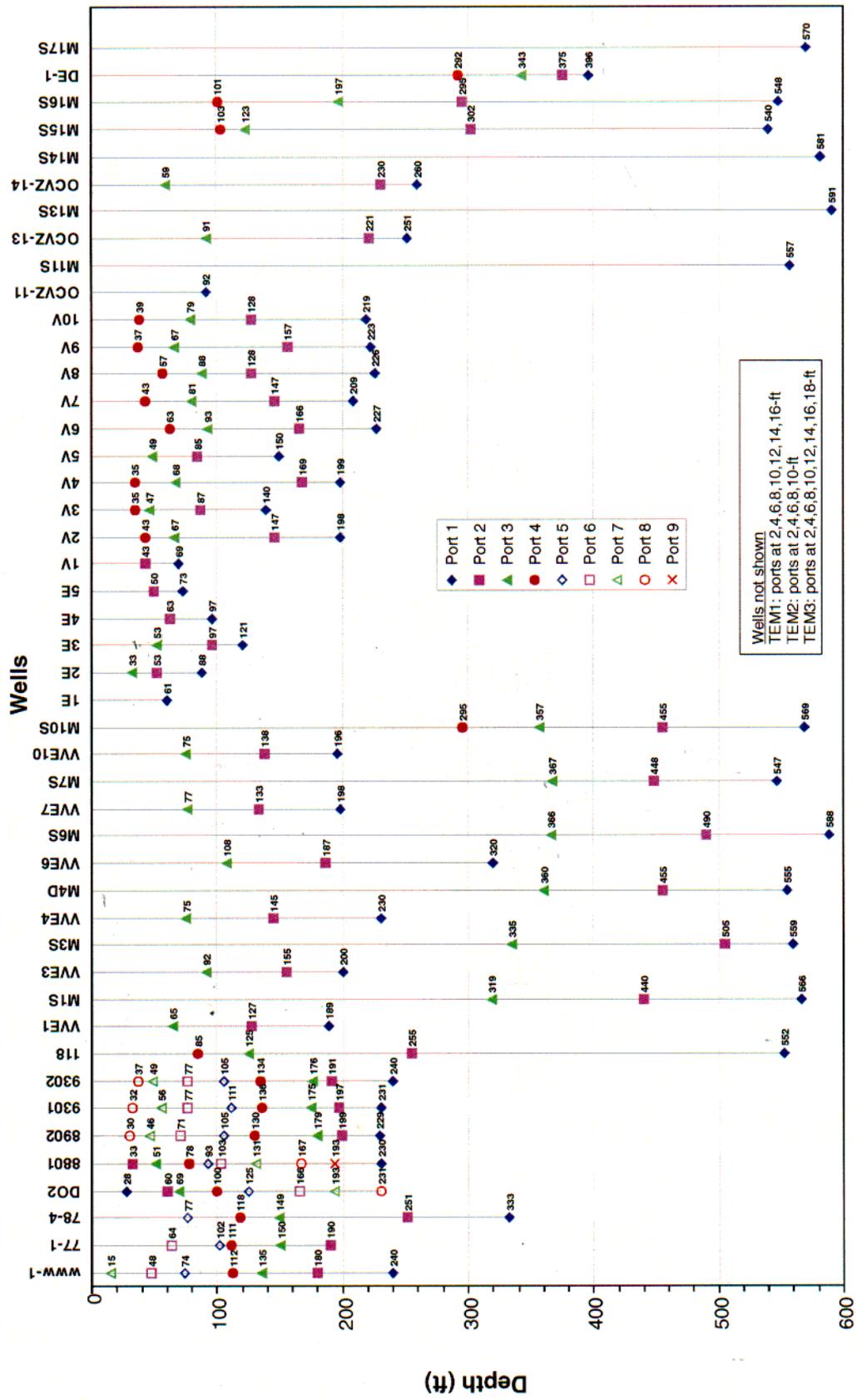


Figure 4-71. Vapor sampling port depths and numbers.

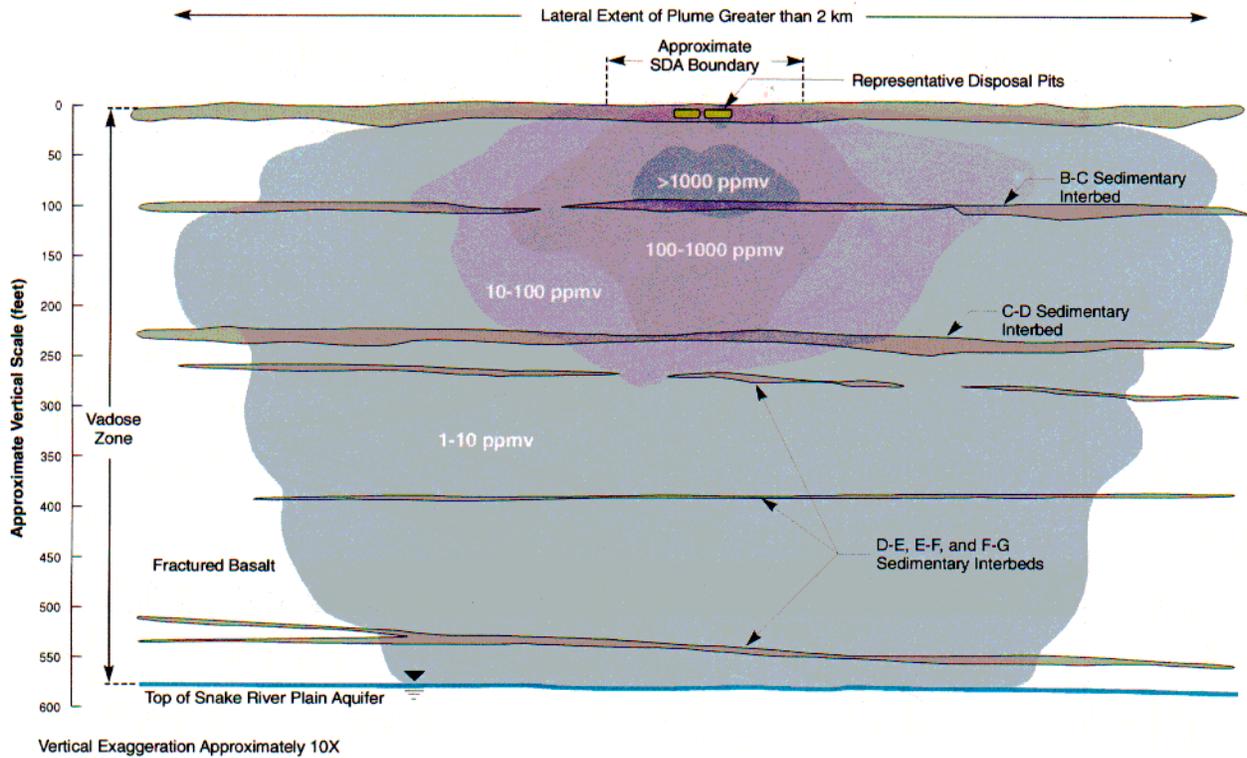


Figure 4-72. Conceptual drawing of the carbon tetrachloride soil gas plume prior to vapor vacuum extraction operations.

distance from the SDA. Carbon tetrachloride concentrations in wells only 250 m (820 ft) from the SDA boundary are approximately two orders of magnitude less than concentrations below source areas. Concentrations in the furthest wells from the SDA, OCVZ-11 and OCVZ-13, are less than 1 ppmv. Though Wells OCVZ-11 and OCVZ-13 were installed after 1996, it is improbable that the VVE system has influenced concentrations so far away.

Vertically, the  $\text{CCl}_4$  contamination extends from land surface down to the water table. Figure 4-73 shows a time-averaged vertical concentration profile of  $\text{CCl}_4$  prior to VVE operations for Wells 8801, 9301, and 9302, located near the center of the SDA. Concentrations increased with depth from near zero at land surface to several thousand ppmv above the B-C interbed. Concentrations decreased sharply across the B-C interbed down to several hundred ppmv. From just below the B-C interbed down to the C-D interbed, concentrations decreased from several hundred ppmv to a few hundred ppmv. Until recently, the concentrations below the C-D interbed inside the SDA were not known.

Figure 4-74 shows the soil gas concentration vertical profile for  $\text{CCl}_4$  in the V- and VVE-series wells. As expected, the concentrations decrease with distance away from the 743 sludge source areas. The highest concentration in the V-series wells inside the SDA is less than 600 ppmv, and in the VVE-series wells outside the SDA the highest concentration is less than 80 ppmv. In the wells furthest away from the 743 sludge source areas (9V, 10V, VVE1, VVE3, VVE4, VVE6, and VVE7), the highest concentrations are located below the B-C interbed and in some cases, below the C-D interbed. This is likely the result of lateral migration of contaminated soil gas after it has migrated below the B-C interbed under the pit source areas. Also, contaminated soil gas above the B-C interbed will dissipate more rapidly as it migrates laterally because of surface volatilization and barometric pumping.

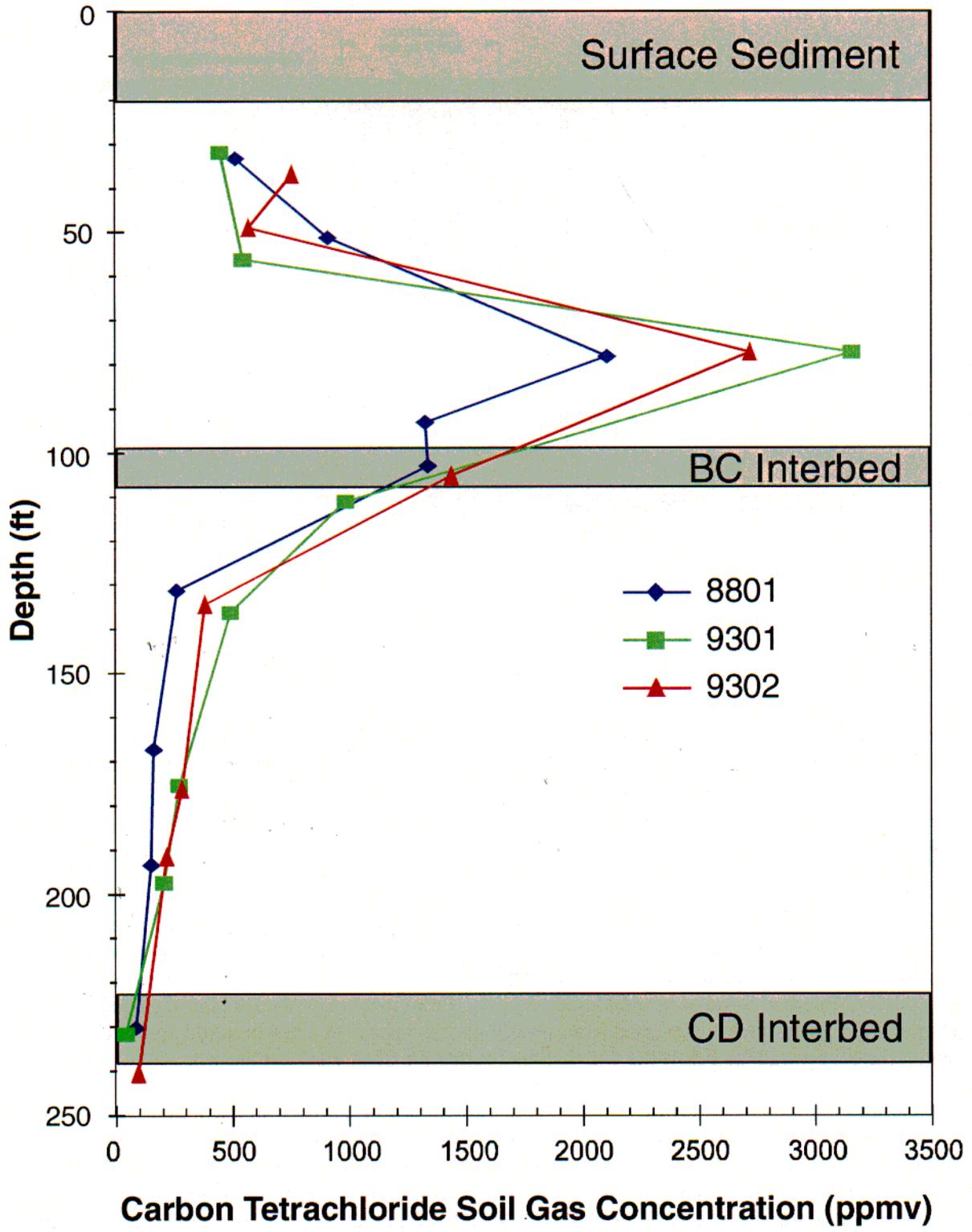


Figure 4-73. Profiles of carbon tetrachloride soil gas vertical concentrations for Wells 8801, 9301, and 9302, near the center of the Subsurface Disposal Area averaged over the period from April 1993 to October 1995, excluding data collected during the 1993 organic contamination in the vadose zone treatability study.

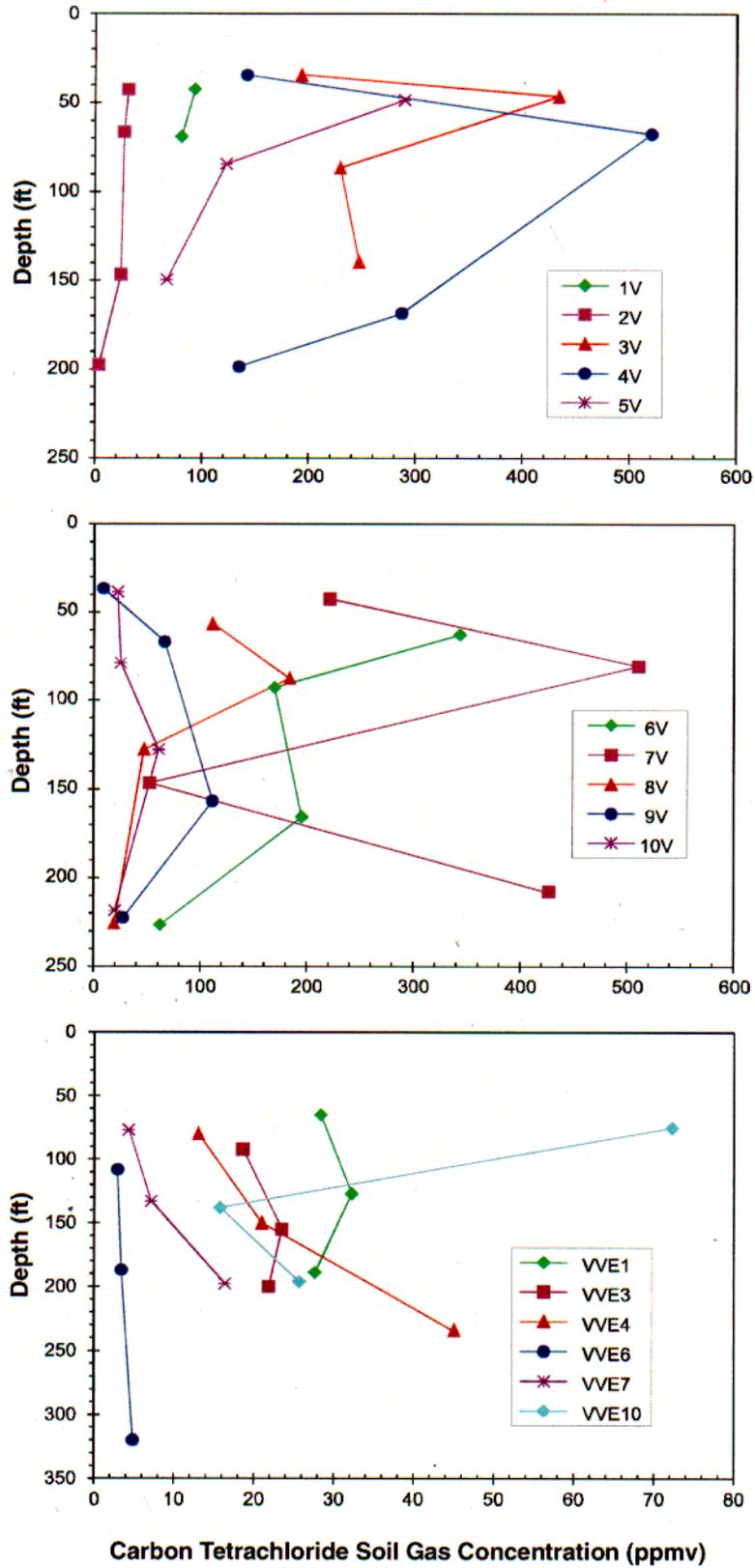


Figure 4-74. Profiles of carbon tetrachloride soil gas concentrations for V- and VVE-series wells averaged over the period from January 1995 to October 1995.

Since the startup of OCVZ operations in January 1996, soil gas concentrations have decreased markedly at many locations in response to the gas extraction. Figures 4-75 and 4-76 show the soil gas concentrations at two wells (8801 and 9301) near vapor extraction Well 8901D. Prior to 1996, the  $\text{CCl}_4$  concentration at the 21-m (70-ft) depth (above the B-C interbed) was approximately 3,000 ppmv in these two wells. After extraction began, the concentration dropped to about 1,000 ppmv. At about the 40-m (130-ft) depth below the B-C interbed, the concentration dropped from about 600 ppmv before VVE operations to 100 ppmv after operations. Concentrations in the deeper ports, around 70 m (230 ft), appear to be unchanged by operations. In Well 9V (Figure 4-77), the initial drop in concentration was not so dramatic, probably because it is located farther away from an extraction well, but the decrease has been steady nonetheless. Even the deep gas port at 68 m (223 ft) shows a clear decline in concentrations.

Results similar to those shown in Figures 4-75, 4-76, and 4-77 have been observed at many of the soil gas monitoring well locations inside the SDA. This is evident from looking at Figure 4-78, which compares the results of soil gas concentrations at the 21-m (70-ft) depth at the beginning of OCVZ operations (January 4, 1996) with those measured after more than five years of operations (April 3, 2001). The figures were created by kriging the data from all ports in three dimensions and then taking a horizontal slice at the 21-m (70-ft) depth. Kriging takes into account the spatial relationship of a series of points, permitting interpolation within a three-dimensional matrix of points and estimation of additional data points. The figure shows concentrations in 2001 to be significantly less than they were five years ago, especially in the center of the SDA. However, the results may be misleading in that the 2001 data do not reflect an equilibrium condition. In a classic soil gas removal system, the subsurface concentrations are reduced and held to low levels when the system is operating. After the system is shut down, the subsurface concentrations rebound (increase) to an equilibrium condition dependent upon several geologic and contaminant-specific factors. The time required for the organics in the vadose zone to achieve full rebound has not been determined. The VVE system was shut down for a nine-week rebound period during the summer of 2000, but the data indicate that full rebound may not have occurred because subsurface concentrations were still increasing at some locations. Though individual VOC treatment units have been shutdown for longer than nine weeks, all VVE units in the system must be shutdown to determine rebound.

One other potentially misleading aspect of Figure 4-78 is that it shows low concentrations in the area around Pit 9 before OCVZ operations and currently. While this may be the case, data pertaining to the vicinity of Pit 9 are lacking. Concentrations are expected to be higher than shown when adjusted to inventory records, but no specific data either support or refute this hypothesis.

**4.8.1.3.4 Perched Water Data**—Only a small set of perched water data exists for the SDA because of the lack of perched water wells and the infrequent development of perched water in the existing wells. Carbon tetrachloride and other VOCs have been detected in samples from Wells USGS-92, 8802D, and D10 located inside the SDA. Sample depths and  $\text{CCl}_4$  concentrations measured in perched water samples are shown in Table 4-130. The highest concentration (2,400  $\mu\text{g/L}$ ) was detected in Well USGS-92 in 1992. Prior to the commencement of OCVZ operations in 1996, concentrations in Well USGS-92 ranged from 1,200 to 2,400  $\mu\text{g/L}$ . Since OCVZ began operations, the concentrations have ranged between 14 and 291  $\mu\text{g/L}$ . Well USGS-92 is located near Well 7V, an OCVZ vapor extraction well. The time history of  $\text{CCl}_4$  concentrations in perched water in Wells USGS-92 and 8802D is shown in Figure 4-79.

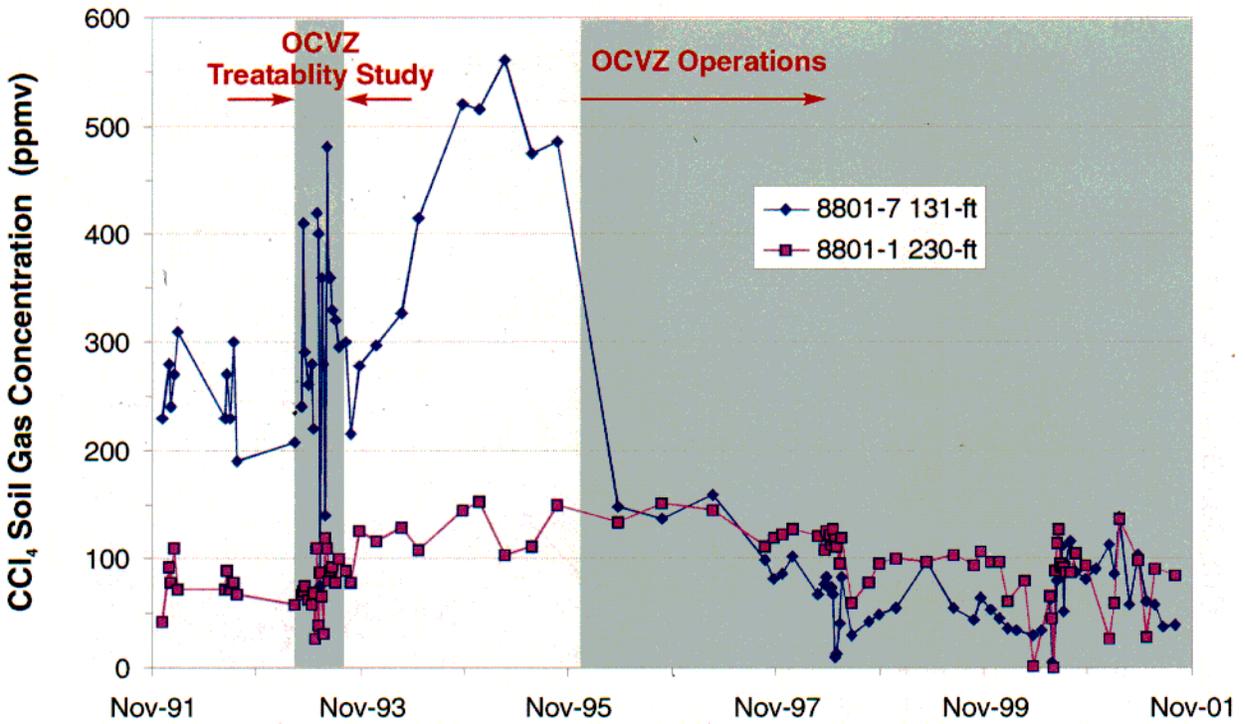
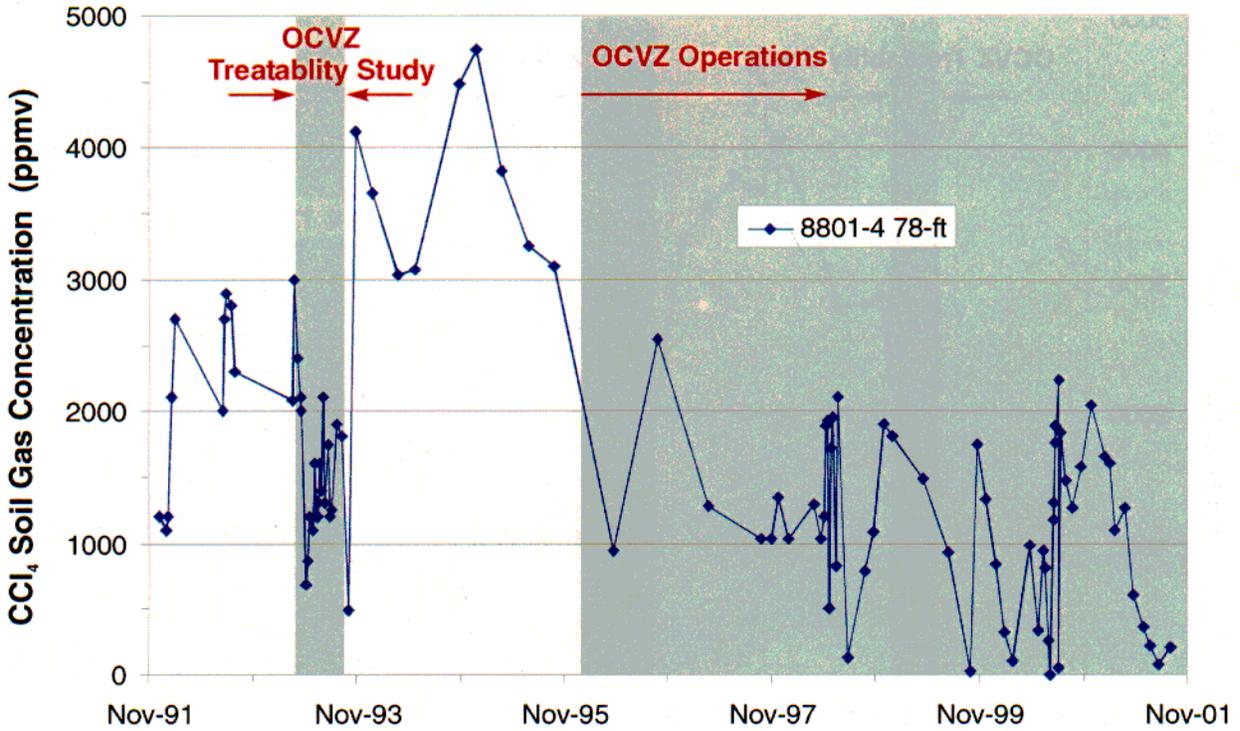


Figure 4-75. Carbon tetrachloride soil gas concentration time history for selected ports in Well 8801.

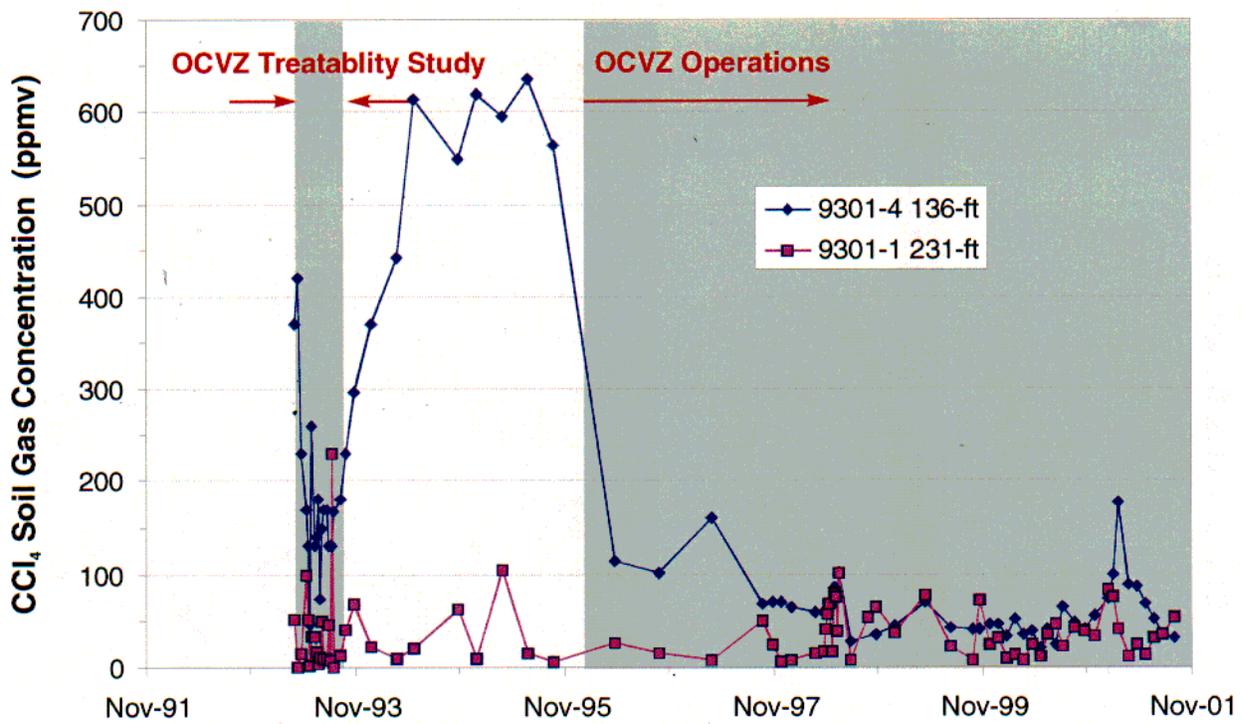
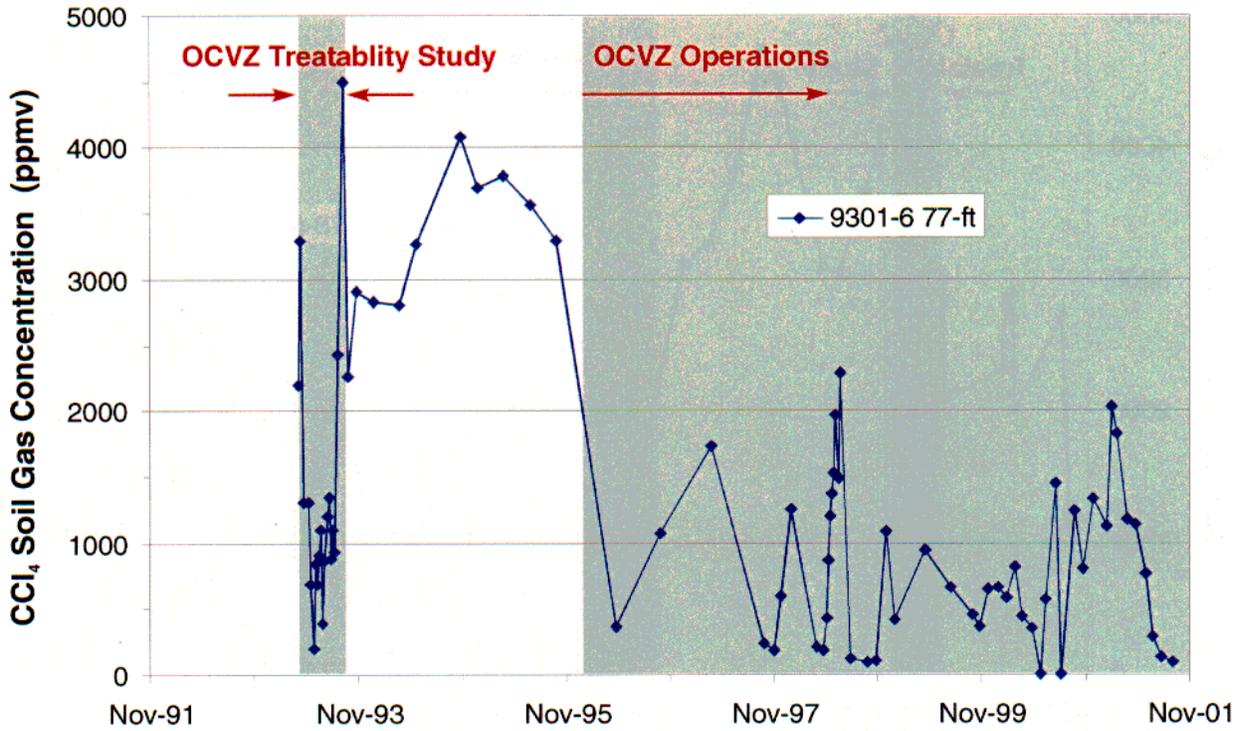


Figure 4-76. Carbon tetrachloride soil gas concentration time history for selected ports in Well 9301.

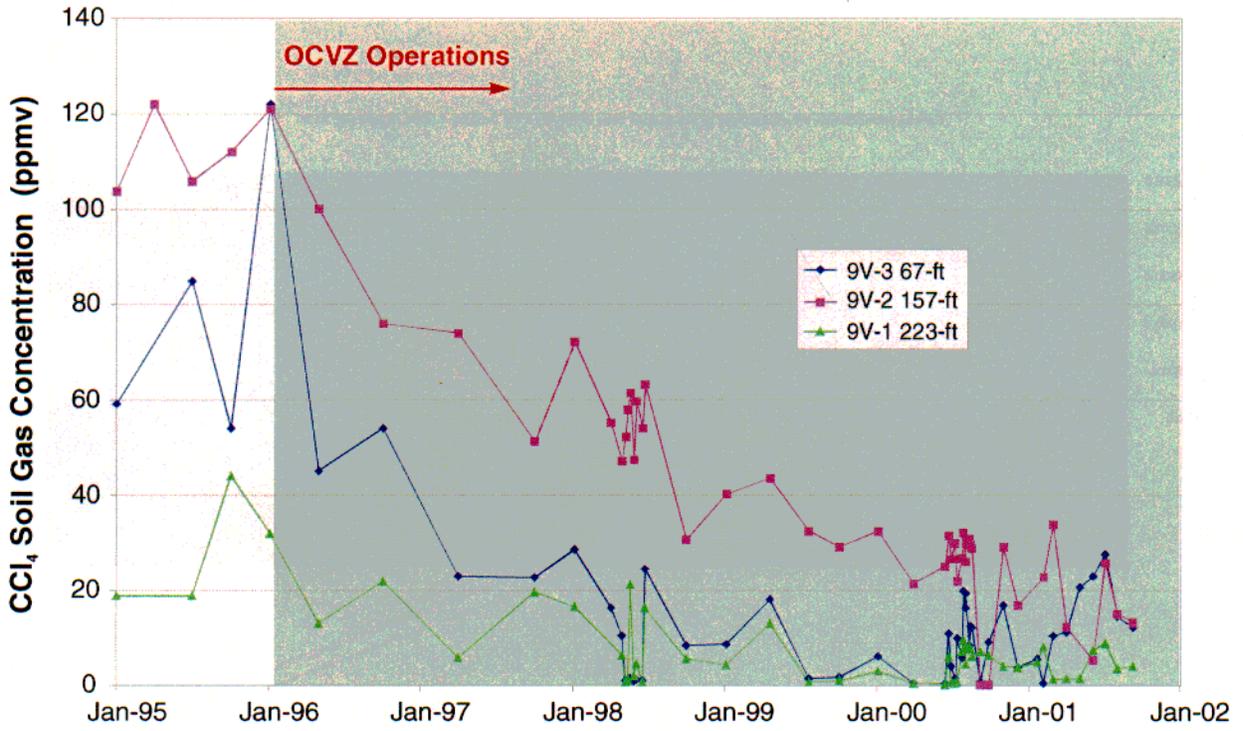
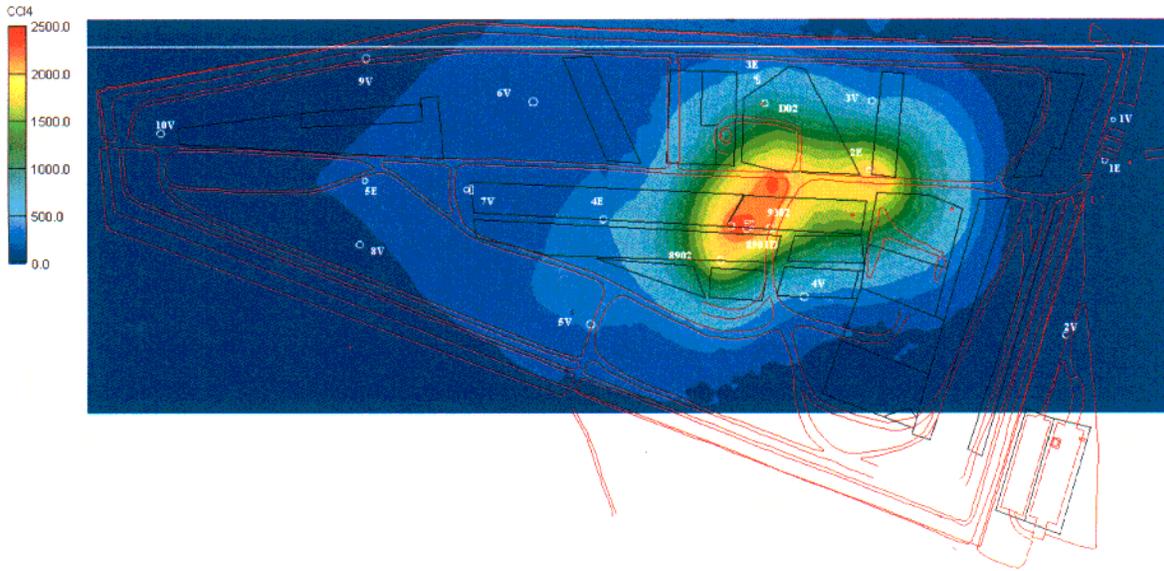


Figure 4-77. Carbon tetrachloride soil gas concentration time history for selected ports in Well 9V.

Carbon tetrachloride concentrations in the vadose zone at the SDA for January 4, 1996 in ppmv at 70 ft.



Carbon tetrachloride concentrations in the vadose zone at the SDA for April 3, 2001 in ppmv at 70 ft.

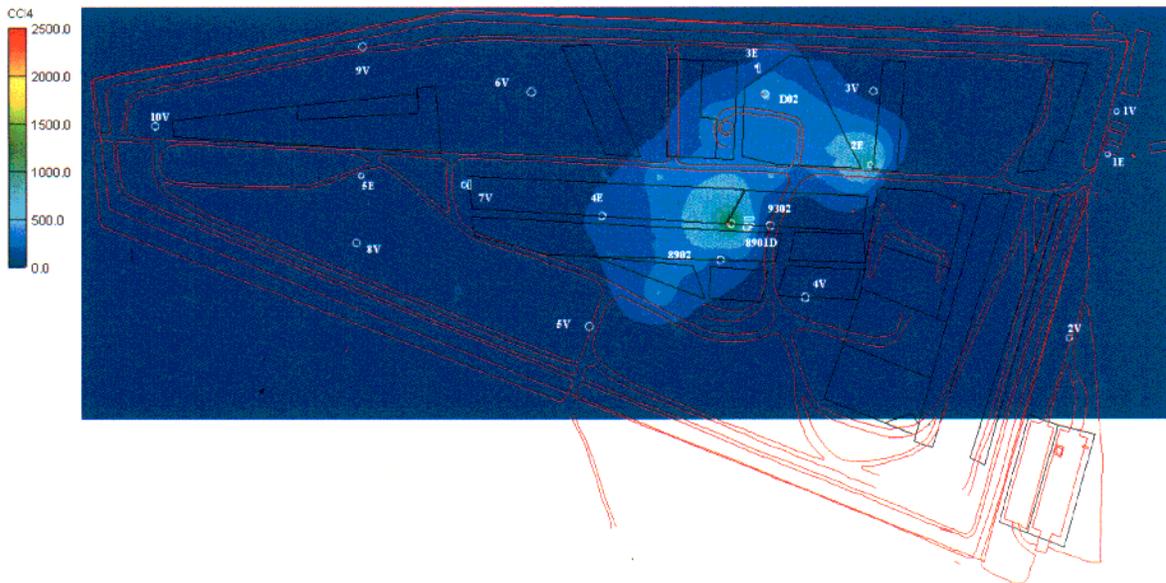


Figure 4-78. Comparison of initial carbon tetrachloride concentrations at the 21-m (70-ft) depth with concentrations after 5 years of vapor vacuum extraction.

Table 4-130. Carbon tetrachloride data for perched water samples in Wells USGS-92, 8802D, and D10 at the Subsurface Disposal Area.

Perched Water Well	Depth (ft)	Concentration ( $\mu\text{g/L}$ )	Date
USGS-92	214	1,200	October 1987
		1,400	April 1988
		2,400	April 1992
		2,100	October 1992
		20	April 1997
		100	August 1997
		31	February 1998
		260	March 1998
		14	March 1999
		291	April 2000
8802D	220	110	July 1989
		190	October 1992
		38	February 1998
D10	238	20	October 1992

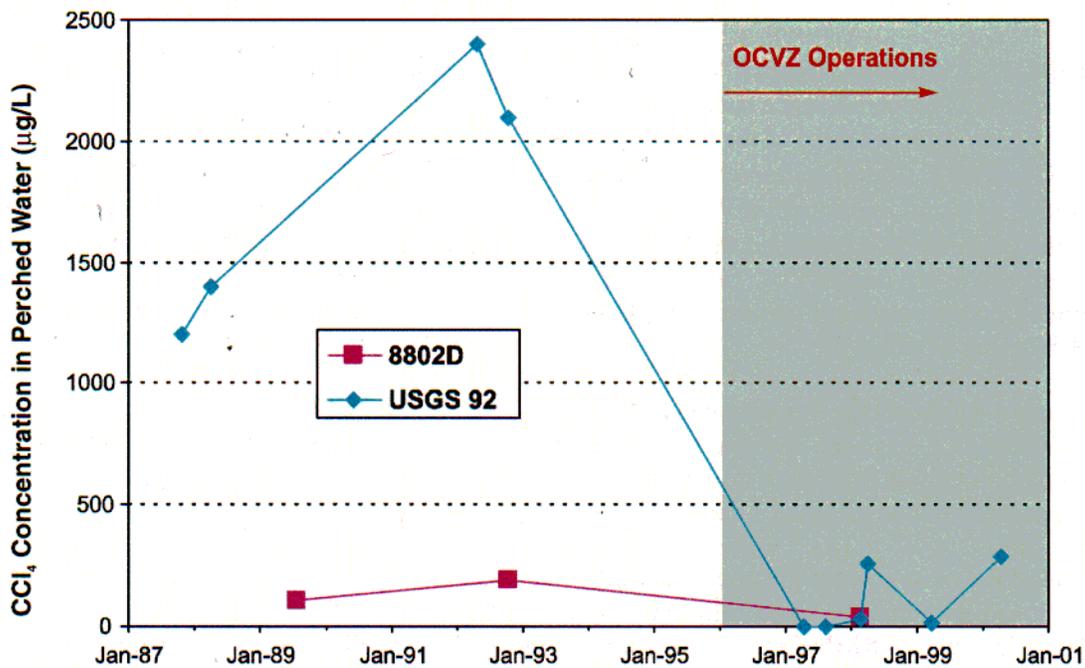


Figure 4-79. Carbon tetrachloride concentrations in perched water in Wells USGS-92 and 8802D.

**4.8.1.3.5 Lysimeter Data**—Carbon tetrachloride was detected in 11 of the 12 lysimeters sampled between 1997 and 2000 (not detected in 98-1L35). Maximum concentrations in each of the wells are shown in Table 4-131. The highest concentrations were detected in Wells PA01-L15, PA02-L16, and D06-DL02, which are near the north-central portion of the SDA at a depth of 4.4 m (14.3 ft), 2.7 m (8.7 ft), and 13.4 m (44 ft), respectively. Lysimeter locations are shown in Figures 4-8 and 4-9.

Table 4-131. Maximum carbon tetrachloride concentrations for the 11 lysimeters with carbon tetrachloride detections.

Lysimeter	Depth (ft)	Concentration ( $\mu\text{g/L}$ )	Date
D06-DL02	44	1,000	April 1997
PA01-L15	14.3	900	December 1998
PA02-L16	8.7	1,000	August 1997
98-5L39	10.5	1.9	August 1998
W05-L26	6.7	19	November 1998
W06-L27	11.8	30	August 1997
W08-L13	11.3	130	April 1997
W08-L14	6.2	73	April 1997
W23-L08	11.8	37	August 1998
W23-L09	7.7	30	August 1997
W25-L28	15.5	110	August 1997

**4.8.1.4 Aquifer.** The first VOC analyses for the aquifer beneath the INEEL were performed in 1987 as part of a reconnaissance survey by the USGS. Since that time, low levels of  $\text{CCl}_4$  have consistently been detected in 16 of the 24 aquifer wells in the vicinity of the SDA that are or have been monitored for VOCs. Concentrations range from nondetect (less than  $0.21 \mu\text{g/L}$ ) to a maximum concentration of  $8 \mu\text{g/L}$  measured in Well M7S during consecutive quarters in 1999. Concentrations in seven of the 24 wells have exceeded the MCL of  $5 \mu\text{g/L}$  at least once. Concentrations in five wells currently exceed or are near MCLs. Table 4-132 contains a summary of the  $\text{CCl}_4$  results as well as the maximum  $\text{CCl}_4$  concentrations measured in SDA-vicinity wells. Maximum concentrations are shown in Figure 4-80 using a bubble plot.

Figure 4-81 shows the transient behavior of  $\text{CCl}_4$  in 20 of the 24 SDA-vicinity aquifer wells. All of the wells where  $\text{CCl}_4$  has been detected are shown on the map with the exception of Wells M11S and M13S. Only one sample from each of those two wells has been above the detection limit and both were estimated concentrations assigned a data qualifier (J flag).

One of the most noteworthy and surprising features of the  $\text{CCl}_4$  distribution is the contrast in concentrations between wells close to the SDA and wells farther away from the SDA. All of the five wells shown in Figure 4-81 that are currently nondetect for  $\text{CCl}_4$  (Wells USGS-89, M1S, USGS-117, M4D, and USGS-119) are very close or relatively close to the SDA boundary. Furthermore, concentrations in Well M17S are also low despite being the only well inside the SDA and immediately below the strongest VOC source area. Conversely, some of the wells with the highest concentrations (Wells M7S, M16S, USGS-120, and A11A31) are located at considerably greater distances from the

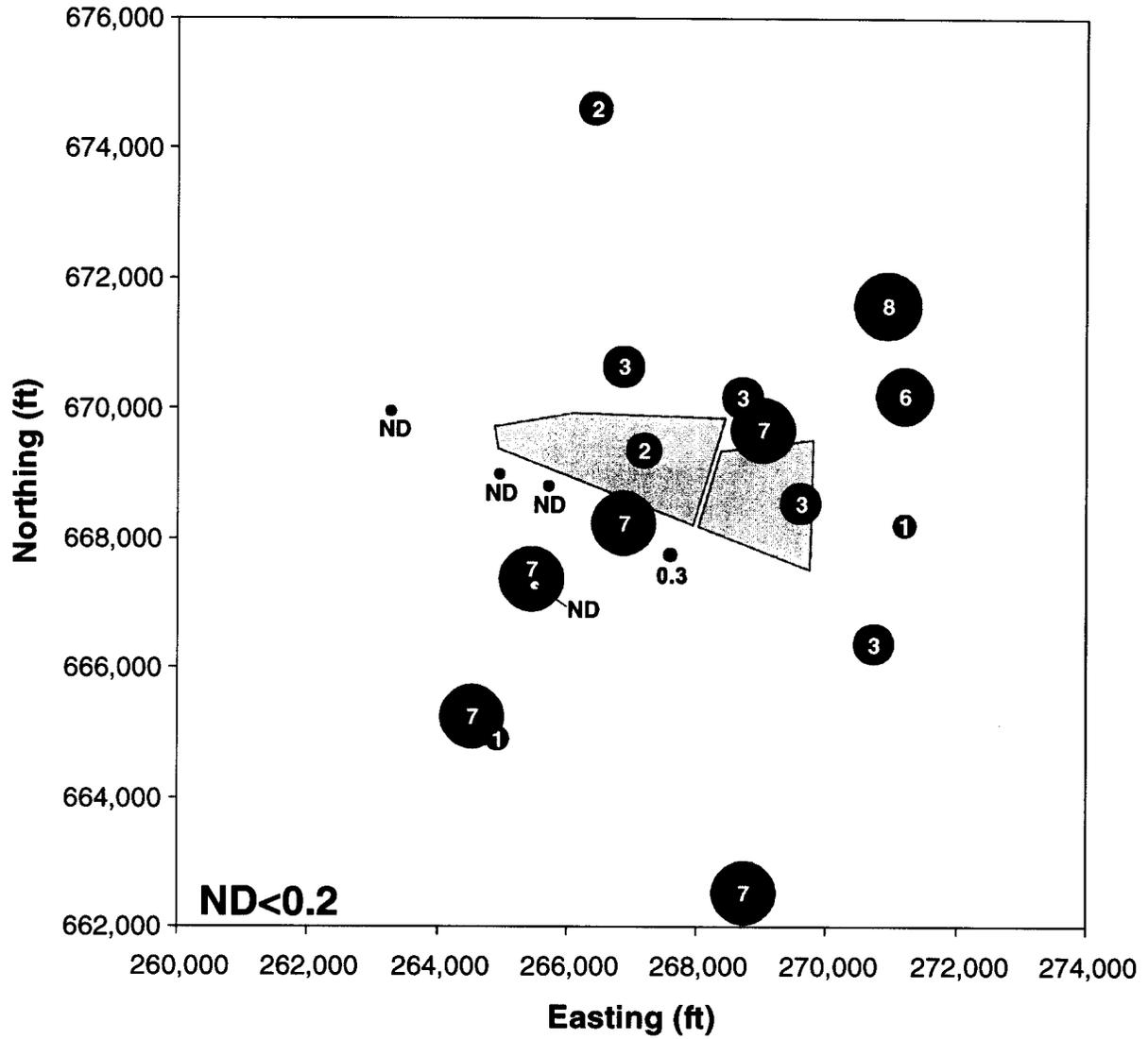


Figure 4-80. Bubble plot showing maximum carbon tetrachloride concentrations in aquifer in Subsurface Disposal Area vicinity monitoring wells.

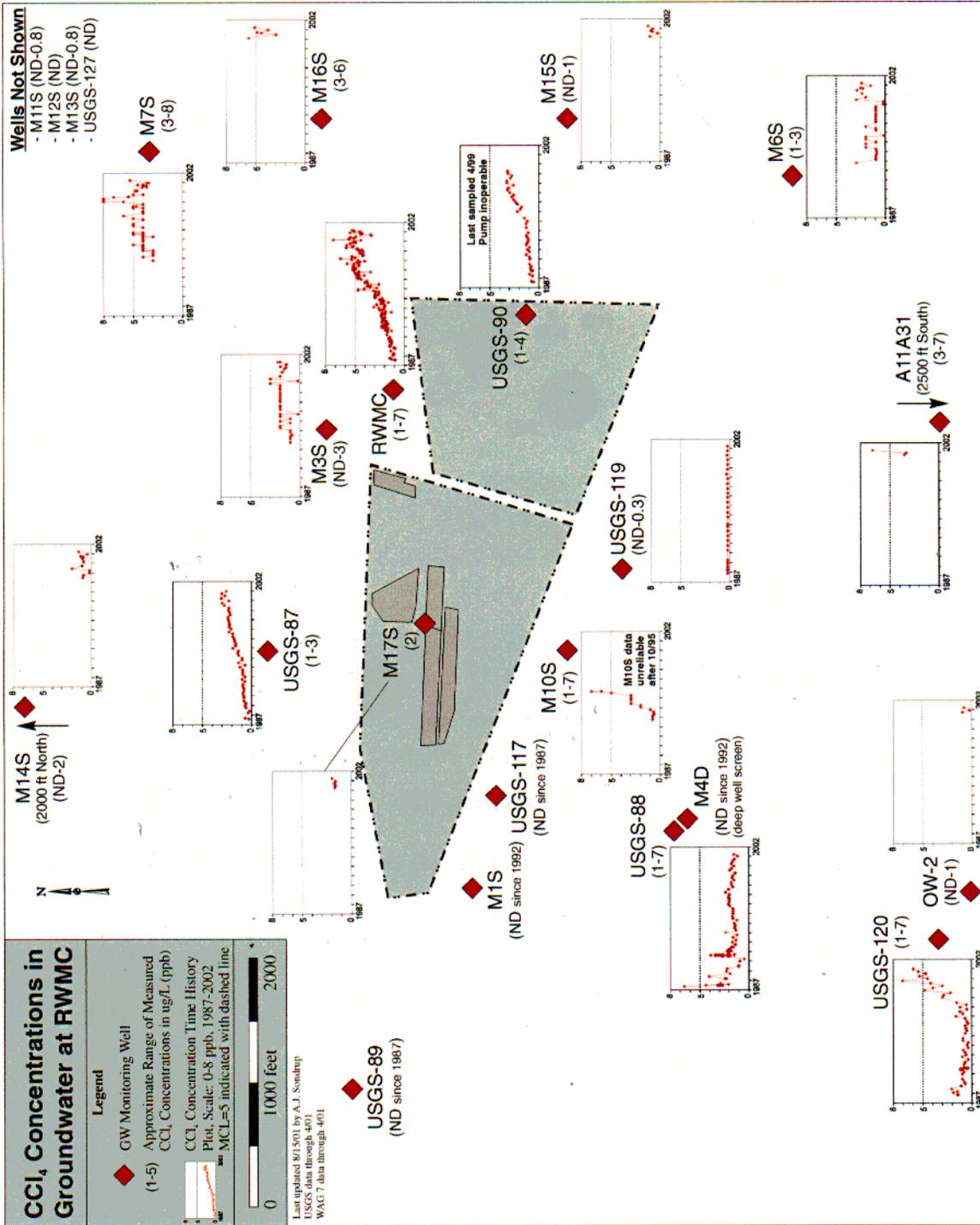


Figure 4-81. Carbon tetrachloride aquifer concentrations in monitoring wells in the vicinity of the Subsurface Disposal Area.

Table 4-132. Summary of carbon tetrachloride data from aquifer monitoring wells in the vicinity of the Subsurface Disposal Area.

Status of Wells (number of wells)	Well Names
Wells monitored for CCl <sub>4</sub> in vicinity of the Subsurface Disposal Area (24)	M1S, M3S, M4D, M6S, M7S, M10S, M11S, M12S, M13S, M14S, M15S, M16S, M17S, OW-2, A11A31, RWMC Production Well, and USGS-87, -88, -89, -90, -117, -119, -120, -127
Wells with positive detects for CCl <sub>4</sub> (15)	M3S, M6S, M7S, M10S, M14S, M15S, M16S, M17S, OW-2, A11A31, RWMC Production Well, and USGS-87, -88, -90, -120
Wells with nondetections for CCl <sub>4</sub> (9)	M1S, M4D, M11S <sup>a</sup> , M12S, M13S <sup>a</sup> , and USGS-89, -117, -119 <sup>a</sup> , -127
Wells with CCl <sub>4</sub> concentrations historically exceeding the MCL (7)	M7S, M10S, M16S, A11A31, RWMC Production Well, and USGS-88, -120,
Wells with CCl <sub>4</sub> concentrations currently exceeding the MCL (5)	M7S, M16S, A11A31, RWMC Production Well, and USGS-120,

a. Only one result per well above minimum detection limit (J flag)

SDA. In fact, of all the wells currently measuring concentrations above detection limit, Well A11A31 is the farthest from the SDA (approximately 1 mile) and yet has the highest current concentration (7 µg/L). The low concentration in many of the wells close to the SDA is probably because the wells are located in a low permeability zone. Otherwise, the concentration in wells near the SDA should be higher, based on vadose zone monitoring.

For wells with sufficient data to determine a trend, concentrations are either increasing or constant. Concentrations steadily increased for many years in Wells USGS-87, USGS-90, M3S, M7S, and the RWMC Production Well. However, the past few years show a relatively flat trend in concentration in these wells. These wells are to the north or east of the SDA. Other wells exhibiting flat concentration trends are Wells USGS-88, M6S, and M14S. Concentrations in Well USGS-120 were flat for several years until they recently began to increase rather dramatically. In terms of historic increases, the rise in concentration in Well M10S is possibly the most remarkable, increasing from 1 to 7 µg/L in a period of two years from 1993 to 1995. Concentrations measured for several years after 1995 in Well M10S were below the detection limit, but the data are not reliable because steel tapes were dropped in the well in late 1995 and 1998. Iron from the disintegrating tapes may have acted as a catalyst in degrading CCl<sub>4</sub>, thus, diminishing the concentrations. Concentrations in the other wells (M15S, M16S, M17S, OW-2, and A11A31) appear to be steady, but the period of data collection is insufficient for making such a determination.

#### 4.8.2 Tetrachloroethylene

Tetrachloroethylene is a manufactured chemical that is widely used for dry cleaning of fabrics and for metal degreasing. Like CCl<sub>4</sub>, PCE can exist as a non-aqueous phase liquid, a vapor phase in the soil gas, an aqueous phase dissolved in soil water, and a solid phase sorbed onto soil particles. Tetrachloroethylene does not occur naturally in the environment; therefore, the true background concentration in any medium should be zero.

Tetrachloroethylene has been detected at the SDA in surficial sediments, vadose zone soil gas, vadose zone soil water (perched water and lysimeters), and groundwater. Tetrachloroethylene vapor has also been detected emanating from the soil surface by surface isolation flux chambers. The primary source of PCE at the SDA is 743-series waste. An examination of PCE contaminant data shows the distribution and trends are similar to CCl<sub>4</sub> data, but PCE concentrations are much less as a result of the smaller inventory. The distribution and trends are similar because both contaminants come from the same waste stream and because they have similar chemical and transport properties. The two contaminants are also similar from a toxicological standpoint. Because of these similarities, and because CCl<sub>4</sub> data are described extensively in Section 4.8.1, this section is a limited presentation of PCE data.

**4.8.2.1 Waste Zone.** Approximately 9.8E+04 kg of PCE has been buried in the SDA (Table 4-133). Varvel (2001) calculated the amount of PCE in 743-series waste by assuming the non-CCl<sub>4</sub> fraction of volatile organic compounds reported by Miller and Varvel (2001) contained equal volumes of PCE, TCE, and 1,1,1-TCA. The 743-series waste was buried in Pits 4, 5, 6, 9, and 10 (see Figure 4-67).

Table 4-133. Waste streams containing tetrachloroethylene.

Waste Stream Code	Waste Stream Description	Mass (kg)	Proportion of Total Mass (%)
RFO-DOW-15H	Organic sludge	9.8E+04	100.0
<b>Total Disposals</b>		9.8E+04	100

**4.8.2.2 Vadose Zone.** Tetrachloroethylene has been detected in vadose zone soil gas, and in perched water and lysimeter samples. The PCE results are consistent with the CCl<sub>4</sub> results in that they are generally less than the CCl<sub>4</sub> results by the ratio of the inventories. The PCE inventory is approximately an order of magnitude less than the CCl<sub>4</sub> inventory and the PCE sample results are less than the CCl<sub>4</sub> results by about the same margin. As a result, many of the PCE sample results are less than detection limits in areas where the CCl<sub>4</sub> concentrations are low.

**4.8.2.2.1 Soil Gas Data—**Tetrachloroethylene has been detected in the soil gas from land surface to the aquifer. The maximum PCE soil gas concentration measured inside the SDA is 135 ppmv in Well 8902 Port 4 at a depth of 39 m (130 ft) on January 4, 1996. This compares to a maximum CCl<sub>4</sub> soil gas concentration of 4,864 ppmv in Well 9302 Port 6 at a depth of 23 m (77 ft). Since April 1998, the PCE concentrations in Well 8902 Port 4 have been less than 10 ppmv. The reduction in concentration is attributed to operation of the OCVZ remediation system. Concentrations at other wells inside the SDA are generally less than 20 ppmv. Inside the SDA below the C-D interbed, concentrations are less than 2 ppmv. This, however, is based on data from one location because the only soil gas sampling wells inside the SDA with sampling ports below the C-D interbed are Wells DE-1 and M17S, and they are very near each other.

The highest PCE concentration measured in soil gas outside the SDA is 75 ppmv in Well 77-1 Port 2 at a depth of 58 m (190 ft). Concentrations in this port are currently less than 30 ppmv. Outside the SDA below the C-D interbed, the maximum PCE concentration measured is 2.98 ppmv in Well 78-4 Port 2 at a depth of 76 m (251 ft). By far the majority of sample results in this region are less than 1 ppmv.

**4.8.2.2.2 Perched Water Data—**Tetrachloroethylene has been detected in perched water samples from Wells USGS-92, 8802D, and D10 located inside the SDA. The highest concentration, 230 µg/L, was detected in Well USGS-92 in 1989. For comparison, the maximum CCl<sub>4</sub> concentration was

2,400 µg/L measured in the same sample. The maximum PCE concentration is less than CCl<sub>4</sub> by about one order of magnitude.

Like CCl<sub>4</sub>, PCE concentrations in perched water have decreased in response to operation of the OCVZ remediation system. This can be seen in Table 4-134, which contains PCE concentrations measured in perched water over time. Before OCVZ operations began in 1996, PCE concentrations in Well USGS-92 ranged from 110 to 230 µg/L. Results from the last four samples taken from February 1998 to April 2000 have been less than or equal to 50 µg/L. Well 7V, an OCVZ vapor extraction well, is located near Well USGS-92.

Table 4-134. Tetrachloroethylene data for perched water samples at the Subsurface Disposal Area.

Perched Water Well	Depth (ft)	Concentration (µg/L)	Date
USGS-92	214	110	October 1987
		120	April 1988
		230	August 1989
		180	April 1992
		110	April 1997
		26	April 1997
		81	August 1997
		5.4	February 1998
		50	March 1998
		23	March 1999
		43	April 2000
8802D	220	7	July 1989
		13	October 1992
		2.6	February 1998
D10	238	4.5	October 1992

**4.8.2.2.3 Lysimeter Data**—Tetrachloroethylene was detected in six of the 12 lysimeters sampled between 1997 and 2000. Lysimeters with positive detections include Wells W23-L08, W23-L09, W25-L28, DO6-DL02, PA01-L15, and PA02-L16. The maximum PCE concentration measured was 27 µg/L at Well W23-L08 at a depth of 3 m (11 ft) on August 3, 1998. For comparison, the maximum CCl<sub>4</sub> concentration in a lysimeter was 1,000 µg/L in Wells D06-DL02 and PA02-L16. Lysimeter locations are shown in Figures 4-8 and 4-9.

**4.8.2.3 Aquifer.** Positive detections of PCE in SDA-vicinity aquifer wells are infrequent. The maximum PCE concentration measured was 0.4 µg/L in Well M7S on five different occasions from 1993 to 1996. This is well below the MCL of 5 µg/L. For comparison, the maximum CCl<sub>4</sub> concentration measured was 8 µg/L also in Well M7S. Again, the PCE results for groundwater are less than the CCl<sub>4</sub> results by approximately an order of magnitude.

**4.8.3 Methylene Chloride**

Methylene chloride (dichloromethane) is an ingredient in many industrial compounds including solvents, paint and varnish removers, degreasing agents for metal parts, aerosols, refrigerants, and also is used as a blowing agent in foams. Methylene chloride contamination can exist in various forms including a non-aqueous phase liquid, a vapor phase in the soil gas, an aqueous phase dissolved in soil water, and a solid phase sorbed onto soil particles. Methylene chloride does not occur naturally in the environment; therefore, the true background concentration in any medium should be zero.

**4.8.3.1 Waste Zone.** About 1.41E+04 kg of methylene chloride was disposed of in the SDA (Table 4-135). Information about the methylene chloride disposal record is scant compared to that for CCl<sub>4</sub>, the most prevalent VOC. It should be noted that CCl<sub>4</sub> can degrade to methylene chloride, thus, considering the large mass of CCl<sub>4</sub> buried in the SDA, detections of methylene chloride in samples may not necessarily be related to the original inventory disposed of in the SDA.

Table 4-135. Waste streams containing methylene chloride.

Waste Stream Code	Waste Stream Description	Mass (kg)	Proportion of Total Mass (%)
RFO-DOW-3H	Sludge	7.16E+03	51.2
RFO-DOW-4H	Paper, rags, and plastic	2.84E+03	20.3
RFO-DOW-9H	Trash	2.56E+03	18.3
RFO-DOW-12H	Dirt, concrete, ash, and soot	1.30E+03	9.3
Miscellaneous	Miscellaneous	1.40E+02	1.0
<b>Total Disposals</b>		<b>1.40E+04</b>	<b>100</b>

**4.8.3.2 Surface.** Methylene chloride is not analyzed as part of the INEEL's routine surface monitoring program.

**4.8.3.3 Vadose Zone.** Methylene chloride has been detected at low levels in the vadose zone. This section discusses the vadose zone sample results including: (a) soil gas data, (b) perched water data, and (c) lysimeter data.

**4.8.3.3.1 Soil Gas Data**—Several hundred soil gas samples have been collected and analyzed for methylene chloride; only five have returned positive detections. One of the samples was collected from Well TEM1-A in April 1993 at a depth of 0.61 m (2 ft). The other four samples were all collected from Well 8801 in September 1991. Two of the samples from Well 8801 were collected from Port 4 at a depth of 23.6 m (77.5 ft), and the other two samples were collected from Port 5 at a depth of 28.2 m (92.5 ft). Though the samples from Well 8801 were reported as positive detects, they should be viewed with caution because of high dilution factors. A summary of these results can be found in Table 4-136.

Table 4-136. Summary of positive detections of methylene chloride in soil gas samples collected near the Subsurface Disposal Area.

Well Name- Port	Sample Depth	Soil Gas Concentration (ppmv)	Dilution Factor <sup>a</sup>	Date
TEM1A	2 ft	2	2	April 1993
8801-4	77.5 ft	70	400	September 1991
		184	400	September 1991
8801-4	92.5 ft	15	100	September 1991
		57	200	September 1991

a. Concentrations are adjusted for dilution factors. High dilution factors increase uncertainty in reported concentrations.

**4.8.3.3.2 Perched Water Data**—Three perched water samples have been collected from Well USGS-92, and one sample from Well 8802D, and analyzed for methylene chloride. The USGS-92 samples were collected on April and August in 1997 and February 1998. The April 1997 sample provided a statistically positive result for methylene chloride of 23 µg/L. The other two samples did not yield positive detections. The sample from Well 8802D was collected in February 1998, and was not statistically positive.

**4.8.3.3.3 Lysimeter Data**—Thirty-four lysimeter samples have been collected from Lysimeter Wells PA01-L15, PA02-L16, 98-1L35, 98-5L39, W05-L26, W08-L13, W08-L14, W23-L08, W23-L09, W25-L28, and D06-DL02 and subsequently analyzed for methylene chloride. The only sample to produce a statistically positive result for methylene chloride (6.8 µg/L) was collected from Lysimeter Well PA01-L15 on August 3, 1998. Lysimeter locations are shown in Figures 4-8 and 4-9.

**4.8.3.4 Aquifer.** Methylene chloride has been detected in 13 aquifer wells in the vicinity of the SDA that are or have been monitored for VOCs including USGS wells. Concentrations range from nondetect (less than 0.21 µg/L) to a maximum concentration of 8 µg/L measured in Well M10S, collected on July 22, 1996. The MCL is 5 µg/L, and the risk-based water concentration is 7 µg/L. Table 4-137 contains a summary of the positive detections of methylene chloride. A large majority of the detections occurred during the same sampling round (July 1996), which raises the question whether the samples were cross-contaminated before or during analysis. Methylene chloride has not been detected in any aquifer wells since October 1997.

Table 4-137. Summary of positive detections for methylene chloride in aquifer samples.

Aquifer Well	Concentration (µg/L)	Dilution Factor	Date
M1SA	6	1	February 1993
M1SA	5	1	October 1997
M3S	7	1	July 1996
M4D	5	1	July 1996
M6S	5	1	July 1996
M7S	5	1	July 1996
M10S	8	1	July 1996

## 4.9 Contaminants of Ecological Concern

Fifty-nine WAG 7 contaminants of ecological concern were identified in the preliminary ecological contaminant screening (Section 3.4.2). Of those, 13 are also contaminants of concern to human health. Ecological risk assessments conducted at the INEEL are based on the evaluation and interpretation of the nature and extent of contaminants conducted for human health (VanHorn, Hampton, and Morris 1995). No WAG 7 samples have been collected and analyzed to specifically address ecological receptors, and sampling data were not analyzed in terms of nature and extent for individual ecological receptors (e.g., compared to ecologically based screening levels). However, INEEL sampling results and results from the Environmental Science and Research Foundation and the Radiological and Environmental Sciences Laboratory, were used to confirm the transport of contaminants from subsurface to surface soil, to locations outside the SDA, and into the food web. The data were also used to identify and substantiate the need for analyzing particular pathways of exposure.

Most surface and subsurface soil data were collected prior to re-contouring and alterations in the overburden thickness on the SDA (Becker et al. 1998). More recent soil sampling activities at the SDA have been limited. In addition, composite samples were generally collected for vegetation and tissue, and sampling locations are poorly documented. Collocated samples were not collected for all media (e.g., both vegetation and soil), so exposure factors and concentrations cannot be reconstructed from sampling results. Therefore, the DOSTOMAN model was used to generate concentrations across the SDA to allow evaluation of receptors in terms of a population-level exposure. The model incorporates subsurface to surface transport by plant root uptake and animal intrusion (see Section 5.4) and the sampling data are used as weight-of-evidence in the ecological risk assessment (ERA) (see Section 6.6). Only soil and food ingestion pathways were evaluated. No pathways to groundwater were identified for ecological receptors (see Section 6.6).

### 4.9.1 Radionuclides of Ecological Concern

Twelve radionuclide COPCs were identified in the preliminary contaminant screening (see Section 3.4.2) (see Table 4-138). Information about how and where biotic soil samples were collected is summarized in Sections 4.2 and 4.3. Results for individual COPCs are presented in the subsections designated in Table 4-139. Both surface and subsurface soil and biotic sampling conducted at the RWMC are discussed in each section.

In addition, sampling and analysis of soil, vegetation, and animal tissue have been conducted in and around the SDA by the Radiological and Environmental Sciences Laboratory (Peterson, Brewer, and Morris 1995) and the Environmental Science and Research Foundation. A summary of sampling results is given in Table 4-139.

Table 4-138. Cross-references to nature and extent sections for radionuclide ecological contaminants of potential concern.

Contaminant of Potential Concern	Report Subsection
Am-241	(Section 4.6.2)
Am-243 <sup>a</sup>	Not applicable
Cm-244 <sup>a</sup>	Not applicable
Cs-137	(Section 4.6.6)
Nb-94	(Section 4.6.9)
Pu-238	(Section 4.6.13)
Pu-239/240	(Section 4.6.13)
Pu-242 <sup>a</sup>	Not applicable
Sr-90	(Section 4.6.17)
U-234	(Section 4.6.19)
U-238	(Section 4.6.19)

a. This contaminant is not a human health contaminant of potential concern.

Table 4-139. Summary of radionuclide data collected in and around the Subsurface Disposal Area by the Radiological and Environmental Sciences Laboratory.

Contaminant of Potential Concern	Medium Concentration <sup>a</sup> (pCi/g)		
	Soil ≤ 10 cm Depth <sup>b</sup>	Vegetation <sup>f</sup>	Tissue (organism) <sup>g</sup>
Am-241	Not detected to 300 <sup>c</sup> Not detected to 51 <sup>d</sup>	0.003 to 5.1 <sup>c</sup>	Not detected to 38 <sup>c</sup> (mammals) Not detected to 270 <sup>d</sup> (mammals) 0.022 ± 0.020 <sup>c,h</sup> (invertebrates)
Am-243 <sup>e</sup>	Not applicable	Not applicable	Not applicable
Cs-137	Not detected to 2.0 <sup>c</sup> Not detected to 16 <sup>d</sup>	Not detected to 57 <sup>c</sup>	Not detected to 6200 <sup>c</sup> (mammals) Not detected to 130 <sup>d</sup> (mammals) Not detected to 4.0 <sup>c</sup> (birds) 0.32 ± 0.21 <sup>c,h</sup> (snake) 0.46 ± 0.54 <sup>c,h</sup> (invertebrates)
Cm-244 <sup>e</sup>	Not applicable	Not applicable	Not applicable
Nb-94 <sup>e</sup>	Not applicable	Not applicable	Not applicable
Pu-238	Not detected to 1.4 <sup>c</sup> Not detected to 2.6 <sup>d</sup>	Not detected to 0.057 <sup>d</sup>	Not detected to 8.9 <sup>c</sup> (mammals) Not detected to 41 <sup>d</sup> (mammals) 0.0081 ± 0.011 <sup>c,h</sup> (invertebrates)
Pu-239/240	Not detected to 54 <sup>c</sup> Not detected to 38 <sup>d</sup>	0.002 to 1.9 <sup>d</sup>	Not detected to 3.0 <sup>c</sup> (mammals) Not detected to 5.7 <sup>d</sup> (mammals) 0.078 ± 0.11 <sup>c,h</sup> (invertebrates)
Pu-242 <sup>e</sup>	Not applicable	Not applicable	Not applicable
Sr-90	Not detected to 4.6 <sup>c</sup> Not detected to 26 <sup>d</sup>	Not detected to 160 <sup>d</sup>	Not detected to 3500 <sup>c</sup> (mammals) 2.4 ± 3.2 <sup>c,h</sup> (invertebrates)

Table 4-139. (continued).

Contaminant of Potential Concern	Medium Concentration <sup>a</sup> (pCi/g)		
	Soil ≤ 10 cm Depth <sup>b</sup>	Vegetation <sup>f</sup>	Tissue (organism) <sup>g</sup>
U-234 <sup>e</sup>	Not applicable	Not applicable	Not applicable
U-238 <sup>e</sup>	Not applicable	Not applicable	Not applicable

a. Data reported in Peterson, Brewer, and Morris (1995).

b. Samples were collected at various locations at and near the Subsurface Disposal Area (SDA) between 1972 and 1985.

c. The range encompasses concentrations for all samples collected at the SDA.

d. The range encompasses concentrations for all samples collected at and beyond the SDA perimeter.

e. No samples have been collected and analyzed for this contaminant of potential concern.

f. Samples were collected at various locations at and near the SDA between 1976 and 1982.

g. Samples were collected at various locations at and near the SDA between 1978 and 1987.

h. Concentration does not meet the 3σ criterion for a positive detection (see Section 4.5.2).

#### 4.9.2 Inorganics of Ecological Concern

Twenty-two inorganic COPCs were identified in the ecological screening (Hampton and Becker 2000) (Table 4-140). Soil samples have been collected on the SDA and analyzed for cadmium, copper, lead, manganese, mercury, and nitrates (Table 4-140). Soil samples have also been collected and analyzed for cadmium, copper, lead, and mercury (Table 4-140) as part of routine monitoring and special investigations conducted on the SDA by the Environmental Monitoring Group (LMITCO 1995a, Appendix F).

Table 4-140. Inorganics of ecological concern and soil sample analyses.

Contaminants of Potential Concern	Waste Area Group 7 <sup>a</sup>		Environmental Monitoring <sup>b</sup>	
	Number of Detects/ Number of Samples	Range (mg/kg)	Number of Samples	Range (mg/kg)
Aluminum nitrate	Not applicable	Not applicable	Not applicable	Not applicable
Asbestos	Not applicable	Not applicable	Not applicable	Not applicable
Beryllium oxide	Not applicable	Not applicable	Not applicable	Not applicable
<b>Cadmium</b>	25/79	0.7 to 2.3	NR	1.9 to 2.7
<b>Copper (total)</b>	71/79	9.6 to 34.6	NR	6.9
<b>Lead</b>	71/79	0.84 to 26	NR	8.8
Lithium hydride	Not applicable	Not applicable	Not applicable	Not applicable
Lithium oxide	Not applicable	Not applicable	Not applicable	Not applicable
<b>Manganese</b>	66/79	164 to 869	Not applicable	Not applicable
Magnesium oxide	Not applicable	Not applicable	Not applicable	Not applicable
<b>Mercury (total)</b>	6/88	0.11–14.3	Not reported	1.40–5,320 <sup>c</sup>
<b>Nitrates</b>	see Section 4.7.1		Not applicable	Not applicable
Potassium chloride	Not applicable	Not applicable	Not applicable	Not applicable
Potassium hydroxide	Not applicable	Not applicable	Not applicable	Not applicable
Potassium nitrate	Not applicable	Not applicable	Not applicable	Not applicable
Potassium phosphate	Not applicable	Not applicable	Not applicable	Not applicable
Potassium sulfate	Not applicable	Not applicable	Not applicable	Not applicable
Sodium chloride	Not applicable	Not applicable	Not applicable	Not applicable
Sodium cyanide	Not applicable	Not applicable	Not applicable	Not applicable

Table 4-140. (continued).

Contaminants of Potential Concern	Waste Area Group 7 <sup>a</sup>		Environmental Monitoring <sup>b</sup>	
	Number of Detects/ Number of Samples	Range (mg/kg)	Number of Samples	Range (mg/kg)
Sodium nitrate	Not applicable	Not applicable	Not applicable	Not applicable
Sodium phosphate	Not applicable	Not applicable	Not applicable	Not applicable
Sodium-potassium	Not applicable	Not applicable	Not applicable	Not applicable

Note: Bolded text indicates contaminants for which soil samples have been collected and analyzed.

a. Data are contained in INEEL monitoring databases.

b. Sample analysis data were obtained from LMITCO (1995, Appendix F).

c. Detection resulted from breach of a disposal unit during drilling operations.

### 4.9.3 Organics of Ecological Concern

Twenty organic COPCs were identified in the preliminary ecological contaminant screening (Hampton and Becker 2000). No routine data for these COPCs have been collected. Most surface soil samples have been collected from areas near the Acid Pit and Pad A, and analyzed for seven of the twenty COPCs (shown in bold in Table 4-141). Sampling results for carbon tetrachloride and methylene chloride are presented in detail in Sections 4.8.1 and 4.8.2.

Table 4-141. Summary of organics of ecological concern and Waste Area Group 7 soil sample analyses.

Contaminants of Potential Concern	Number of Detections/ Number of Samples	Range (mg/kg)
1,1,2-trichloro-1,2,2-trifluoroethane	Not applicable	Not applicable
3-methylcholanthrene	Not applicable	Not applicable
Alcohols	Not applicable	Not applicable
<b>Carbon tetrachloride</b> (see Section 4.8.1)	3/103	6 to -11
<b>Chloroform</b>	3/103	6 to -39
Dibutylethylcarbutol	Not applicable	Not applicable
Ether	Not applicable	Not applicable
Ethyl alcohol	Not applicable	Not applicable
Hydrofluoric acid	Not applicable	Not applicable
<b>Methylene chloride</b> (see Section 4.8.2)	60/103	7 to -139
<b>Nitrobenzene</b>	0/68	Not applicable
Nitric acid	Not applicable	Not applicable
<b>Organophosphates (tributylphosphate)</b>	1/68	590
Organic acids (ascorbic acid)	Not applicable	Not applicable
Sulfuric acid	Not applicable	Not applicable
Tetrachloroethylene	Not applicable	Not applicable
Trimethylpropane-triester	Not applicable	Not applicable
<b>Toluene</b>	2/103	23 to -28
Versenes (EDTA)	Not applicable	Not applicable
<b>Xylene</b>	0/103	Not applicable

EDTA = ethylenediaminetetraacetic acid

Note: Bolded text indicates contaminants for which soil samples have been collected and analyzed.

## 4.10 Nature and Extent of Contamination Summary

Thousands of samples have been collected in the proximity of the RWMC and in the SDA over the past 30 years, and many thousands of analyses have been performed. All the analytical data associated with the contaminants of potential concern at the RWMC and identified in the 1998 IRA were compiled and evaluated. The compilation encompasses analytical data from 1971 to 2001, and includes results generated by the DOE, the USGS, and the various INEEL contractors.

Some significant trends have been identified. In the aquifer around the RWMC,  $\text{CCl}_4$  has been detected above MCLs, nitrate levels in the southeast corner of the SDA (M6S) are steadily increasing, and low concentrations of C-14 are reported. In addition, low concentrations of C-14, Tc-99, Am-241, uranium, and plutonium have been detected in the vadose zone, suggesting that migration from the waste zone is occurring. The highest density of detections seems to be located above the B-C interbed in the vadose zone; however, some contaminants have been detected at the C-D interbed, and  $\text{CCl}_4$  extends to the aquifer.

### 4.10.1 Vadose Zone

Low concentrations of numerous contaminants have been detected in the vadose zone. Some data sets exhibit perceptible trends. Data indicate that  $\text{CCl}_4$ , C-14, Tc-99, Am-241, and uranium and plutonium isotopes have been detected in the vadose zone beneath the SDA, and some are migrating both vertically and laterally. The main cluster of contaminants beneath the SDA seems to be located above the B-C interbed; however, some contaminants have been detected in the interval above the C-D interbed, and  $\text{CCl}_4$  extends to the aquifer. Though concentrations in the vadose zone do not pose an imminent threat to the aquifer, the perceptible trends in the vadose zone indicate that some of these contaminants may ultimately impact the aquifer over time.

The evaluation of the analytical data from perched water, soil moisture and core samples has revealed four areas in the SDA vadose zone that contain the most prevalent number of contaminant detections. The areas are shown below (Figure 4-82), and are numbered and shaded in order of their relative detection rates (see Table 4-142). Carbon tetrachloride is not included in the analysis because it is detected in the vapor phase nearly everywhere in and around the SDA. However, a summary of  $\text{CCl}_4$  contamination is included following the discussion of detection rates.

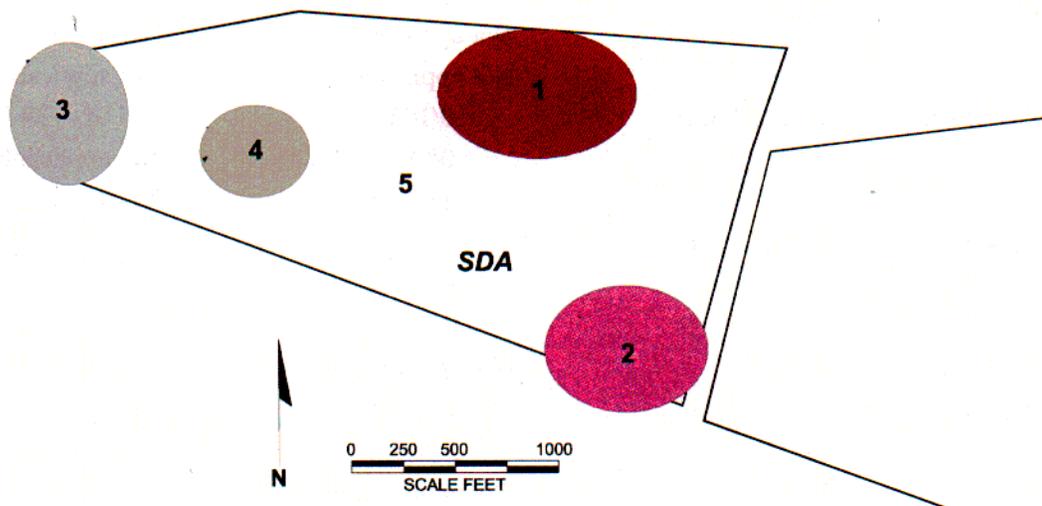


Figure 4-82. Areas with the most frequent statistically positive detections of contamination in the vadose zone.

Table 4-142. Detection rates for all contaminants of potential concern (except carbon tetrachloride) in the vadose zone within specified regions of the Subsurface Disposal Area.

Subsurface Disposal Area	1	2	3	4	5
Number of detections	303	62	131	103	54
Number of samples	998	355	947	1036	1053
Detection rate (%)	30	17	14	10	5
Detection rate ranking	1	2	3	4	5

Each identified SDA detection area also was ranked by the detection rate associated with selected contaminants in the vadose zone (see Table 4-143). This shows which contaminants are most prevalent in each SDA area. The magnitude of the detection rates are shown in Table 4-143 as shaded circles, with the darkest being the highest and lightest circles representing the lowest detection rate for all media in the vadose zone. The numbers shown below each shaded circle represent the actual number of detections versus the number of samples collected within each SDA detection area.

Table 4-143. Relative detection rate ranking for selected contaminants detected in the vadose zone.

Contaminant	Area 1	Area 2	Area 3	Area 4	Area 5
Am-241	21/106	0/36	8/107	6/127	5/158
C-14	6/41	1/15	1/29	9/40	0/13
Pu-238	21/113	0/36	2/116	5/135	0/151
Pu-239/240	19/115	0/36	1/120	3/135	2/157
Tc-99	13/46	1/19	16/38	3/39	2/36
U-233/234 (>bkgd)	68/83	23/31	32/61	25/62	8/47
U-235/236 (>bkgd)	44/83	4/31	9/60	1/62	5/47
U-238 (>bkgd)	69/83	25/31	33/64	24/65	9/50
Nitrates	26/41	3/9	15/19	12/17	17/18
= Detection Rate Ranking 1 (high rate of detection) = Detection Rate Ranking 2 (medium rate of detection) = Detection Rate Ranking 3 (low rate of detection) = Detection Rate Ranking 4 and 5 (lowest rate of detection) = Indicates areas with elevated uranium levels (>>background)					
Background (bkgd) values for lysimeter data are based on soil moisture sample results from lysimeter wells outside the SDA [ie., the "O" wells and the control well (D15)].					

Uranium detection rates in Table 4-143 are actually background exceedance rates and represent the number of samples exceeding a local background per total number of samples taken. Background values for the vadose zone cores were based on comparison to surface soil background concentrations reported by Rood, Harris, and White (1996) for U-234, U-235, and U-238. Background uranium concentrations in

soil moisture are not established, so were calculated from the soil moisture samples taken from lysimeters located outside the SDA (O-series wells) and from the lysimeter samples taken from well D15 designated local background location. While the number of samples exceeding background appears high for uranium isotopes in the vadose zone, some of these exceedances appear to be within the normal range of variance for background. However, samples from Areas 1 and 3 (highlighted in Table 4-143) contain relatively high concentrations of uranium and appear to be truly above background.

The high mobility of uranium coupled with the emerging trends in the vadose zone may indicate migration from the SDA. Elevated concentrations of U-238 emerging at 88 ft, along with steadily high concentrations at 44 ft depth in well D06 (near Pad A) suggest that uranium is migrating in the vadose zone. In addition, preliminary indications from the ultra low-level uranium analyses suggest that man-made uranium (depleted and enriched) is also present in the perched water at about 220 ft deep. Additional wells with lysimeters at various depths could help to confirm if similar uranium trends are evident elsewhere in the SDA region. Periodic sensitive analysis with TIMS and continued interpretation of monitoring data could be used to validate or refute the emerging trends.

#### **4.10.2 Aquifer**

The contaminants detected in the aquifer are CCl<sub>4</sub>, nitrates, and C-14. Carbon tetrachloride and nitrates have been consistently detected in the aquifer around the RWMC area, and C-14 is detected near the SDA as well as 1 to 3 miles upgradient of the RWMC.

Carbon-14 is often seen with H-3 and CCl<sub>4</sub>, and all three contaminants can travel in the vapor phase. The observed C-14 concentrations may emanate from the SDA or from an upgradient source. Currently, no trends in the data are apparent but C-14 monitoring should endeavor to verify the source of C-14.

The CCl<sub>4</sub> and nitrate concentrations in some wells show significant trends and several are near or slightly above the MCL. Nitrate levels in the southeast corner of the SDA (M6S) are steadily increasing; however, the concentration remains in the range typical of nitrate background values in groundwater. The cause of the increasing nitrate levels in this area of the SDA has not been determined, but nitrate is a common contaminant associated with farming and other activities not associated with the INEEL.

Plutonium and americium have not adversely impacted the aquifer. Only about 1% of the total number of aquifer samples collected and analyzed for plutonium and americium over the past 30 years are actual 3-sigma detections (i.e., 15 reliable and defensible detections out of 1,510 plutonium sample analysis, and 7 reliable and defensible detections of Am-241 out of 757 sample analyses). The detections of Pu-238 are two orders of magnitude below the 1E-05 risk-based concentration for the aquifer. There were a couple of Pu-239/240 results in 1993 from M4D that were unusually high, but no detectable concentrations in that well since then. There were also a couple of unusually high Am-241 detections in well M1S in 1997 and 1998. The concentrations were between 1-2 pCi/L, which is below the 1E-05 aquifer RBC of 4.58 pCi/L but much higher than positive detections in other wells (around 0.03 pCi/L). Subsequent analyses since 1998 have not indicated Am-241 presence. In general, the sporadic nature of the plutonium and americium detections precludes defensible conclusions about impacts to the aquifer below the RWMC. The detections are likely statistical anomalies associated with making analytical measurements near the detection limit, or are associated with randomly occurring particles.

Anthropic uranium, though present in the vadose zone, has not been detected in the aquifer. Calculated ratios from the ultra low-level TIMS analyses of aquifer samples indicate uranium in the aquifer is naturally occurring. Uranium concentrations in the aquifer from routine analyses appear to be within the normal range of background concentrations. In the following discussion and graphics, the

U-234 will appear elevated above background concentrations, which is likely an artifact of using background concentrations that are too low for the aquifer samples beneath the RWMC. Section 4.6.19 discusses how isotopic background concentrations were derived.

### 4.10.3 Integrated Assessment

This section uses three-dimensional illustrations to depict the combined monitoring results from the vadose zone and aquifer, and discusses these results. To better illustrate the extent and depth of the contaminants of potential concern detected in the SDA vicinity, some of the upgradient and downgradient aquifer wells were excluded from the figures. Each illustration shows the SDA outline at the surface, at the B-C interbed, the C-D interbed and at the top of the aquifer. Sample locations where no detections were observed are shown as white circles, and locations where positive detections were observed are shown as colored circles. The vadose zone data include both soil moisture (lysimeter and perched water) and vadose zone core sample results.

Figure 4-83 shows the locations of Am-241 detections and nondetections in the vadose zone and aquifer directly beneath the RWMC. Most positive detections in the vadose zone are associated with core samples. Few soil moisture samples from the vadose zone indicate the presence of Am-241, and aquifer detections are very few, suggesting that Am-241 has not migrated into the aquifer. The sporadic nature of Am-241 detections in the aquifer, the low detection rate, and the low detected concentration are not conclusive, but imply that Am-241 detections do not show a trend.

Figure 4-84 shows the locations of C-14 detections and nondetections in the vadose zone and aquifer directly beneath the RWMC. Most positive detections are associated with liquid samples from shallow and mid-depth lysimeters and the aquifer, but not with the vadose zone core samples or deep suction lysimeters. Carbon-14 is in the aquifer at low concentrations in the vicinity of the RWMC, however, there were several detections of C-14 in upgradient wells not shown in this figure. Carbon-14 may be migrating in the vadose zone, and has apparently migrated to the perched water at a depth of 67 m (220 ft). However, data are too sparse to clearly define the extent of C-14 movement in the vadose zone.

Figure 4-85 shows the locations of Pu-238 detections and nondetections in the vadose zone and aquifer directly beneath the RWMC. Plutonium detections in the vadose zone are numerous; however, most are associated with core samples, and only a few detections are associated with the soil moisture (lysimeter) samples. Significant quantities of plutonium do not appear to be moving in the vadose zone. However, a very small fraction may possibly be moving in the vadose zone at concentrations too low to be measured by the most sophisticated analytical technology available. Most of the Pu-238 detections in the aquifer are from the sampling event that took place in September and October 2000. The reliability of these data is questionable because of the absence of corresponding Pu-239/240 detections.

Overall, there is little evidence to show that there is extensive or widespread migration of Pu-238 in the vadose zone.

Figure 4-86 shows the locations of Pu-239/240 detections and nondetections in the vadose zone and aquifer directly beneath the RWMC. Most positive detections in the vadose zone are associated with core samples. Few soil moisture samples from the vadose zone indicate the presence of Pu-239/240. There is no extensive or widespread migration of Pu-239/240 in the vadose zone. The sporadic nature of Pu-239/240 detections in the aquifer and the low detection rate do not provide sufficient evidence to conclude that low levels of Pu-239 are widespread in the aquifer beneath the RWMC.

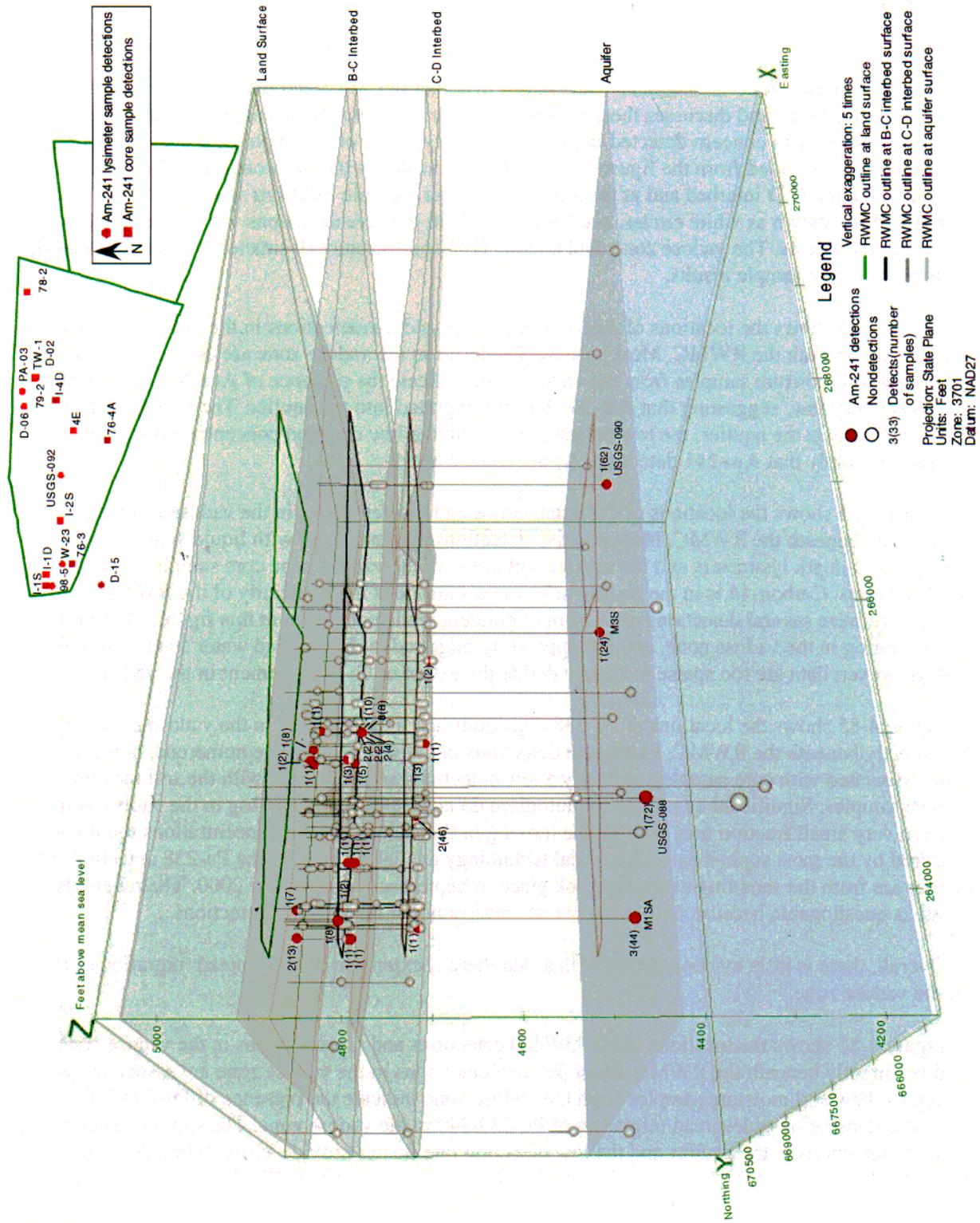


Figure 4-83. Americium-241 detections in the vadose zone and aquifer around the Subsurface Disposal Area.







Figure 4-87 shows the locations of Tc-99 detections and nondetections in the vadose zone and aquifer directly beneath the RWMC. Most positive detections in the vadose zone are from the core samples and soil moisture samples, suggesting that Tc-99 may be moving in the vadose zone. Technetium-99 was detected in all the I-series well core samples at the B-C and C-D interbeds and in soil moisture samples from the shallow lysimeters in SDA Areas 1 and 3. The sporadic nature of Tc-99 detections in the aquifer and the low detection rate do not provide sufficient evidence to conclude that low levels of Tc-99 are widespread in the aquifer beneath the RWMC.

Figure 4-88 shows the locations of U-233/234 detections above background concentrations in the vadose zone and aquifer directly beneath the RWMC. Most of the detections above background in the vadose zone are associated with the shallow and mid-depth lysimeters. Many of the measured U-234 concentrations only slightly exceed the average soil moisture background (3 pCi/L) and are likely to be characteristic of background concentrations. However, not enough soil moisture background data exist to establish a usable statistical interval. Many soil moisture results are much greater than U-234 background (i.e., approximately 4 to 30 times higher), and are primarily associated with SDA contamination Areas 1 and 3. Many of the low U-234 concentrations measured in the aquifer are only slightly above established and published groundwater background concentrations (1.1 pCi/L). The U-234 aquifer results are likely in the concentration range of normal background ranges.

Figure 4-89 shows the locations of U-235 detections above background concentrations in the vadose zone and aquifer directly beneath the RWMC. Most of the detections above background in the vadose zone are associated with the shallow and mid-depth lysimeters. Many of the measured U-235 concentrations only slightly exceed the average soil moisture background (0.5 pCi/L) and are likely to be characteristic of background concentrations. Not enough soil moisture background data exist to establish a usable background concentration range for soil moisture samples. Several soil moisture results are much greater than U-235 background (i.e., approximately 2 to 9 times higher), and are primarily associated with SDA contamination Areas 1 and 3. Many of the low U-235 concentrations measured in the aquifer are only slightly above established and published groundwater background concentrations (0.05 pCi/L). It is our opinion that all of the U-235 results associated with the aquifer beneath the RWMC are within the concentration range of normal background concentrations.

Figure 4-90 shows the locations of U-238 detections above background concentrations in the vadose zone and aquifer directly beneath the RWMC. Most of the detections above background in the vadose zone are associated with the shallow and mid-depth lysimeters. Many of the measured U-238 concentrations that only slightly exceed the average soil moisture background (1.5 pCi/L) are likely to be characteristic of background concentrations. However, not enough soil moisture background data exist to establish a usable statistical interval.

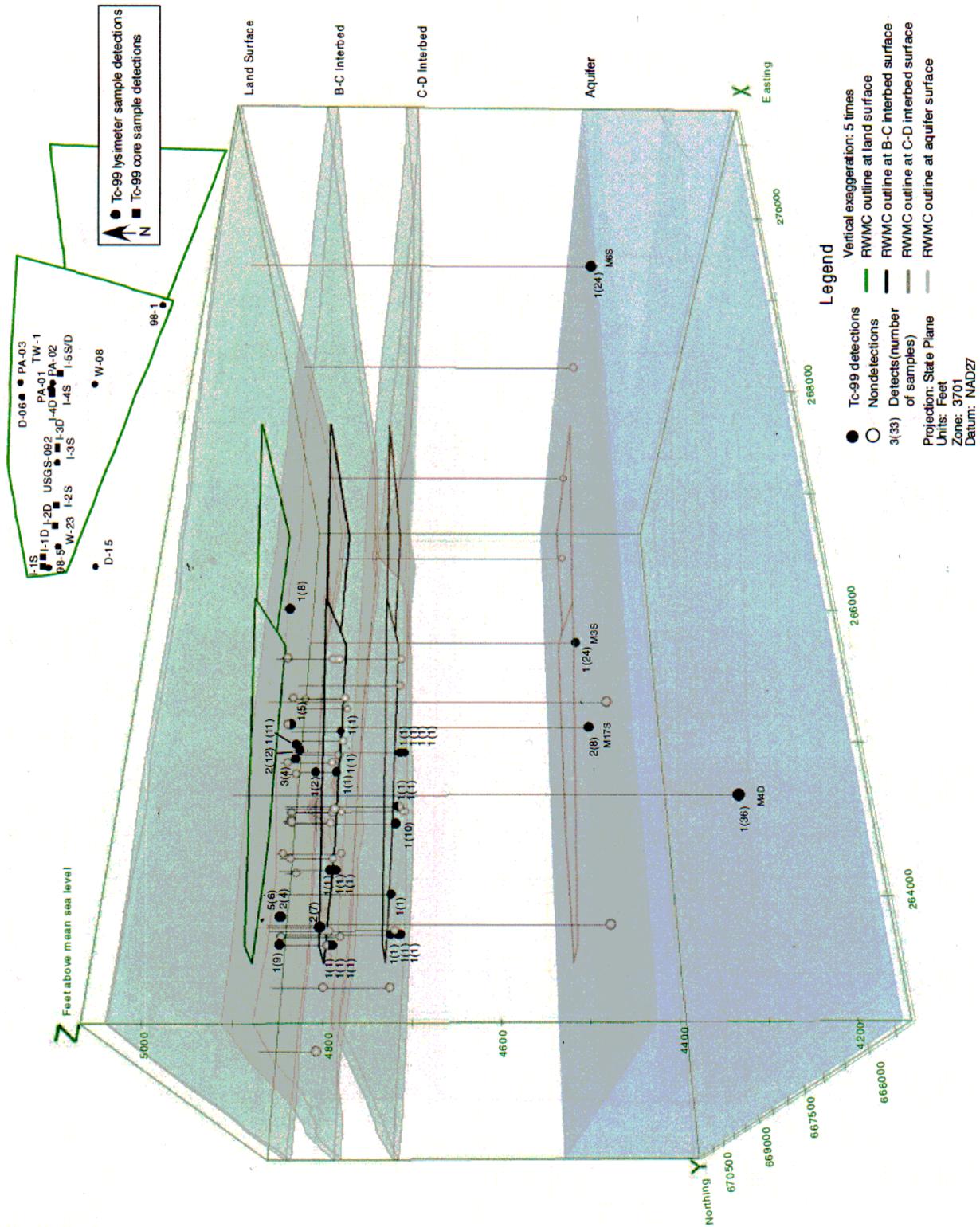


Figure 4-87. Technetium-99 detections in the vadose zone and aquifer near the Subsurface Disposal Area.





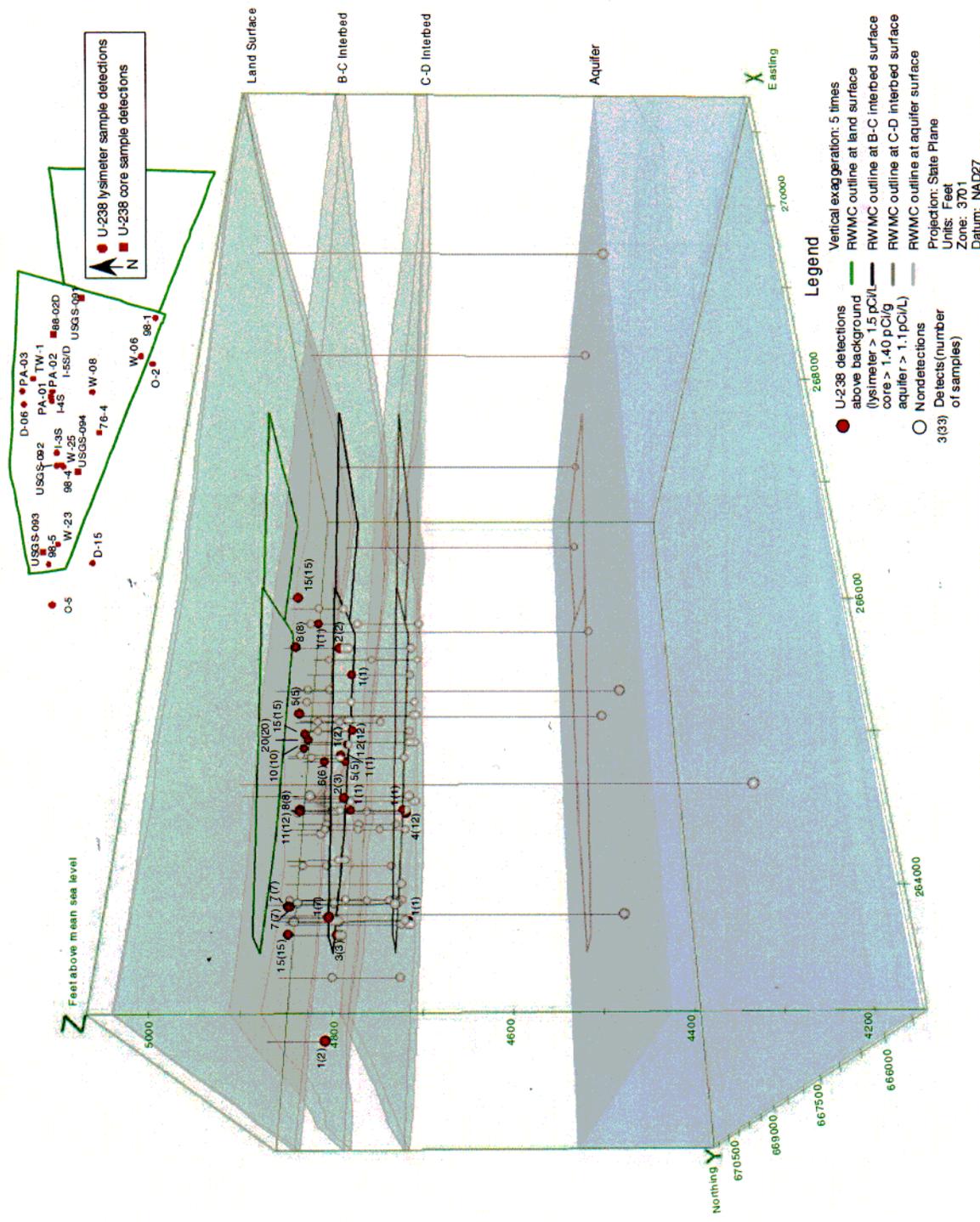


Figure 4-90. Uranium-238 detections in the vadose zone and aquifer around the Radioactive Waste Management Complex.

Table 4-144 identifies some of the general comments about each one of the Contamination areas. Many soil moisture results are much greater than the U-238 background (i.e., approximately 5 to 30 times higher), and are primarily associated with SDA detection Areas 1 and 3. Many of the low U-238 concentrations measured in the aquifer are only slightly above established and published groundwater background concentrations (1.1 pCi/L), and are likely within the concentration range of normal background concentrations.

Table 4-144. Summary of each contamination area at the Subsurface Disposal Area.

Subsurface Disposal Area	Summary
1	<p>Contains numerous contaminants in the vadose zone, most associated with actinides (uranium, plutonium, americium) and mobile activation and fission products (C-14 and Tc-99).</p> <p>C-14, Tc-99, and anthropic uranium may be moving in the vadose zone. C-14 detections in soil moisture samples from Lysimeter Well PA02 are accompanied by H-3 detections, which may indicate activated beryllium is buried in this area.</p> <p>Numerous detections of transuranic radionuclides are noted in the core data, but few detections or trends were observed in the soil moisture data.</p> <p>Lysimeter Well TW1 soil moisture samples show evidence of enriched uranium and perched water Well 8802D samples show evidence of depleted uranium.</p> <p>Waste buried in Pit 5 and Pad A appear to be the sources of contamination in Area 1.</p>
2	<p>The main contaminant detected in this area is uranium.</p> <p>Tritium is also present at elevated concentrations in this area, and its source is thought to be the buried beryllium blocks in Soil Vault Row 20.</p>
3	<p>Contains Tc-99, nitrates, U-235 and Am-241 in the vadose zone.</p> <p>Uranium ratios suggest that anthropic uranium may be present.</p> <p>Numerous detections of americium are noted in the vadose zone core data. Few detections were observed in the soil moisture data.</p>
4	<p>The contaminants detected in this area are C-14 and plutonium.</p> <p>Most C-14 detections in this area are from the USGS-92 perched water well. C-14 may have migrated to the 220-ft perched water zone.</p>
5	<p>Sporadic and inconsequential concentrations detected throughout this general area.</p> <p>Detections in this general area are primarily from Well W08 (Acid Pit) and scattered vadose zone core samples.</p>

Table 4-145 summarizes the key issues and trends associated with each of the COPCs.

Table 4-145. Summary associated with each contaminant.

Contaminant	Summary
Am-241	<p>Most Am-241 detections are in Subsurface Disposal Area (SDA) Areas 1 and 3.</p> <p>Most detections are associated with vadose zone core samples.</p> <p>No noted trends.</p>
C-14	<p>Most detections in Area 1 are from shallow lysimeter Well PA02 (along with elevated H-3).</p> <p>C-14 may have migrated to the 220-ft perched water.</p>
Pu-238	<p>Most detections are associated with vadose zone core samples from SDA Area 1.</p> <p>No noted trends on core data.</p> <p>Possible trend developing in Area 1 (shallow lysimeter Well PA02).</p>
Pu-239/240	<p>Most detections are associated with vadose zone core samples from SDA Area 1.</p> <p>No noted spatial trends on core data.</p> <p>Possible trend developing in Area 1 (shallow lysimeter Well PA02).</p> <p>Results from thermal ionization mass spectrometry (TIMS) analysis of Pu-239 on filtered material from Wells PA03, TW1, and 8802D are statistically higher than all other sample results, further suggesting the possible presence of Pu-239 in the vadose zone of Area 1.</p>
Tc-99	<p>Numerous detections were obtained from both vadose zone core samples and lysimeter samples. The results suggest that Tc-99 is moving in the vadose zone.</p> <p>Elevated concentrations detected in Area 1 (Lysimeter Well PA03 and Cores I-4S and I-4D) and Area 3 (Lysimeter Well W23 and Cores I-1S, I-1D, and I-2D).</p>
U-233/234	<p>Elevated concentrations and trends in Areas 1 and 3 suggest uranium is moving in the vadose zone.</p> <p>Routine analysis and TIMS data confirm the presence of enriched uranium in mid-depth lysimeter Well TW1 (Area 1).</p> <p>Data from TIMS confirm the presence of depleted uranium in deep perched water Well 8802D (Area 1).</p>
U-235	<p>Elevated concentrations and trends in Areas 1 and 3 suggest uranium is moving in the vadose zone.</p> <p>Routine analysis and TIMS data confirm the presence of enriched uranium in mid-depth lysimeter Well TW1 (Area 1).</p> <p>Data from TIMS confirm the presence of depleted uranium in deep perched water Well 8802D (Area 1).</p>

Table 4-145. (continued).

Contaminant	Summary
U-238	<p>Elevated concentrations and trends in Areas 1 and 3 suggest U-238 is moving in the vadose zone.</p> <p>Routine analysis and TIMS data confirm the presence of enriched uranium in mid-depth lysimeter Well TW1 (Area 1).</p> <p>Data from TIMS confirm the presence of enriched uranium in the vicinity of lysimeter well TW1 (Area 1) and depleted uranium in deep perched water Well 8802D (Area 1).</p>
Nitrates	<p>Most elevated nitrates are associated with shallow and mid-depth soil moisture samples collected in SDA areas 3 and 5.</p>
CCl <sub>4</sub>	<p>CCl<sub>4</sub> is widely detected in the vadose zone in the vicinity of the SDA as determined from vapor sampling. The highest concentrations are found in the shallow and mid-depth vadose zone below the source areas shown in Figure 4-24. CCl<sub>4</sub> has been detected more than 1 km away from the SDA, but concentrations decrease significantly with distance away from the source areas. Deep soil gas concentrations (below the C-D interbed) are small compared to concentrations in the upper vadose zone, yet are capable of causing groundwater concentrations above maximum contaminant levels (MCLs).</p> <p>Organic contamination in the vadose zone vapor extraction operations have considerably decreased the levels of CCl<sub>4</sub> and other volatile organic compounds in the vadose zone.</p>

#### 4.10.4 Discussion and Conclusions

Several contaminants (C-14, Tc-99 and uranium) have been detected in the vadose zone of the RWMC, and low concentrations of CCl<sub>4</sub>, nitrates, and C-14 have also been detected in the aquifer. With the possible exception of CCl<sub>4</sub>, no consistent trends are present in the vadose zone, and detections in the aquifer are sporadic.

The monitoring network has been greatly expanded since 1998 with 22 vadose zone lysimeters, 4 upgradient aquifer wells, an aquifer well inside the SDA, and Type A and B probes in the buried waste. In addition, analyte target lists have been modified to focus on those contaminants that may be migrating. Contaminants that pose an unacceptable risk (see Section 6) have been identified as a priority, especially for vadose zone samples where sample volumes are consistently small. Most of these changes have not been in place long enough to provide data necessary to refine our understanding of contaminant distribution or trends.

The expanded monitoring network and ongoing studies continue to produce data for assessing source release into the vadose zone, contaminant migration through the vadose zone, and potential impacts to the aquifer beneath the SDA. Until additional analyses are completed, the only conclusion that can be drawn is that contaminants have been detected sporadically at low concentrations in the vadose zone and in the aquifer. The mobile contaminants buried in the SDA have not impacted groundwater quality thus far, but as long as infiltration through the buried waste continues, contaminant migration is likely to continue. The impact of these contaminants can be assessed and validated through continued monitoring and careful interpretation of spatial and temporal patterns.

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