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Natural Strontium, Iodine, Cesium, and Cobalt in Savannah River Site Groundwater: Data Report (U)

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INTRODUCTION

The purpose of this investigation was to obtain baseline groundwater concentrations for naturally occurring stable isotopes of Sr, I, Cs, and Co in shallow aquifers at the Savannah River Site (SRS). These data are necessary to fully understand migration and remediation of ^{90}Sr, ^{129}I, ^{137}Cs, and ^{60}Co. Fourteen P-wells were selected and sampled based on their close proximity to facilities, available water table and Gordon aquifer wells, and archived core. This report provides the analytical results from the groundwater sampling and core leaching studies. A separate report compares these results with those of other studies and discusses the implications of these data.

BACKGROUND

Several radioactive contaminants have naturally occurring counterparts that are non-radioactive, but have chemical behavior that is identical to the radioactive contaminants. For example, ^{90}Sr is a common contaminant at SRS and is accompanied in groundwater by naturally occurring ^{84}Sr, ^{86}Sr, ^{87}Sr, and ^{88}Sr. Of these, ^{88}Sr makes up about 83%. The most abundant natural counterparts for ^{129}I, ^{137}Cs, and ^{60}Co are ^{127}I, ^{133}Cs, and ^{59}Co. These naturally occurring isotopes are typically present in groundwater at mass concentrations that are orders of magnitude greater than their associated radionuclides (Table 1). A consequence of this is that the natural constituents compete for adsorption and cation exchange sites with their radioactive counterparts, reducing retardation of the radioactive species. To accurately predict the fate and transport of these radionuclides requires consideration of this effect, which, in turn, requires knowledge of the concentrations of the natural constituents. Likewise, concentrations of these natural constituents are important to understanding precipitation reactions that may retard the radionuclides in the subsurface or remove them in treatment systems. Hence, the concentrations of these natural species are important to the modeling of monitored natural attenuation, performance assessments, and other regulatory documents that require a fate and transport analysis. Furthermore, remediation system designs should account for the presence of these natural constituents. Yet, the only systematic study of background concentrations of strontium, iodine, and cobalt is Strom and Kaback (1992). They report reasonable values for strontium and iodine, but all cobalt concentrations were below detection. They did not analyze for cesium in groundwater. The present work compliments the strontium and iodine data of Strom and Kaback (1992) with analyses at lower detection limits, and provides cobalt and cesium analyses that are significantly above detection limits.

Table 1: Comparison of Concentrations of Radionuclides and their Natural Counterparts

Constituent	Molar Concentration of 1 pCi/L	Molar Concentration of 1 ug/L of the Natural Counterpart
^{60}Co	1.5×10^{-17}	1.7×10^{-8}
^{90}Sr	8.0×10^{-17}	1.1×10^{-8}
^{129}I	4.4×10^{-11}	7.9×10^{-9}
^{137}Cs	8.5×10^{-17}	7.5×10^{-9}

Since the objective of this study was to obtain baseline data from the water table and Gordon Aquifers near facilities at the Savannah River Site, fourteen P-wells were selected for this investigation (Figure 1). The P-Wells were installed in the late 1980's as part of the Savannah River Plant Baseline Hydrogeological Investigation (Bledsoe, 1984; Bledsoe, 1987; Bledsoe, 1988) for the purpose of updating and improving the current knowledge and understanding of the hydrogeological systems underlying the Savannah River Site. They were specifically placed at locations with minimal groundwater contamination so that they could serve as indicators of background water quality. Wells were screened in all identified aquifer systems including the water table (Upper Three Runs) and Gordon aquifers at each P-Well cluster. The P-Wells provide a good platform for this study because of their close proximity to facilities, available water table and Gordon aquifer wells, and archived core. Twelve of the fourteen wells selected for this study are located adjacent to five reactor sites (C,K,L,P and R) and F and H areas, which were all involved in the production and processing of nuclear materials. The remaining two P-Wells (P-23B and P-23D) are located in the southwest portion of the site.

METHODS

As outlined in the Sampling and Analysis Plan for Investigating the Abundance of Natural Stable Counterparts of ^{90}Sr, ^{129}I, ^{137}Cs, and ^{60}Co in SRS Groundwater (U) (WSRC-TR-2001-00605), each of the fourteen wells was sampled three times during 2002. Fieldwork began on January 7, 2002 to collect groundwater samples for initial analyses, followed by a second sampling event in April and a final sampling event in July.

Before sampling, each well was purged in excess of two well volumes, and field parameters (pH, conductivity, temperature, oxygen reduction potential, dissolved oxygen and turbidity) were recorded in five-minute intervals to confirm stabilization. A YSI 6-Series Environmental Monitoring System and a DRT-15C turbidimeter were used to measure and record water quality parameters. All samples were filtered through 0.45 um in-line filters. Samples for analysis of ^{88}Sr, ^{133}Cs, and ^{59}Co were preserved with nitric acid. A separate unacidified sample was obtained for analysis of ^{127}I to avoid volatilization of iodine. Groundwater sampling followed WSRC Hydrogeologic Data Collection Procedures (Procedure 3Q5, Chapter 15).

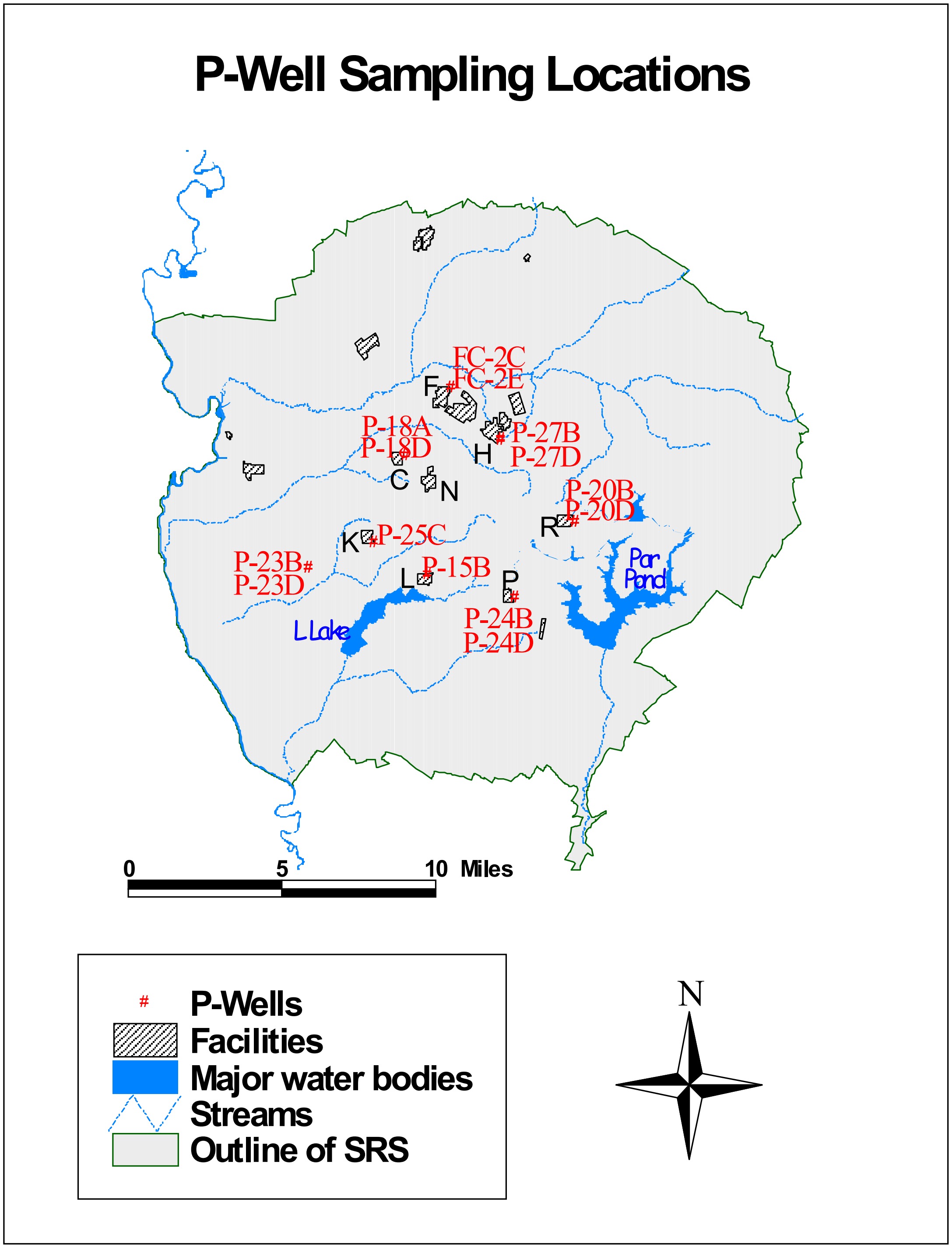

Figure 1: Location of P-wells sampled in this study, major facilities (F and H areas and reactor sites C,K,L,P and R) and water bodies.

For all three sampling events groundwater samples were analyzed for ^{88}Sr, ^{127}I, ^{133}Cs, and ^{59}Co, the stable counterparts of ^{90}Sr, ^{129}I, ^{137}Cs, and ^{60}Co, at the Savannah River Ecology Lab (SREL) using inductively coupled plasma-mass spectrometry (ICP-MS). SREL's method of analysis allows for lower detection limits than the inductively coupled plasma – emission spectrometry (ICP-ES) normally used for these constituents. As part of the second sampling event, groundwater samples were also analyzed for major cations and anions using ICP-ES and ion chromatography (IC) by SRTC's Analytical Development Section (ADS). In addition, confirmatory analyses were performed by ADS on select samples for ^{88}Sr, ^{133}Cs, and ^{59}Co using ICP-MS.

Based on the analytical results from the first two sampling events, subsurface sediment samples were collected from four P-Well cores for leaching analyses. These were conducted to gain a better understanding of the effects of an acidic groundwater on concentrations of ^{88}Sr, ^{127}I, ^{133}Cs, and ^{59}Co. Six sediment samples were collected from core at intervals corresponding to the screen zones of P-Wells sampled in this study and two sediment samples were collected from formations above the P-Well screen zones. These samples were characteristic of sediments found in the water table aquifer (Upper Three Runs) and Gordon aquifers in the central and southern parts of the Savannah River Site. Table 2 identifies each sediment sample collected and the corresponding P-Well, midscreen depth, and aquifer unit.

Table 2: Sediment Samples Collected from P-Well Core

Sediment Sample	Sample Depth (ft msl)	Corresponding P-Well	Well Midscreen Depth (ft msl)	Aquifer Unit of P-Well
P20B-196	196	P-20B	249	Gordon Aquifer
P20B-247	247	P-20B	249	Gordon Aquifer
P20D-51	51	P-20D	54	Upper Three Runs
P23B-114	114	P-23B	135	Gordon Aquifer
P23B-137	137	P-23B	135	Gordon Aquifer
P23D-41	41	P-23D	46	Upper Three Runs
P24D-55	55	P-24D	55	Upper Three Runs
P27D-65	65	P-27D	65	Upper Three Runs

5 grams of each sediment sample were leached with 50 mL of pH 3 nitric acid solution for 24 hours. Select samples were also leached with deionized water for 24 hours to

serve as controls. Using 60 mL syringes and 25 mm diameter syringe filters (0.45 um pore size), the resultant leachate was collected and analyzed for pH. SREL then analyzed the leachate for ^{88}Sr, ^{127}I, ^{133}Cs, and ^{59}Co using ICP-MS. The ^{127}I analyses should be viewed with caution because of potential iodine loss by volatilization in the acidic solution.

RESULTS

Results from the ICP-MS analyses of ^{88}Sr, ^{127}I, ^{133}Cs, and ^{59}Co by SREL for all of the groundwater sampling events are presented in Table 3. In addition, Table 4 shows a comparison of the isotopic results analyzed and reported by SREL and ADS for selected samples from the second groundwater sampling event (April 2002). Table 5 provides the results from the major cation and anion analyses conducted by ADS for the groundwater collected during the second sampling event (April 2002). Field analyses for all groundwater sampling events are presented on Table 6. Details and results of the leaching analyses are provided on Table 7.

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Table 3: Results of ICP-MS Analyses by SREL
(concentrations in ug/L)

WELL ID	**^{133}Cs** (Detection Limit = ~ 0.001)			**^{88}Sr** (Detection Limit = ~ 0.0015)			**^{59}Co** (Detection Limit = ~ 0.0012)			**^{127}I** (Detection Limit = ~ 0.02)		
	Jan-02	**Apr-02**	**Jul-02**	**Jan-02**	**Apr-02**	**Jul-02**	**Jan-02**	**Apr-02**	**Jul-02**	**Jan-02**	**Apr-02**	**Jul-02**
FC-2C	0.28	0.24	0.31	177.80	165.85	184.81	0.09	0.23	0.11	2.70	3.37	2.84
FC-2E	0.18	0.11	0.10	14.01	10.54	8.71	1.21	1.06	1.51	4.55	5.34	4.49
P-15B	0.09	0.07	0.09	59.63	43.32	50.80	0.15	0.03	0.11	3.51	3.35	2.99
P-18A	NS	0.46	0.49	NS	421.86	455.28	NS	0.14	0.26	NS	2.58	4.45
P-18D	0.02	0.01	0.02	40.84	31.09	18.42	0.13	0.18	1.15	2.98	3.21	2.75
P-20B	0.06	<0.001	0.08	276.34	247.21	293.86	0.58	0.02	0.06	3.88	4.67	3.63
P-20D	0.05	<0.001	0.04	22.79	11.61	12.33	0.87	0.12	0.20	2.66	3.62	3.42
P-23B	0.16	0.03	0.11	117.75	60.26	72.48	0.04	0.01	0.08	4.36	3.78	3.43
P-23D	0.04	<0.001	0.03	11.65	8.73	4.69	0.46	0.31	0.34	4.93	4.86	4.79
P-24B	0.36	0.06	0.49	263.35	188.00	369.41	0.66	0.01	0.14	2.69	2.03	2.88
P-24D	0.05	<0.001	0.04	9.04	4.48	3.79	0.26	0.11	0.22	12.75	14.31	13.11
P-25C	0.08	0.05	0.07	38.21	36.17	34.80	0.11	0.09	0.07	5.15	6.72	6.59
P-27B	0.11	<0.001	0.10	152.81	70.87	64.02	0.11	0.05	0.07	5.11	6.24	6.35
P-27D	0.11	<0.001	0.11	5.81	5.40	4.11	0.45	0.36	0.47	1.69	1.58	2.21

NS = not sampled

Table 4: Comparison of Analytical Results - April 2002
(concentrations in ug/L)

WELL ID	**^{133}Cs**		**^{88}Sr**		**^{59}Co**	
	ADS	**SREL**	**ADS**	**SREL**	**ADS**	**SREL**
FC-2E	0.13	0.11	11	10.54	1.10	1.06
P-20B	<0.1	<0.001	270	247.21	0.14	0.02
P-20D	<0.1	<0.001	18	11.61	0.19	0.12

Table 5: Results of ICP-ES and IC Analyses by ADS - April 2002 (concentrations in mg/L)

WELL	**P15B**	**P-18D**	**P-18A**	**P-20D**	**P-20B**	**P-23D**	**P-23B**
Al	<0.028	<0.028	0.15	<0.028	<0.028	<0.028	0.039
B	<0.024	<0.024	<0.024	<0.024	<0.024	0.074	<0.024
Ba	0.018	0.006	0.047	0.116	0.106	0.191	0.068
Ca	37.9	3.24	38.2	2.45	44.5	2.20	34.9
Cd	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Co	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cr	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
Cu	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007
Fe	0.66	0.23	<0.005	<0.005	0.067	0.064	0.28
Li	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Mg	0.89	0.30	0.67	0.58	0.92	0.87	0.81
Mn	0.008	0.009	<0.001	0.003	0.009	0.009	0.015
Mo	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Na	2.13	2.27	1.84	1.99	1.79	6.76	1.51
Ni	0.009	0.010	0.011	<0.007	0.017	0.009	0.011
P	<0.080	<0.080	<0.080	<0.080	<0.080	0.14	<0.080
Pb	<0.080	<0.080	<0.080	<0.080	<0.080	<0.080	<0.080
Si	6.33	3.06	9.14	3.59	15.1	3.57	7.89
Sn	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Sr	0.054	0.035	0.48	0.017	0.28	0.015	0.091
Ti	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
V	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
Zn	<0.045	0.093	<0.045	0.052	<0.045	0.19	<0.045
Zr	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
La	<0.080	<0.080	<0.080	<0.080	<0.080	<0.080	<0.080
K	1.04	0.32	1.49	0.43	0.95	0.37	1.18
S	4.60	0.17	2.36	0.15	4.31	1.37	4.00
Cl	2.00	2.00	2.00	1.00	2.00	2.00	2.00
F	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
NO3	<1	1	<1	4	<1	7	<1
NO2	<1	<1	<1	<1	<1	<1	<1
PO4	<1	<1	<1	<1	<1	<1	<1
SO4	11	0.5	5	0.3	11	0.3	10

Table 5 (continued): Results of ICP-ES and IC Analyses by ADS - April 2002
(concentrations in mg/L)

WELL	P-24D	P-24B	P-25C	P-27D	P-27B	FC-2E	FC-2C
Al	<0.028	<0.028	<0.028	<0.028	<0.028	0.032	<0.028
B	<0.024	0.036	0.036	0.043	0.028	<0.024	<0.024
Ba	0.053	0.362	0.006	0.085	0.169	0.025	0.048
Ca	1.20	28.2	32.9	1.42	10.2	1.31	33.3
Cd	0.003	<0.002	<0.002	0.002	<0.002	0.007	<0.002
Co	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cr	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
Cu	<0.007	<0.007	<0.007	<0.007	<0.007	0.010	<0.007
Fe	0.018	<0.005	<0.005	0.011	<0.005	0.12	0.027
Li	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Mg	0.12	0.74	0.53	0.39	0.41	1.30	0.69
Mn	<0.001	<0.001	<0.001	0.011	0.002	0.10	0.044
Mo	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Na	11.7	5.47	1.66	1.82	2.26	1.15	1.92
Ni	<0.007	0.011	0.011	0.010	0.009	<0.007	0.020
P	<0.080	<0.080	<0.080	<0.080	0.30	<0.080	0.11
Pb	<0.080	<0.080	<0.080	<0.080	<0.080	<0.080	<0.080
Si	3.31	8.17	6.04	6.27	5.98	3.09	18.5
Sn	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Sr	0.009	0.20	0.048	0.007	0.086	0.012	0.18
Ti	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
V	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
Zn	<0.045	0.047	<0.045	0.064	0.054	0.10	<0.045
Zr	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
La	<0.080	<0.080	<0.080	<0.080	<0.080	<0.080	<0.080
K	0.86	1.33	0.41	0.55	0.40	0.59	1.25
S	3.91	1.78	0.76	0.17	0.50	0.72	3.91
Cl	3.00	2.00	3.00	2.00	2.00	1.00	2.00
F	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
NO3	5	<1	2	1	0.5	6	<1
NO2	<1	<1	<1	<1	<1	<1	<1
PO4	<1	<1	<1	<1	0.7	<1	<1
SO4	10	1	1	0.4	0.8	2	10

Table 5 (continued): Results of ICP-ES and IC Analyses by ADS - April 2002
(concentrations in mg/L)

WELL	P-15B blank	P-20B dup	P-24D dup
Al	<0.028	<0.028	<0.028
B	<0.024	<0.024	<0.024
Ba	<0.002	0.076	0.088
Ca	**** 0.079***	44.5	1.15
Cd	0.002	<0.002	<0.002
Co	<0.005	<0.005	<0.005
Cr	<0.006	<0.006	<0.006
Cu	<0.007	<0.007	<0.007
Fe	<0.005	0.073	0.012
Li	<0.020	<0.020	<0.020
Mg	<0.0093	0.92	0.13
Mn	<0.001	0.010	0.001
Mo	<0.020	<0.020	<0.020
Na	<0.111	1.52	11.8
Ni	<0.007	0.017	<0.007
P	<0.080	<0.080	<0.080
Pb	<0.080	<0.080	<0.080
Si	**** 0.035***	15.2	3.34
Sn	<0.030	<0.030	<0.030
Sr	<0.0005	0.28	0.009
Ti	<0.020	<0.020	<0.020
V	<0.015	<0.015	<0.015
Zn	<0.045	<0.045	<0.045
Zr	<0.006	<0.006	<0.006
La	<0.080	<0.080	<0.080
K	<0.056	0.89	0.79
S	<0.056	4.29	4.00
Cl	<0.2	2.00	3.00
F	<0.2	<0.2	<0.2
NO3	<1	NR	5
NO2	<1	<1	<1
PO4	<1	<1	<1
SO4	<0.5	11	10

* Sample P-15B-Blank may have carryover for Ca and Si from previous samples in sample batch.

Table 6: Results of Field Analyses

Well	Date	Time	Temp °C	SpCond uS/cm	DO mg/L	pH	ORP mV	Turbidity NTU	Total Purged gallons
FC-2C	1/8/2002	14:23:11	21.7	144	3.3	7.00	86	2.1	33
	4/2/2002	12:00:00	*	*	*	*	*	1.2	*
	7/30/2002	11:20:00	22.7	130	5.8	7.73	88	-	45
FC-2E	1/8/2002	16:44:39	21.1	28.1	6.8	5.12	218	1.4	72
	4/2/2002	11:20:00	21.5	28	6.9	5.08	182	2	68
	7/30/2002	11:40:00	21.2	76	8.1	5.18	181	-	100
P-15B	1/7/2002	13:46:00	20.5	127	0.2	6.89	-65	5	240
	4/3/2002	14:35:00	21.0	168	0.1	6.87	-251	2	240
	7/29/2002	10:15:00	20.6	267	0.2	6.82	-75	-	247
P-18A	4/2/2002	16:25:00	20.6	161	4.2	8.8	36	1.5	228
	7/31/2002	8:45:00	20.4	150	6.7	8.73	52	-	266
P-18D	1/15/2002	15:14:32	18.8	30.6	8.5	6.05	135	21.6	109
	4/3/2002	12:05:00	26.8	31	7.3	6.03	91	6.2	378
	7/31/2002	9:25:00	22.8	21	9.9	6.11	136	-	90
P-20B	1/9/2002	15:48:00	20.3	205.6	0.1	7.43	-85	0.2	267
	4/5/2002	11:15:00	20.2	187	0.1	7.52	-229	0.2	275
	7/30/2002	8:30:00	20.2	160	0.2	7.51	-124	-	450
P-20D	1/9/2002	16:23:00	20.8	27.2	7.7	5.08	188	0.8	135
	4/4/2002	15:40:00	21.3	26	5.6	5.01	177	3.7	120
	7/30/2002	8:55:00	21.0	22	6.5	4.84	164	-	160
P-23B	1/15/2002	12:20:56	20.0	194.6	0.1	8.21	-243	0.2	240
	4/8/2002	12:58:00	19.9	148	0.1	7.05	-105	0.15	360
	7/31/2002	10:15:00	20.0	124	3.8	7.04	-66	-	420
P-23D	1/15/2002	13:30:02	27.0	46.2	7.9	4.93	249	1.2	11.8
	4/8/2002	13:48	29.3	33	9.4	4.93	182	2.1	20
	7/31/2002	10:55	24.3	18	10.6	4.96	194	-	22
P-24B	1/9/2002	12:21:02	20.3	144	7.8	8.99	105	0.5	218
	4/3/2002	16:05:00	20.7	131	8.7	8.56	24	1	200
	7/29/2002	11:26:00	20.8	124	10.0	9.25	66	-	511
P-24D	1/9/2002	13:07:03	20.0	70.8	8.8	5.53	189	3.7	148
	4/4/2002	14:34:00	20.1	56	8.9	5.39	151	1.4	105
	7/29/2002	10:55:00	21.5	122	9.5	5.4	129	-	25
P-25C	1/7/2002	15:27:00	19.9	116.4	9.2	7.81	115	0.5	258
	4/2/2002	15:05:00	20.2	139	8.0	7.83	83	1.8	240
	7/30/2002	13:30:00	20.3	119	10.3	7.98	95	-	202
P-27B	1/10/2002	10:00:00	19.3	60	7.7	6.11	210	0.8	279
	4/4/2002	10:10:00	19.5	51	7.7	6.1	96	1.1	234
	8/1/2002	9:45:00	19.6	42	9.4	6.02	145	-	180
P-27D	1/10/2002	11:07:11	19.9	22.1	0.9	5.13	224	0.2	222
	4/402	11:00	20.0	19	1.3	5.17	152	0.4	198
	8/1/2002	10:15	21.6	17	2.2	5.09	157	-	150

* No water quality parameters recorded because of equipment failure

\- No data collected

Table 7: Leaching Method and Results of ICP-MS Analyses

Sample	Leaching Method	pH after 24hr	^{133}Cs	^{88}Sr	^{59}Co	^{127}I
P20D-51 DI	5g sediment/50mL DI water	5.45	0.06	0.30	0.39	13.34
P23D-41 DI	5g sediment/50mL DI water	5.69	0.22	0.41	0.53	0.98
P24D-55 DI	5g sediment/50mL DI water	5.00	0.04	2.89	1.15	12.92
P27D-65 DI	5g sediment/50mL DI water	6.10	0.03	0.19	0.16	8.67
P20D-51	5g sediment/50mL HNO_3 solution (pH=3)	2.95	0.24	23.64	0.51	10.75
P23D-41	5g sediment/50mL HNO_3 solution (pH=3)	3.25	0.20	58.85	6.61	5.81
P24D-55	5g sediment/50mL HNO_3 solution (pH=3)	2.97	0.15	41.07	10.15	253.33
P27D-65	5g sediment/50mL HNO_3 solution (pH=3)	3.62	0.18	49.73	15.76	133.51
P20B-196	5g sediment/50mL HNO_3 solution (pH=3)	7.57	0.14	709.51	0.61	1.85
P20B-247	5g sediment/50mL HNO_3 solution (pH=3)	2.73	0.11	43.96	2.28	7.18
P23B-114	5g sediment/50mL HNO_3 solution (pH=3)	7.58	0.29	260.80	0.53	1.75
P23B-137	5g sediment/50mL HNO_3 solution (pH=3)	2.70	0.20	26.37	1.86	12.40

Approximate detection limits: Cs = 0.001, Sr = 0.0015, Co = 0.0012, I = 0.02