Potential Ecological Effects of Contaminants in the Exposed Par Pond Sediments

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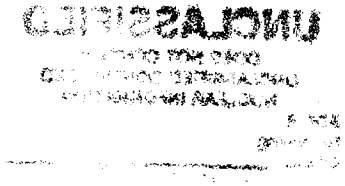

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Executive Summary

Sediment and small mammal samples were collected from the exposed sediments of Par Pond in early 1995, shortly before the reservoir was refilled after a 4-year drawdown. Sampling was confined to elevations between 58 and 61 meters (190 and 200 feet) above mean sea level, which includes the sediments likely to be exposed if the Par Pond water level is permitted to fluctuate naturally. Both soil and small mammal samples were analyzed for a number of radionuclides and metals. Some of the soil samples were also analyzed for organic contaminants. The objective of the study was to determine if contaminant levels in the Par Pond sediments were high enough to cause deleterious ecological effects.

None of the metals or organic constituents measured in the Par Pond exposed sediments exceeded the U.S. Environmental Protection Agency, the National Oceanographic and Atmospheric Administration, or Canadian ecological screening criteria for contaminants in terrestrial soils. However, the maximum total mercury concentration (485 μg/kg, geometric mean of 62 μg/kg) slightly exceeded the U.S. Environmental Protection Agency screening criterion for ecological effects in submerged (i.e., aquatic) sediments. These results suggest that mercury may pose a problem when the Par Pond sediments are submerged and mercury bioavailability increases but not when the sediments are exposed and acting as terrestrial soils.

A number of radionuclides were detected in the Par Pond sediments, but only cesium-137 occurred consistently and at levels well in excess of levels at the control sites. The geometric mean cesium-137 concentration was 7.2 pCi/g; the maximum was 56.7 pCi/g. Cesium-137 was nonuniformly distributed on both small and large spatial scales, but usually higher downslope (58-59 meters [190-195 feet] above mean sea level) than upslope (59-61 meters [195-200 feet] above mean sea level). Cesium-137 concentrations were higher in sediments with high organic content, and the patchy distribution of these sediments probably contributed to the patchy distribution of cesium-137. The spatial distribution of total mercury and cesium-137 in the exposed sediments was significantly correlated, but the correlation was relatively weak ($R^2 = 0.25$).

Cotton rats were the most commonly collected small mammal on the exposed Par Pond sediments. Cotton rats bioaccumulated cesium-137; the geometric mean total body burden of cesium-137 in Par Pond cotton rats was 57.0 pCi/g, and the maximum was 181.0 pCi/g. Cesium-137 levels in Par Pond exposed sediments and in cotton rats were strongly correlated ($R^2 = 0.57$ to 0.90). Other radionuclides occurred in Par Pond cotton rats but inconsistently or at comparatively low levels when compared to cotton rats from control sites. There was no evidence that mercury bioaccumulated in Par Pond cotton rats.

The total radiation dose (internal and external) to cotton rats residing on the exposed sediments of Par Pond was approximately 0.003 rad/day, well under the 1.0 rad/day standard set by the U.S. Department of Energy for the exposure of native organisms to radiation.

In summary, cesium-137 and mercury are the principal contaminants in the Par Pond sediments at the elevations likely to be exposed if the Par Pond water level is permitted to fluctuate naturally. Neither contaminant is present in concentrations likely to produce deleterious effects on terrestrial organisms that may utilize the sediments when they are exposed by lowered water levels. However, mercury concentrations are high enough to be of possible concern when these sediments are inundated and mercury bioavailability has the potential to increase within the aquatic environment.

Introduction

Par Pond is a 1012-hectare (2500-acre) reservoir on the Savannah River Site (SRS) that formerly received cooling water from P and R Reactors. Radionuclides leaking from R Reactor contaminated Par Pond from 1954 to 1964. The water level of Par Pond was artificially maintained at 61 meters ([m] 200±1 feet) above mean sea level (msl) by pumping water from the Savannah River until 1991 when it was reduced to 55 m (181 feet) above msl because of a defect in the Par Pond dam. The drawdown resulted in the exposure of sediments contaminated with radionuclides, especially cesium-137. The defect was repaired and Par Pond was refilled in early 1995 to its previous level, thus shielding people and other terrestrial organisms from exposure to the radionuclides in the sediments. The potential human health risks posed by these radionuclides has been the subject of studies that indicated a significantly increased cancer risk to permanent human residents on the exposed sediments (WSRC 1992; Whicker et al. 1993).

Because the nuclear reactors on SRS no longer operate, the river water distribution system that was used to supply them with cooling water, and that maintains the constant water level in Par Pond, may be shut down. Hydrological models indicate that the watershed of Par Pond is large enough to maintain the average water level near historical levels without input from the Savannah River, but fluctuations of several feet could be expected (COE 1994). These fluctuations would result in the exposure of contaminated sediments, which could pose human health and ecological risks.

Just before Par Pond was refilled, soil and small mammals were collected from the exposed sediments and analyzed for a number of radioactive and nonradioactive constituents. Sampling was confined to the upper elevations of the lake bed (approximately 58 to 61 m [190-200 feet] above msl) where sediments would likely be exposed if water levels fluctuate naturally.

The objectives of this study were to:

- determine what contaminants are present and assess their concentrations in the sediments likely to be exposed if the Par Pond water level fluctuates
- assess levels of contamination in small mammals that lived and fed on the exposed sediments during drawdown and that could serve as vectors of contaminant transfer up the food chain
- determine the relationships between levels of contamination in the sediments and in small mammals.

Methods and Materials

Field Methods

Field work was conducted between January and March 1995. At the start of the sampling period, the surface elevation of Par Pond was approximately 58 m (190 feet) above msl, approximately 3 m (10 feet) higher than the lowest level reached during drawdown and 3 m (10 feet) lower than full pool.

Soil samples and small mammals were collected from 15 sites on the exposed sediments of Par Pond and from 2 reference sites (Figure 1). Within each of the four major arms of Par Pond (North Arm, South Arm, Middle Arm, and Main Body) sample

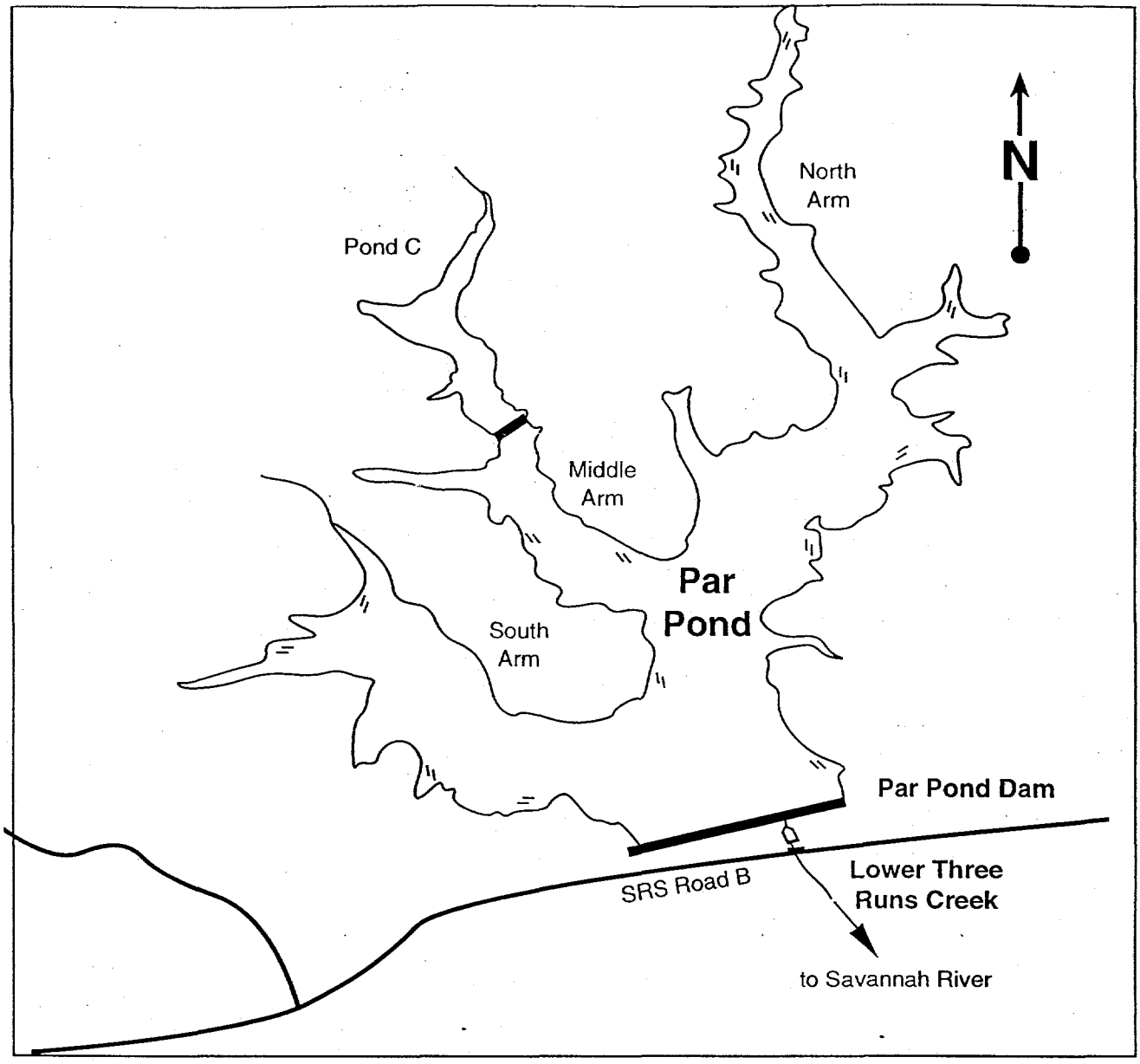

Figure 1. Soil and small mammal sampling sites on the exposed sediments of Par Pond. Upper and lower transects were located at each sample site.

sites were randomly selected by measuring the length of the predrawdown shoreline in the arm (using aerial photographs), randomly selecting with a random number generator numbers less than the total length of the arm, and marking the point that corresponded to that length within the arm on a map. This procedure ensured coverage of the entire lake and avoided the bias associated with subjective selection of sample sites. The 15 sample sites were apportioned among the 4 regions on the basis of the total length of shoreline among the regions. The two reference sites were located near Lost Lake and Road D; both areas are uncontaminated with the exception of fallout from airborne releases.

Visual cues (e.g., shoreline contours) from aerial photographs of Par Pond were used to locate each sample site marked on the map. At each site, two 100-m (328-foot) transects were established run-

ning approximately parallel to the original shoreline (Figure 1). The lower transect (A) was located near the water line at the time of sampling (approximate elevation of 58-59 m [191-195 feet] above msl) and the upper transect (B) was located near the old full pool water line (approximate elevation of 60-61 m [197-200 feet] above msl). The A and B transects usually were offset to maximize spatial separation.

Soil samples to a depth of approximately 10-15 centimeters (4-6 inches) were collected at five locations spaced at 20 m intervals along each transect. This depth corresponds to the root zone of many of the herbaceous plants that colonized the Par Pond sediments after the drawdown. A spade with the blade wrapped with polyethylene was used to collect each sample. The plastic was discarded and replaced after each sample to prevent inter-sample contamination. Each soil sample was homogenized by mixing it thoroughly by hand on a sheet of clean polyethylene plastic, then transferred to appropriately labeled jars and placed on ice for shipment to the analytical laboratory.

In addition to the individual soil samples, a composite soil sample was collected from each of the four arms of Par Pond and from one of the reference sites. Each composite sample consisted of several randomly collected subsamples of soil from each transect in the arm or at the reference site. The subsamples were thoroughly mixed together before compositing the sample.

Small mammals were collected from Par Pond between January 16 and 20, 1995. Two 100-m (328-foot) trap lines were established at each sampling site. These usually corresponded to the lower (A) and upper (B) transects, although at several sites the transects and the trap lines were separated by 25-50 m (8-15 feet) because of increases in lake water level between the times of trapping and soil sampling. Two Victor snap traps and one Sherman live trap were set at each trapping point for a total of 30 traps along each transect. Snap traps were baited with peanut butter and Sherman traps with bird seed and rolled oats. All traps were checked each morning for four consecutive days and rebaited as necessary. Trapped animals were identified; placed in appropriately labeled, individual plastic bags; and then conveyed to the laboratory where they were weighed and frozen. The procedure for collecting small mammals at the reference sites was similar except that there was a 250-m (820-foot) trapline rather than a 100-m (328-foot) trapline with trapping points at 10 m intervals. The longer trapline was necessary to collect sufficient numbers of small mammals, which were less abundant at the reference sites.

To prepare small mammal tissue for the laboratory, sufficient numbers of individuals from each species at each transect (or trapline where transects and traplines did not overlap) were composited to attain the minimum sample mass needed for radiological and chemical analyses. The individuals were homogenized in a blender to produce a whole-body composite sample (hereafter referred to as a transect sample). In addition, randomly selected individuals of one species from transects in each arm of Par Pond were composited to create a composite sample on a larger spatial scale (hereafter referred to as lake arm samples).

Descriptive information about each site was recorded. These included Munsell soil color of each soil sample, a general site description emphasizing floristic composition, and the Global Positioning System coordinates corresponding to the beginning and end points of each transect.

Laboratory Methods

Each of the individual soil samples was analyzed for total mercury, gamma emissions (gamma pulse height analysis), gross alpha emissions, and beta emissions from nonvolatile radionuclides (nonvolatile beta). The composite soil samples were analyzed for the preceding constituents plus target compound list (TCL) volatile organic compounds,

TCL semivolatile organic compounds, pesticides/polychlorinated biphenyls (PCBs), and target analyte list (TAL) metals. Specific constituents within each of these categories are listed in tables in this report.

Each of the transect tissue samples was analyzed for total mercury, gamma emissions (gamma pulse height analysis), gross alpha emissions, beta emissions from nonvolatile radionuclides (nonvolatile beta), and a number of metals including total mercury. Each lake arm sample and one of the reference site transect samples was analyzed for all of the preceding constituents, strontium-90, plutonium-238, plutonium-239/240, and several other constituents. Detailed information on analytical methods and QA/QC procedures can be found in quality control summary documents for Par Pond risk assessments (WSRC 1995a, b).

Data Analysis

The results of the sediment and tissue analyses are presented as arithmetic means, geometric means, maxima, and percentage of samples with concentrations above the detection limit for each variable. Geometric means were calculated by back transforming the average value of the log transformed (i.e., $X'=\log10(X+1)$) data (Sokal and Rohlf 1981). Geometric means were presented with arithmetic means because environmental contaminant data are often logarithmically distributed (Gilbert 1987). When calculating means, values below the detection limit were assumed to be one half the detection limit following U.S. Environmental Protection Agency (EPA) guidance (Gilbert 1987). Standard errors of arithmetic means and confidence intervals were calculated for geometric means as is customary and shown in Sokal and Rohlf (1981). Standard errors and confidence intervals were not calculated for a constituent unless the majority (>50%) of its measurements were above detection limits. Protocols for handling soil sample duplicates are as described in Koch et al. (1996).

Analysis of variance (ANOVA) was used to assess the differences among elevations (i.e., transects), sample sites, and lake arms on soil cesium-137 concentrations. Residual error (i.e., the variation among individual soil samples within transects) was used to test the significance of differences among elevations and the interaction between sample site and elevation. The variation among sample sites within lake arms was used to test the significance of differences among lake arms. Variance component estimates for sample sites within arms and replicates within transects were calculated as shown in Sokal and Rohlf (1981). Cesium-137 concentrations were $\log10(X+1)$ transformed to better meet the assumptions of ANOVA for homoscedascity and normality (Sokal and Rohlf 1981).

A one-way factorial ANOVA tested for differences in cesium-137 concentrations among different soil types. Three basic soil types (clay, organic, sand) were identified based on field observations and Munsell soil color. Soil samples were assigned to each category based on the predominant component.

Cesium-137 small mammal tissue concentrations were regressed on cesium-137 soil concentrations to determine if concentrations in small mammal tissues could be predicted from soil concentrations. Two models were constructed. One was based on average small mammal tissue concentrations and average soil concentrations at each station ($n = 17$; 15 Par Pond sample sites and 2 reference sample sites) and one was based on average concentrations in small mammal tissues and average soil concentrations at each transect ($n = 32$). Both small mammal tissue and soil concentrations were $\log10(X+1)$ transformed for this analysis.

Contaminant levels in the Par Pond sediments were compared with various soil and sediment criteria for contaminants compiled by several organizations. These criteria included:

- National Oceanographic and Atmospheric Ad-

ministration (NOAA) (Long and Morgan 1990), EPA (1995), and Canadian Council of Ministers of the Environment (CCME) (1995) criteria for contaminants in aquatic sediments, and

- soil contamination criteria derived from a number of sources as summarized in Beyer (1990).

Criteria for both aquatic sediments and soils were used because the substrate sampled during the drawdown could be aquatic sediments or terrestrial soils in the future, depending upon reservoir level. NOAA and CCME aquatic sediment criteria are expressed as probable effect levels (PEL) and threshold effect levels (TEL). The PEL is the concentration above which adverse effects are expected frequently; the TEL is the concentration below which adverse effects are expected infrequently; and the concentrations between the PEL and TEL are expected to cause adverse biological effects occasionally. The EPA aquatic sediment criteria are expressed as screening levels below which adverse effects are unlikely. The soil contamination criteria summarized in Beyer (1990) are usually expressed as soil cleanup criteria; that is, levels below which no remediation is required since they probably do not pose a significant environmental risk.

The methods of Baker and Soldat (1992) were used to calculate the radiation dose to a hypothetical small mammal residing on the exposed sediments of Par Pond. Internal dose was calculated as follows:

$$R_c = \sum_{i=1}^{N} b_i E_i, \text{ where}$$

R_c = the internal dose rate to the whole body (rad/day),
E_i = the effective absorbed energy rate for nuclide i given the radius of the organism, and
b_i = the body burden of nuclide i in the organism.

External dose was calculated as follows:

$$R_s = F_{sed} F_{ruf} \sum_{i=1}^{N} C_i DF_{gnd\,i}, \text{ where}$$

R_s = the external dose rate to the whole body (rad/day),
F_{sed} = the sediment deposition transfer factor,
F_{ruf} = the geometry roughness factor,
DF_{gnd} = the ground irradiation dose factor for nuclide i, and
C_i = the concentration of radionuclides in the sediments.

Baker and Soldat (1992) also included a term for decay rate in their external dose computations. However, this term was not used in the present calculation since the life span of a typical small mammal is very short compared with the half-lives of the radionuclides occurring in the Par Pond sediments. Total dose was the sum of the internal and external doses.

Results and Discussion

Potential Constituents of Concern in Par Pond Exposed Sediments

Of the 26 radionuclides screened by gamma pulse height analysis, 12 were never detected and 4 were detected very infrequently (in fewer than 3% of the samples) in Par Pond soils (Table 1). However, actinium-228, cesium-137, and lead-212 were detected in 100% of the soil samples; and cobalt-60, manganese-54, potassium-40, thorium-234, europium-155, and zirconium-95 were detected in approximately 30-80% of the samples. Neptunium-239 was detected in 9% of the samples. Cesium-137 and cobalt-60 concentrations averaged approximately 10-30 times higher in the Par Pond soils than in the reference site soils. Differences in europium-155, manganese-54, neptunium-239, and zirconium-95 concentrations between Par Pond and reference site soils were relatively small (approximately two fold).

Element-specific analyses were not conducted for alpha and beta emitting radionuclides, although gross alpha and nonvolatile beta emissions were analyzed. Gross alpha levels were slightly higher

Table 1. Concentrations of radionuclides (pCi/g)[1] and mercury (µg/kg)[2] found in Par Pond sediments and reference soils. 1995.

Constituent	Par Pond								Reference locations							
	Average detection limit	Percent above DL[3] (n=149)	Max	Arithmetic mean	Arithmetic mean SE	Geometric mean	Geometric mean confidence limit: Lower	Upper	Average detection limit	Percentt above DL (n=10)	Max	Arithmetic mean	Arithmetic mean SE	Geometric mean	Geometric mean confidence limit: Lower	Upper
Actinium-228	0.033	100	2.35	0.992	0.034	0.949	0.884	1.016	0.025	100	1.25	0.716	0.088	0.696	0.513	0.901
Antimony-124	0.021	0		0.010		0.010			0.01	0		0.005		0.005		
Antimony-125	0.062	0		0.031		0.031			0.023	0		0.012		0.012		
Barium-133	0.024	0		0.012		0.012			0.01	0		0.005		0.005		
Cerium-144	0.108	0	0.148	0.054		0.053			0.058	0		0.028		0.028		
Cesium-134	0.014	1	0.027	0.007		0.007			0.007	0		0.004		0.004		
Cesium-137	0.016	100	56.7	10.912	0.960	7.231	6.198	8.411	0.009	100	0.662	0.306	0.046	0.299	0.204	0.402
Cobalt-57	0.014	0		0.007		0.007			0.007	0		0.004		0.004		
Cobalt-58	0.012	2	0.032	0.006		0.006			0.009	0		0.004		0.004		
Cobalt-60	0.009	69	0.319	0.040	0.005	0.038	0.029	0.047	0.007	0		0.004		0.004		
Europium-152	0.053	0		0.027		0.027			0.023	0		0.012		0.012		
Europium-154	0.084	0		0.042		0.042			0.066	0		0.032		0.032		
Europium-155	0.055	40	0.163	0.053		0.053			0.03	30	0.04	0.024		0.024		
Gross alpha	3.8	93	25.7	8.9	0.4	7.9	7.3	8.6	3.8	100	21.0	7.6	1.874	6.2	3.758	9.999
Lead-212	0.029	100	2.4	1.042	0.035	0.998	0.931	1.066	0.014	100	1.33	0.756	0.095	0.734	0.538	0.955
Manganese-54	0.010	83	0.047	0.018	0.001	0.018	0.017	0.020	0.008	40	0.03	0.009		0.009		
Neptunium-239	0.097	9	0.185	0.055		0.1			0.053	10	0.06	0.028		0.029		
Nonvolatile beta	6.7	85	71.3	17.2	1.1	13.291	11.8	15.0	6.5	40	10.8	5.240		4.7		
Potassium-40	0.086	44	4.38	0.442		0.346			0.07	60	1.51	0.649	0.183	0.554	0.192	1.025
Promethium-144	0.010	0		0.005		0.005			0.008	0		0.004		0.004		

1 picoCuries per gram.
2 micrograms per kilogram or ppb.
3 DL=detection limit.

Table 1 (continued). Concentrations of radionuclides (pCi/g)[1] and mercury (µg/kg)[2] found in Par Pond sediments and reference soils. 1995.

Constituent	Par Pond								Reference locations							
	Average detection limit	Percent above DL[3] (n=149)	Max	Arithmetic mean	Arithmetic mean SE	Geometric mean	Geometric mean confidence limit: Lower	Upper	Average detection limit	Percentt above DL (n=10)	Max	Arithmetic mean	Arithmetic mean SE	Geometric mean	Geometric mean confidence limit: Lower	Upper
Promethium-146	0.032	1		0.016		0.016			0.011	0		0.006		0.006		
Ruthenium-106	0.14	1		0.073		0.07			0.07	0		0.036		0.036		
Sodium-22	0.009	0		0.005		0.005			0.008	0		0.004		0.004		
Thorium-234	0.633	82	2.41	1.035	0.039	0.979	0.905	1.056	0.336	90	5.59	1.642	0.516	1.304	0.582	2.358
Tin-113	0.030	0		0.016		0.016			0.011	0		0.007		0.007		
Yttrium-88	0.012	0		0.006		0.006			0.009	0		0.005		0.005		
Zinc-65	0.020	0		0.010		0.010			0.015	0		0.008		0.008		
Zirconium-95	0.025	32	0.07	0.021		0.021			0.019	0		0.010		0.010		
Mercury (µg/kg)	233.29	85	484.80	76.92	4.83	62.11	56.13	68.72	184.2	100	142.00	67.32	9.87	61.19	44.87	83.33

1 picoCuries per gram.
2 micrograms per kilogram or ppb.
3 DL=detection limit.

in the Par Pond soils than in the reference sites soils but not significantly so (as indicated by overlapping confidence intervals; Table 1). Plutonium-241 and americium-244 have previously been detected in very low concentrations in Par Pond exposed sediments (Whicker et al. 1993) and probably contributed to the alpha radiation observed in this study.

Nonvolatile beta emissions were approximately three times higher in the Par Pond soils than in the reference site soils. Specific constituents that probably contributed to elevated beta emissions in Par Pond include cesium-137, which emits beta as well as gamma radiation; strontium-90, which occurs at very low concentrations in Par Pond exposed sediments (Whicker et al. 1993); and possibly tritium.

Of the 23 metals included in our study, mercury was of greatest interest because Par Pond has been contaminated with mercury from Savannah River water that was pumped into Par Pond (Newman and Messier 1994). Mercury was detected in 85% of the soil samples from Par Pond, and in all of the soil samples from the reference sites (Table 1). Further, mean mercury concentrations in Par Pond soils were quite similar to concentrations in reference site soils. Of the other metals (which were measured only in the four lake arm composite samples and at the two reference sites), none were significantly higher in Par Pond soils than in reference site soils (Table 2).

Of the extensive list of organic compounds screened for, only two were present at concentrations exceeding detection limits (Table 2). Acetone was present in similar concentrations in both Par Pond and reference site soils and xylene exceeded detection limits in only two of four Par Pond samples. There is no historical evidence that Par Pond was contaminated with either material. Both are common laboratory chemicals, and it is probable that their occurrence represents laboratory contamination.

Comparison of the Par Pond soil data with soil contamination criteria indicated that all of the metals for which there are criteria occur at concentrations below those likely to cause environmental harm. Mercury, the metal of greatest interest, was characterized by geometric mean and maximum levels (62 and 485 micrograms per kilogram [µg/kg], respectively; Table 1) below even the comparatively restrictive Canadian criteria for agricultural soils (486 µg/kg; Table 3). None of the organic compounds exceeded soil contamination criteria.

The contamination criteria for aquatic sediments (Table 3) are often more restrictive than those for soils. The maximum mercury level in Par Pond (485 µg/kg) exceeded the EPA screening level (100 µg/kg) and the CCME TEL (174 µg/kg) but not the CCME PEL (490 µg/kg) for mercury in sediments. The average mercury concentration in Par Pond soils (62-77 µg/kg, depending upon whether geometric or arithmetic means are used) was below EPA and CCME screening levels for sediments.

Of the other constituents in Par Pond soils, several were characterized by detection limits that exceeded either the TEL or PEL for sediments. Constituents with detection limits that exceeded the CCME TEL but not the PEL were arsenic and endrin. Constituents with detection limits that exceeded both TEL and PEL were silver, dieldrin, lindane, and DDT-related compounds. While there is no indication that these constituents were elevated in Par Pond compared to reference site concentrations, their relatively high detection limits makes it impossible to eliminate them as possible constituents of concern.

In summary, cesium-137 is the radionuclide of greatest ecological concern, reaffirming the findings of Whicker et al. (1993) in their human health risk assessment of the Par Pond sediments. While several other radionuclides, especially cobalt-60, also were elevated, their activity was much lower indicating their lesser contribution to the total dose.

Table 2. Concentrations of metals (mg/kg) and organics (µg/kg) in Par Pond sediments and reference soils. 1995.

		Par Pond								Reference locations							
Analyte	Units[1]	Average DL[2]	Number of detects (n=4)	Max	Average	SE	Geometric mean	LCI[3]	UCI[4]	Average DL	Number of detects (n=11)	Max	Average	SE	Geometric mean	LCI	UCI
Silver	mg/kg	3.6	0	2	1.7		1.7			3.2	0	2.3	1.4		1.4		
Aluminum	mg/kg	7.1	4	2100	1618.8	165.8	1595.6	1225	2078.9	6.4	10	11600	6456	1036.6	5519.1	3628.7	8394.2
Arsenic	mg/kg	7.1	1	4	3.4		3.4			6.4	0	4.6	2.5		2.8		
Barium	mg/kg	3.6	4	24.7	17.2	3.1	16.4	9.7	27.3	3.2	10	89.8	43.4	8	34.8	20.7	58.1
Beryllium	mg/kg	3.6	4	0.1	0.1	0	0.1	0	0.1	3.2	10	0.3	0.2	0	0.2	0.1	0.2
Calcium	mg/kg	14.2	4	234.9	211.5	18.6	208.7	159.6	272.7	12.9	10	1150	568.7	134.5	348.2	150.8	802.4
Cadmium	mg/kg	3.6	0	2	1.7		1.7			3.2	1	2.3	1.5		1.4		
Cobalt	mg/kg	3.6	4	0.7	0.5	0.1	0.5	0.4	0.7	3.2	10	1	0.6	0.1	0.6	0.5	0.7
Chromium	mg/kg	3.6	4	3.2	2.4	0.3	2.3	1.7	3.2	3.2	10	12.2	6.6	1.1	5.7	3.5	8.8
Copper	mg/kg	3.6	4	2.4	1.8	0.3	1.8	1.1	2.7	3.2	10	6.3	3.3	0.6	2.9	1.8	4.4
Iron	mg/kg	3.6	4	2495	1861.3	293.4	1788.3	1131	2827.1	3.2	10	3700	2227	322.5	2010.3	1460.3	2767.4
Potassium	mg/kg	355	4	85.1	61.5	9.3	59.3	38.5	91.2	321.2	10	226	126	19	110.7	75.7	161.5
Magnesium	mg/kg	3.6	4	56.6	45.4	3.9	45	35.9	56.2	3.2	10	303	134.4	22.7	117.7	81.4	170.1
Manganese	mg/kg	3.6	4	396.2	169.1	76.8	129.9	42.5	392.9	3.2	10	218	137.4	14.7	129	99.2	167.8
Sodium	mg/kg	71.4	1	39.9	32		30.5			64.2	4	46.1	23.7	3.4	21.3	15.2	29.8
Nitrogen	mg/kg	3.6	4	1.3	1	0.1	1	0.6	1.4	3.2	10	5.8	2.5	0.5	2.2	1.3	3.3
Lead	mg/kg	7.1	4	6.1	4.1	0.8	3.9	2.1	6.8	6.4	9	9.8	5.7	0.7	5.3	4	7
Antimony	mg/kg	7.1	1	4	3.4		3.4			6.4	0	4.6	2.7		2.4		
Selenium	mg/kg	7.1	1	4	3.1		2.9			6.4	1	4.6	2.8		2.7		
Thallium	mg/kg	7.1	2	6.4	4.1	0.8	3.9	2.3	6.4	6.4	2	4.6	3	0.3	2.9	2.3	3.7
Vanadium	mg/kg	3.6	4	5.5	3.6	0.7	3.5	2	5.7	3.2	10	16.7	9.9	1.7	8.4	5.3	13.2
Zinc	mg/kg	3.6	4	5.2	3.3	0.7	3.2	1.8	5.1	3.2	10	11.8	6.6	0.9	6.1	4.4	8.3
Cyanide	µg/kg	1320	2	735	506	94	481	288.4	801.8	1178	0	805	572		565.2	505.6	631.7
Tetrachloro-m-xylene	µg/kg	-[5]	-[6]	0	0		0			-	-	0	0		0		
alpha-Benzene hexachloride	µg/kg	22	0	12	11		11			20	0	14	10		10		
alpha-chlordane	µg/kg	44	0	25	22		22			39	0	27	20		19		
Aldrin	µg/kg	22	0	12	11		11			20	0	14	10		10		
beta-Benzene hexachloride	µg/kg	44	0	25	22		22			39	0	27	20		19		
Restneide surrogate	µg/kg	-	-	0	0		0			-	-	0	0		0		

1 mg/kg = milligrams per kilogram or ppm; µg/kg = micrograms per kilogram or ppb.
2 DL = detection limit.
3 LCI = lower confidence interval.
4 UCI = upper confidence interval.
5 Detection limit not given.
6 Could not be calculated because detection limit not given.

Table 2 (continued). Concentrations of metals (mg/kg) and organics (µg/kg) in Par Pond sediments and reference soils. 1995.

		Par Pond								Reference locations							
Analyte	Units[1]	Average DL[2]	Number of detects (n=4)	Max	Average	SE	Geometric mean	LCI[3]	UCI[4]	Average DL	Number of detects (n=11)	Max	Average	SE	Geometric mean	LCI	UCI
delta-Benzene hexachloride	µg/kg	44	0	25	22		22			39	0	27	20		19		
Dieldrin	µg/kg	44	1	25	19		18			39	0	27	20		19		
Endrin ketone	µg/kg	87	0	49	44		43			78	0	55	39		39		
Endrin	µg/kg	44	0	25	22		22			39	0	27	20		19		
Endosulfan I	µg/kg	44	0	25	22		22			39	0	27	20		19		
Endosulfan II	µg/kg	88	0	49	44		44			79	0	55	39		39		
Endosulfan sulfate	µg/kg	88	0	49	44		44			79	0	55	39		39		
gamma-chlordane	µg/kg	44	0	25	22		22			39	0	27	20		19		
Heptachlor	µg/kg	44	0	25	22		22			39	0	27	20		19		
Heptachlor epoxide	µg/kg	44	0	25	22		22			39	0	27	20		19		
Lindane	µg/kg	22	0	12	11		11			20	0	14	10		10		
Methoxychlor	µg/kg	440	0	245	219		218			393	0	275	197		195		
PCB 1016	µg/kg	877	0	491	440		437			789	0	550	394		391		
PCB 1221	µg/kg	877	0	491	440		437			789	0	550	394		391		
PCB 1232	µg/kg	882	0	491	440		437			789	0	550	394		391		
PCB 1242	µg/kg	877	0	491	440		437			789	0	550	394		391		
PCB 1248	µg/kg	877	0	491	440		437			789	0	550	394		391		
PCB 1254	µg/kg	877	0	491	440		437			789	0	550	394		391		
PCB 1260	µg/kg	877	0	491	440		437			789	0	550	394		391		
p,p'-DDD	µg/kg	438	0	246	220		219			394	0	275	197		195		
p,p'-DDE	µg/kg	44	0	25	22		22			39	0	27	20		19		
p,p'-DDT	µg/kg	441	0	246	219		218			394	0	275	197		195		
Toxaphene	µg/kg	869	0	487	436		433			782	0	545	391		387		
1,1,1-Trichloroethane	µg/kg	0.13	0	0.08	0.07		0.07			0.12	0	0.08	0.06		0.06		
1,1,2-Trichloroethane	µg/kg	0.13	0	0.08	0.07		0.07			0.12	0	0.08	0.06		0.06		
Dichloroethylene-1	µg/kg	1.34	0	0.91	0.75		0.75			1.21	0	0.85	0.6		0.6		
1,1-Dichloroethane	µg/kg	0.13	0	0.08	0.07		0.07			0.12	0	0.08	0.06		0.06		
Dichloroethylene-2	µg/kg	0.27	0	0.15	0.13		0.13			0.24	0	0.17	0.12		0.12		
1,2 Dichloroethane-1	µg/kg	0.13	0	0.08	0.07		0.07			0.12	0	0.08	0.06		0.06		
1,2 Dichloropropane	µg/kg	0.13	0	0.08	0.07		0.07			0.12	0	0.08	0.06		0.06		
cis-1,3-Dichloropropene	µg/kg	0.13	0	0.08	0.07		0.07			0.12	0	0.08	0.06		0.06		

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Table 2 (continued). Concentrations of metals (mg/kg) and organics (µg/kg) in Par Pond sediments and reference soils. 1995.

		Par Pond								Reference locations							
Analyte	Units[1]	Average DL[2]	Number of detects (n=4)	Maxi	Average	SE	Geometric mean	LCI[3]	UCI[4]	Average DL	Number of detects (n=11)	Max	Average	SE	Geometric mean	LCI	UCI
trans-1,3-Dichloropropene	µg/kg	0.13	0	0.08	0.07		0.07			0.12	0	0.08	0.06		0.06		
2-Hexanone	µg/kg	2.69	0	1.52	1.34		1.34			2.42	0	1.7	1.21		1.2		
Acetone	µg/kg	13.45	4	20.6	16.16	1.88	15.85	11.5	21.8	12.06	10	25.3	18.71	1.47	18.12	14.98	21.89
Bromodichloromethane	µg/kg	0.13	0	0.08	0.07		0.07			0.12	0	0.08	0.06		0.06		
Chloroethene	µg/kg	0.27	0	0.15	0.13		0.13			0.24	0	0.17	0.12		0.12		
Chloroethane	µg/kg	0.27	0	0.15	0.13		0.13			0.24	0	0.17	0.12		0.12		
Benzene	µg/kg	1.34	0	0.89	0.75		0.74			1.21	0	0.85	0.6		0.6		
Carbon tetrachloride	µg/kg	0.13	0	0.08	0.07		0.07			0.12	0	0.08	0.06		0.06		
Dichloromethane	µg/kg	1.34	0	0.76	0.67		0.67			1.21	0	0.85	0.6		0.6		
Bromomethane	µg/kg	0.27	0	0.15	0.13		0.13			0.24	0	0.17	0.12		0.12		
Chloromethane	µg/kg	0.27	0	0.15	0.13		0.13			0.24	0	0.17	0.12		0.12		
Bromoform	µg/kg	0.13	0	0.08	0.07		0.07			0.12	0	0.08	0.06		0.06		
Chloroform	µg/kg	0.13	0	0.08	0.07		0.07			0.12	0	0.08	0.06		0.06		
Chlorobenzene	µg/kg	0.13	0	0.52	0.18		0.17			0.12	0	0.08	0.06		0.06		
Carbon disulfide	µg/kg	2.68	0	1.52	1.34		1.34			2.42	0	1.7	1.21		1.2		
1,4-Dichlorobenzene-d4	µg/kg	-	-	0	0		0			-	0	0	0		0		
Dibromochloromethane	µg/kg	0.13	0	0.08	0.07		0.07			0.12	0	0.08	0.06		0.06		
Dibromofluoromethane	µg/kg	0	4	0.01	0		0			-	0	0	0		0		
Ethylbenzene	µg/kg	0.13	0	0.08	0.07		0.07			0.12	0	0.08	0.06		0.06		
Toluene-d8	µg/kg	-	-	0	0		0			-	3	0.02	0		0		
Toluene	µg/kg	1.34	1	2.39	1.16		1.06			1.21	0	0.85	0.6		0.6		
Methyl ethyl ketone	µg/kg	2.69	0	1.52	1.34		1.34			2.42	2	2.75	1.23	0.18	1.17	0.86	1.55
Methyl isobutyl ketone	µg/kg	2.69	0	1.52	1.34		1.34			2.42	0	1.7	1.21		1.2		
Styrene	µg/kg	0.13	0	0.08	0.07		0.07			0.12	0	0.08	0.06		0.06		
1,1,2,2-Tetrachloroethane	µg/kg	0.13	0	0.08	0.07		0.07			0.12	0	0.08	0.06		0.06		
Tetrachloroethylene	µg/kg	0.13	0	0.08	0.07		0.07			0.12	0	0.08	0.06		0.06		
Trichloroethylene	µg/kg	0.13	0	0.48	0.17		0.16			0.12	0	0.08	0.06		0.06		
Vinyl acetate	µg/kg	2.68	0	1.52	1.34		1.34			2.42	0	1.7	1.21		1.2		
Xylene	µg/kg	0.4	2	0.46	0.28	0.06	0.28	0.1	0.5	0.36	0	0.25	0.18		0.18		
1,2,4-Trichlorobenzene	µg/kg	4.38	0	2.49	2.2		2.2			8.88	0	10.95	4.44		3.62		
1,2-Dichlorobenzene	µg/kg	43.85	0	24.9	22.05		21.95			88.93	0	109.5	44.45		34.57		

1 mg/kg = milligrams per kilogram or ppm; µg/kg = micrograms per kilogram or ppb.

2 DL = detection limit.

3 LCI = lower confidence interval.

4 UCI = upper confidence interval.

5 Detection limit not given.

6 Could not be calculated because detection limit not given.

Table 2 (continued). Concentrations of metals (mg/kg) and organics (µg/kg) in Par Pond sediments and reference soils. 1995.

		Par Pond								Reference locations							
Analyte	Units[1]	Average DL[2]	Number of detects (n=4)	Max	Average	SE	Geometric mean	LCI[3]	UCI[4]	Average DL	Number of detects (n=11)	Max	Average	SE	Geometric mean	LCI	UCi
1,3-Dichlorobenzene	µg/kg	43.85	0	24.9	22.05		21.95			88.93	0	109.5	44.45		34.57		
1,4-Dichlorobenzene	µg/kg	43.85	0	24.9	22.05		21.95			88.93	0	109.5	44.45		34.57		
2,4,5 -Trichlorophenol	µg/kg	44.38	0	24.9	22.05		21.95			88.87	0	109.5	44.45		34.57		
2,4,6-Tribromophenol	mg/kg	-	1	0.01	0		0			-	1	0.01	0		0		
2,4,6-Trichlorophenol	µg/kg	4.38	0	2.49	2.2		2.2			8.88	0	10.95	4.44		3.62		
2,4-Dichlorophenol	µg/kg	44.38	0	24.9	22.05		21.95			88.93	0	109.5	44.45		34.57		
2,4-Dimethyl phenol	µg/kg	44.38	0	24.9	22.05		21.95			88.93	0	109.5	44.45		34.57		
2,4-Dinitrophenol	µg/kg	443.25	0	249	220.34		219.28			888.2	0	1095	443.93		343.29		
2,4-Dinitrotoluene	µg/kg	4.43	0	2.49	2.2		2.2			8.85	1	10.95	4.02		3.31		
2,6-Dinitrotoluene	µg/kg	4.43	0	2.49	2.2		2.2			8.88	0	10.95	4.44		3.62		
2-Chlorophenol	µg/kg	43.85	0	24.9	22.05		21.95			88.87	1	71.5	36.09		30.65		
2-Chloronaphthalene	µg/kg	43.85	0	24.9	22.05		21.95			88.93	0	109.5	44.45		34.57		
2-Fluorobiphenyl	mg/kg	-	1	0.01	0		0			-	0	0	0		0		
2-Fluorophenol	mg/kg	-	0	0	0		0			-	3	0.01	0		0		
2-Methylnaphthalene	µg/kg	44.38	0	24.9	22.05		21.95			88.93	0	109.5	44.45		34.57		
o-Cresol (2-Methylphenol)	µg/kg	44.38	0	24.9	22.05		21.95			88.87	0	109.5	44.45		34.57		
o-Nitroaniline	µg/kg	44.38	0	24.9	22.05		21.95			88.87	0	109.5	44.45		34.57		
2-Nitrophenol	µg/kg	43.82	0	24.9	22.05		21.95			88.87	0	109.5	44.45		34.57		
3,3'-Dichlorobenzidine	µg/kg	43.82	0	24.9	22.05		21.95			88.87	0	109.5	44.45		34.57		
m/p-Cresol	µg/kg	0.44	0	0.25	0.22		0.22			0.89	0	1.1	0.44		0.41		
m-Nitroaniline	µg/kg	43.85	0	24.9	22.05		21.95			88.93	0	109.5	44.45		34.57		
2-Methyl-4,6-dinitrophenol	µg/kg	438.5	0	249	220.53		219.48			889.3	0	1095	444.5		343.65		
4-Bromophenyl phenyl ether	µg/kg	43.85	0	24.9	22.05		21.95			88.93	0	109.5	44.45		34.57		
4-Chloroaniline	µg/kg	43.85	0	24.9	22.05		21.95			88.93	0	109.5	44.45		34.57		
4-Chloro-m-cresol	µg/kg	43.85	0	24.9	22.05		21.95			88.87	0	109.5	40.91		32.47		
4-Chlorophenyl phenyl ether	µg/kg	43.82	0	24.9	22.05		21.95			88.87	0	109.5	44.45		34.57		
p-Nitroaniline	µg/kg	43.82	0	24.9	22.05		21.95			88.87	0	109.5	44.45		34.57		
4-Nitrophenol	µg/kg	44.38	0	24.9	22.05		21.95			88.47	1	109.5	40.63		32.23		
Acenaphthene	µg/kg	43.85	0	24.9	22.05		21.95			88.87	0	109.5	40.37		32		
Acenaphthylene	µg/kg	43.85	0	24.9	22.05		21.95			88.93	0	109.5	44.45		34.57		
Anthracene	µg/kg	43.82	0	24.9	22.05		21.95			88.87	0	109.5	44.45		34.57		

1 mg/kg = milligrams per kilogram or ppm; µg/kg = micrograms per kilogram or ppb.

2 DL = detection limit.

3 LCI = lower confidence interval.

4 UCI = upper confidence interval.

5 Detection limit not given.

6 Could not be calculated because detection limit not given.

Table 2 (continued). Concentrations of metals (mg/kg) and organics (µg/kg) in Par Pond sediments and reference soils. 1995.

		Par Pond								Reference locations							
Analyte	Units[1]	Average DL[2]	Number of detects (n=4)	Max	Average	SE	Geometric mean	LCI[3]	UCI[4]	Average DL	Number of detects (n=11)	Max	Average	SE	Geometric mean	LCI	UCI
Bis (2-chloroethoxy) methane	µg/kg	43.82	0	24.9	22.05		21.95			88.87	0	109.5	44.45		34.57		
Bis (2-chloroethyl) ether	µg/kg	43.82	0	24.9	22.05		21.95			88.87	0	109.5	44.45		34.57		
Bis (2-ethylhexyl) phthalate	µg/kg	44.38	1	26.9	22.55		22.38			88.87	0	109.5	44.45		34.57		
Benzo[α] anthracene	µg/kg	4.43	0	2.49	2.2		2.2			8.87	0	10.95	4.44		3.62		
Benzo [α] pyrene	µg/kg	4.43	0	2.49	2.2		2.2			8.87	0	10.95	4.44		3.62		
Benzo [β] fluoroanthene	µg/kg	4.38	0	2.49	2.2		2.2			8.88	0	10.95	4.44		3.62		
Butylbenzyl phthalate	µg/kg	43.85	0	24.9	22.05		21.95			88.87	0	109.5	44.45		34.57		
Bis (2-chloroisopropyl) ether	µg/kg	44.38	0	24.9	22.05		21.95			88.87	0	109.5	44.45		34.57		
Benzoic acid	µg/kg	44.38	0	24.9	22.05		21.95			88.93	3	247	95.99	24.01	66.86	34.59	128.39
Benzo [*g,h,i*] perylene	µg/kg	44.38	0	24.9	22.05		21.95			88.87	0	109.5	44.45		34.57		
Benzo [*k*] fluoranthene	µg/kg	4.43	0	2.49	2.2		2.2			8.88	0	10.95	4.44		3.62		
Benzyl alchohol	µg/kg	44.38	0	24.9	22.05		21.95			88.87	0	109.5	44.45		34.57		
Chrysene	µg/kg	4.43	0	2.49	2.2		2.2			8.87	0	10.95	4.44		3.62		
Hexachlorobenzene	µg/kg	4.43	0	2.49	2.2		2.2			8.88	0	10.95	4.44		3.62		
Hexachlorocyclopenta-diene	µg/kg	44.38	0	24.9	22.05		21.95			88.87	0	109.5	44.45		34.57		
Hexachloroethane	µg/kg	4.38	0	2.49	2.2		2.2			8.87	0	10.95	4.44		3.62		
Dibenz [*a,h*] anthracene	µg/kg	4.38	0	2.49	2.2		2.2			8.87	0	10.95	4.44		3.62		
Diethyl phthalate	µg/kg	43.85	0	24.9	22.05		21.95			88.87	0	109.5	44.45		34.57		
Dibenzofuran	µg/kg	43.85	0	24.9	22.05		21.95			88.93	0	109.5	44.45		34.57		
Dimethyl phthalate	µg/kg	44.38	0	24.9	22.05		21.95			88.93	0	109.5	44.45		34.57		
Di-n-butyl phthalate	µg/kg	44.38	0	24.9	22.05		21.95			88.93	0	109.5	44.45		34.57		
Di-n-octyl phthalate	µg/kg	44.38	0	24.9	22.05		21.95			88.93	0	109.5	44.45		34.57		
Fluoranthene	µg/kg	44.38	0	24.9	22.05		21.95			88.93	1	109.5	45.82		36.39		
Fluorene	µg/kg	43.85	0	24.9	22.05		21.95			88.93	0	109.5	44.45		34.57		
Hexachlorobutadiene	µg/kg	43.85	0	24.9	22.05		21.95			88.93	0	109.5	44.45		34.57		
Indeno [1,2,3-*c,d*] pyrene	µg/kg	4.38	0	2.49	2.2		2.2			8.88	0	10.95	4.44		3.62		
Isophorone	µg/kg	43.82	0	24.9	22.05		21.95			88.93	0	109.5	44.45		34.57		
Naphthalene	µg/kg	44.38	0	24.9	22.05		21.95			88.93	0	109.5	44.45		34.57		
Nitrobenzene	µg/kg	44.38	0	24.9	22.05		21.95			88.93	0	109.5	44.45		34.57		

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Table 2 (continued). Concentrations of metals (mg/kg) and organics (µg/kg) in Par Pond sediments and reference soils. 1995.

		Par Pond								Reference locations							
Analyte	Units[1]	Average DL[2]	Number of detects (n=4)	Max	Average	SE	Geometric mean	LCI[3]	UCI[4]	Average DL	Number of detects (n=11)	Max	Average	SE	Geometric mean	LCI	UCI
Nitrobenzene-d5	mg/kg	-	0	0	0		0			-	1	0.01	0		0		
N-Nitrosodipropylamine	µg/kg	43.82	0	24.9	22.05		21.95			88.93	0	109.5	40.41		32.04		
N-Nitrosodiphenylamine	µg/kg	43.82	0	24.9	22.05		21.95			88.87	0	109.5	44.45		34.57		
Pentachlorophenol	µg/kg	43.82	0	24.9	22.05		21.95			88.87	0	109.5	40.21		31.86		
Phenanthrene	µg/kg	43.82	0	24.9	22.05		21.95			88.93	0	109.5	44.45		34.57		
Phenol-d6	mg/kg	-	1	0.01	0		0			-	2	0.01	0		0		
Phenol	µg/kg	44.38	0	24.9	22.05		21.95			88.93	0	109.5	40.69		32.28		
p-Terphenyl-d14	mg/kg	-	1	0.01	0		0			-	1	0.01	0		0		
Pyrene	µg/kg	44.38	0	24.9	22.05		21.95			88.93	0	109.5	41.41		32.84		

1 mg/kg = milligrams per kilogram or ppm; µg/kg = micrograms per kilogram or ppb.

2 DL = detection limit.

3 LCI = lower confidence interval.

4 UCI = upper confidence interval.

5 Detection limit not given.

6 Could not be calculated because detection limit not given.

Table 3. Probable effects levels and threshold effects levels for common constituents found in Par Pond and reference soils.

		Soil		Sediment		
Constituent	Units[1]	NOAA PEL[2]	CCME PEL[3]	EPA screening[4]	NOAA TEL[5]	CCME TEL
Acenaphthylene	ppb			330		
Benz(a)anthracene	ppb		385	330		31.7
Benz(a)pyrene	ppb		782			31.9
Chlordane	ppb		8.9			4.5
Chrysene	ppb		862	330		57.1
DDT	ppb			3.3		
DDT, total	ppb		4450			6.98
Dieldrin	ppb		6.67			2.85
Endrin	ppb		62.4			2.67
Fluoranthene	ppb		2355	330		111
Fluorene	ppb			330		
Heptachlor epoxide	ppb		2.74			0.6
Lindane	ppb		1.38			0.94
Naphthalene	ppb			330		
p,p'-DDD	ppb		8.51			3.54
p,p'-DDE	ppb		6.75			1.42
PAHs, High Molecular Weight	ppb			330		
PAHs, Low Molecular Weight	ppb			330		
Phenanthrene	ppb		515			41.9
Pyrene	ppb		875			53
Total PCBs	ppb		277	33		34.1
Antimony	ppm			12		
Arsenic	ppm	41.6	17		7.24	5.9
Cadmium	ppm		3.53	1		0.596
Chromium	ppm	160.4	90		52.3	37.3
Copper	ppm	106.2	197	28	18.7	35.7
Lead	ppm	112.2	91.3		30.2	35
Mercury	ppb		486	100		174
Nickel	ppm		35.9			18
Silver	ppm			2		
Zinc	ppm		315			123

1 ppb=parts per billion or µg/kg; ppm=parts per million or mg/kg.

2 NOAA PEL-National Oceanographic and Atmospheric Administration Probable Effects Level (1990).

3 CCME PEL-Canadian Council of Ministries of the Environment Probable Effects Level (1995).

4 EPA screening (1995).

5 TEL-Threshold Effects Level.

Of the nonradioactive constituents, mercury concentrations in the sediments should have little or no impact on the environment when the lake bed is exposed and the sediments become terrestrial soils. When the sediments are submerged and mercury bioavailability increases (Manahan 1994), maximum mercury concentrations are high enough to possibly produce deleterious effects but not so high that such effects are certain. Other nonradioactive constituents in Par Pond soils were not elevated in relation to the reference site soils nor did they exceed existing aquatic sediment contaminant criteria. However, some organic compounds were not measured with sufficient resolution to definitively eliminate them as constituents of concern.

Spatial Distribution of Cesium-137 in Exposed Sediments

Because cesium-137 may be the most important contaminant in Par Pond soils, its spatial distribution was investigated closely. Differences in cesium-137 concentration among lake arms were not significant (Table 4). In contrast, there were highly significant differences among elevations and sample sites. Concentrations were usually higher at the 57-58-m (190-195 feet) above msl elevation (geometric mean of 8.56 pCi/g) than at the 58-61-m (195.1-200 feet) above msl elevation (geometric mean of 4.86 pCi/g). However, this was not always the case as indicated by the significant interaction between elevation and site (3 of the 15 stations had lower cesium-137 concentrations at the 57-58 m [190-195 feet] elevation). In summary, cesium-137 concentrations were generally higher downslope, in areas that should remain submerged during natural water level fluctuation cycles. (See Appendix A for a comparison of upslope and downslope concentrations of all radionuclides.) However, the distribution of cesium-137 in Par Pond sediments was quite patchy on both large and small spatial scales. Large scale patchiness is indicated by significant differences among sample sites. Small scale patchiness is indicated by the variance component estimate for individual soil measurements, which was more than three times greater within transects than the variance component estimate for sites within arms (Table 4).

The spatial distribution of cesium-137 on the exposed sediments was related to sediment type. Analysis of variance indicated that cesium-137 concentrations significantly differed among the three sediment categories identified (ANOVA, $P<0.001$). The highest cesium-137 concentrations occurred in sediments that were primarily organic (geometric mean of 10.71 pCi/g), followed by sediments that were predominantly sand (5.85 pCi/g), and sediments that were predominantly clay (1.86 pCi/g). Sediment type could be very heterogeneous on a scale of several meters or less as a result of erosion following the drawdown and possibly biological and physical processes operating when the reservoir was full. The association of cesium-137 with certain types of sediments combined with the heterogeneous distribution of these sediments undoubtedly contributed to the spatial variation in cesium-137 concentrations observed in Par Pond.

The arithmetic mean cesium-137 concentration (approximately 11 pCi/g; Table 1) measured in the Par Pond exposed sediments during 1995 is substantially lower than the cesium-137 concentrations (in excess of 30 pCi/g) reported by Whicker et al. (1993). The higher average concentration reported by Whicker et al. (1993) may reflect the occurrence of relatively high cesium-137 concentrations at elevations below the 58 m (190 foot) contour where samples were not collected (Whicker et al. sampled between the 55 and 61 m [180 and 200 foot] contours) since cesium-137 concentrations tend to be higher in the deeper parts of Par Pond (Winn 1993). It is also possible that cesium-137 concentrations were higher within the 58-61 m (190-200 foot) contours during 1993 than during 1995. Erosion and downslope transport of sediments containing cesium-137 may have occurred after 1992, resulting in reduced cesium-137 concentrations within the 58-61-m (190-200-foot) contours by 1995.

Table 4. Analysis of variance of cesium-137 concentrations in the exposed sediments of Par Pond between the elevations of 58 and 61 m (190 and 200 feet) above mean sea level. 1995.

Source of variation	Mean square	F ratio	P	Variance estimate component
Elevation[1]	3.19	36.52	<0.001	
Sample site x Elevation interaction	0.66	7.55	<0.001	
Lake arm[2]	0.11	0.32	<0.812	
Sites within lake arms	0.35	4.04	<0.001	0.027
Residual	0.09			0.087

1. 58-59 m (190-195 feet) above mean sea level (msl) vs 59-61 (195.1-200 feet) above msl.
2. North Arm, South Arm, Middle Arm, and Main Body.

The spatial distributions of cesium-137 and total mercury were investigated to determine if they were similar, since this information could be important if remediation of Par Pond sediments became a requirement. Regression analysis indicated a significant relationship ($P<0.001$) between sediment mercury and cesium-137 concentrations; however, the R^2 of this relationship was comparatively low (0.25; Figure 2). Cesium-137 and mercury exhibited some similarity in distribution patterns, but much of the variability of each was unrelated to the variability of the other.

Constituents in Small Mammal Tissues

Although other species of small mammals were collected from Par Pond, cotton rats (*Sigmodon hispidus*) were selected for detailed analysis because they were most abundant, most widespread, and had the greatest tissue mass. There were 29 tissue transect samples from individual sample sites in Par Pond (including several duplicate samples from the same station), 4 composite lake arm samples, and 2 samples from reference sites. Other small mammal species were not collected in sufficient quantities from each site for tissue analysis.

Twenty-three nonradioactive constituents were examined in cotton rat tissues. Metals were generally analyzed in all of the samples while other constituents were measured only in the composite lake arm samples. Eighteen constituents were present in detectable concentrations. Several of these including calcium, potassium, magnesium, and sodium are macronutrients normally found in animal tissues in large quantities. Others, such as zinc and selenium, are micronutrients that can be toxic at high levels but are necessary in small quantities for good health. Lack of replication at the reference sites precluded statistical comparisons of these constituents between cotton rats from Par Pond and from the reference sites. However, there is no evidence that any of these compounds were present in toxic concentrations in Par Pond soils. None exceeded the soil screening criteria (Table 3) and many were present in comparable or higher concentrations in the reference site soils.

Mercury was present in detectable concentrations in 37% of the 29 cotton rat samples from individual sample sites at Par Pond (Table 5). The maximum and geometric mean concentrations were 30 and 11 µg/kg, respectively. These concentrations were lower than the mercury concentrations in the soil (Table 1), indicating that mercury was not bioconcentrated in cotton rats from Par Pond.

Table 5. Concentrations of radionuclides (pCi/g), mercury (µg/kg), and other metals (mg/kg) in cotton rat tissue from Par Pond and reference transect samples. 1995.

	Par Pond								Reference locations[1]							
Constituent	Average DL[2]	Percent detects (n=29)	Max	Arithmetic mean	SE	Geometric mean	LCI[3]	UCI[4]	Average DL	Percent detects (n=2)	Max	Arithmetic mean	SE	Geometric mean	LCI	UCI
Actinium-228	0.56	0	0.60	0.28		0.28			0.65	0	0.39	0.33		0.32		
Antimony-124	2.10	0	1.79	1.05		1.02			1.95	0	1.16	0.98		0.97		
Antimony-125	0.87	0	0.76	0.44		0.43			0.39	0	0.23	0.20		0.20		
Barium-133	0.30	0	0.25	0.15		0.15			0.17	0	0.10	0.08		0.08		
Cerium-144	1.56	0	1.42	0.78		0.76			1.08	0	0.60	0.54		0.54		
Cesium-134	0.20	0	0.20	0.10		0.10			0.16	0	0.10	0.08		0.08		
Cesium-137	0.17	100	181.00	71.99	8.72	56.97	42.97	75.44	0.14	50	0.78	0.42		0.38		
Cobalt-57	0.20	0	0.18	0.10		0.10			0.14	0	0.08	0.07		0.07		
Cobalt-58	0.93	0	0.87	0.46		0.45			1.37	0	0.83	0.68		0.68		
Cobalt-60	0.15	0	0.17	0.07		0.07			0.18	0	0.10	0.09		0.09		
Europium-152	0.66	0	0.57	0.33		0.32			0.37	0	0.21	0.19		0.18		
Europium-154	1.23	0	1.35	0.62		0.60			1.50	0	0.87	0.76		0.76		
Europium-155	0.52	0	0.48	0.26		0.25			0.35	0	0.19	0.17		0.17		
Gross alpha	2.03	55	10.20	2.51	0.39	2.12	1.62	2.72	2.17	50	1.39	1.13		1.11		
Lead-212	0.41	21	0.47	0.25		0.25			0.26	50	0.53	0.33		0.32		
Manganese-54	0.19	3	0.19	0.10		0.10			0.21	0	0.13	0.11		0.11		
Neptunium-239	0.88	0	0.84	0.44		0.43			0.59	0	0.34	0.29		0.29		
Nonvolatile beta	2.42	100	150.00	70.30	6.82	61.43	49.96	75.47	2.56	100	13.40	12.64	0.76	12.62	5.71	26.67
Potassium-40	1.35	93	12.70	9.67	0.47	8.98	7.33	10.97	1.20	100	12.50	11.98	0.52	11.96	6.73	20.74
Promethium-144	0.18	0	0.18	0.09		0.09			0.21	0	0.12	0.10		0.10		
Promethium-146	0.43	0	0.38	0.21		0.21			0.17	0	0.11	0.09		0.09		
Radium-226	0.38	14	0.53	0.24		0.24										
Radium-228	0.59	0	0.60	0.29		0.29										
Ruthenium-106	2.37	0	2.41	1.19		1.14			1.65	0	1.00	0.85		0.85		
Sodium-22	0.16	0	0.17	0.08		0.08			0.20	0	0.10	0.10		0.10		
Thorium-234	5.02	38	13.90	4.50	0.60	3.77	2.90	4.85	3.30	100	6.04	4.19	1.85	3.85	-0.96	55.71
Tin-113	1.14	0	0.90	0.57		0.55			0.63	0	0.35	0.30		0.30		
Yttrium-88	0.54	0	0.45	0.27		0.27			0.78	0	0.46	0.39		0.39		
Zinc-65	0.50	0	0.49	0.25		0.25			0.65	0	0.37	0.31		0.31		
Zirconium-95	2.08	0	1.88	1.04		1.01			2.77	0	1.56	1.39		1.38		

1 These data are repeated in Table 6.
2 DL = average detection limit.
3 LCI = lower confidence interval.
4 UCI = upper confidence interval.

Table 5 (continued). Concentrations of radionuclides (pCi/g), mercury (µg/kg), and other metals (mg/kg) in cotton rat tissue from Par Pond and reference transect samples. 1995.

	Par Pond								Reference locations[1]							
Constituent	Average DL[2]	Percent detects (n=29)	Max	Arithmetic mean	SE	Geometric mean	LCI[3]	UCI[4]	Average DL	Percent detects (n=1)	Max	Arithmetic mean	SE	Geometric mean	LCI	UCI
Total silver	1189	3	625	460	66	595	261	1357	1110	0	555					
Total arsenic	28023	0	36850	12720	2498	11044	3717	32808	15800	0	7900					
Total barium	1079	100	30900	21312	608	21074	19919	22295	306	100	9800					
Total cadmium	400	20	765	190	35	149	119	186	1420	0	710					
Total chromium	1871	87	3325	1441	126	1307	1106	1545	6160	0	3080					
Total mercury	30.57	37	29.70	13.47	1.02	11.03	8.15	14.83	15.65	0	8.45					
Total manganese	1318	13	14741	10913	705	10712	3237	35438	3750	100	1950					
Total nickel	2265	13	1258	741	53	654	282	1514	5420	0	2710					
Total lead	4737	27	2500	2187	61	2156	2012	2310	4410	0	2205					
Total selenium	33767	7	36850	15977	2446	12432	6179	25011	58300	0	29150					

1 These data are repeated in Table 6.
2 DL = average detection limit.
3 LCI = lower confidence interval.
4 UCI = upper confidence interval.

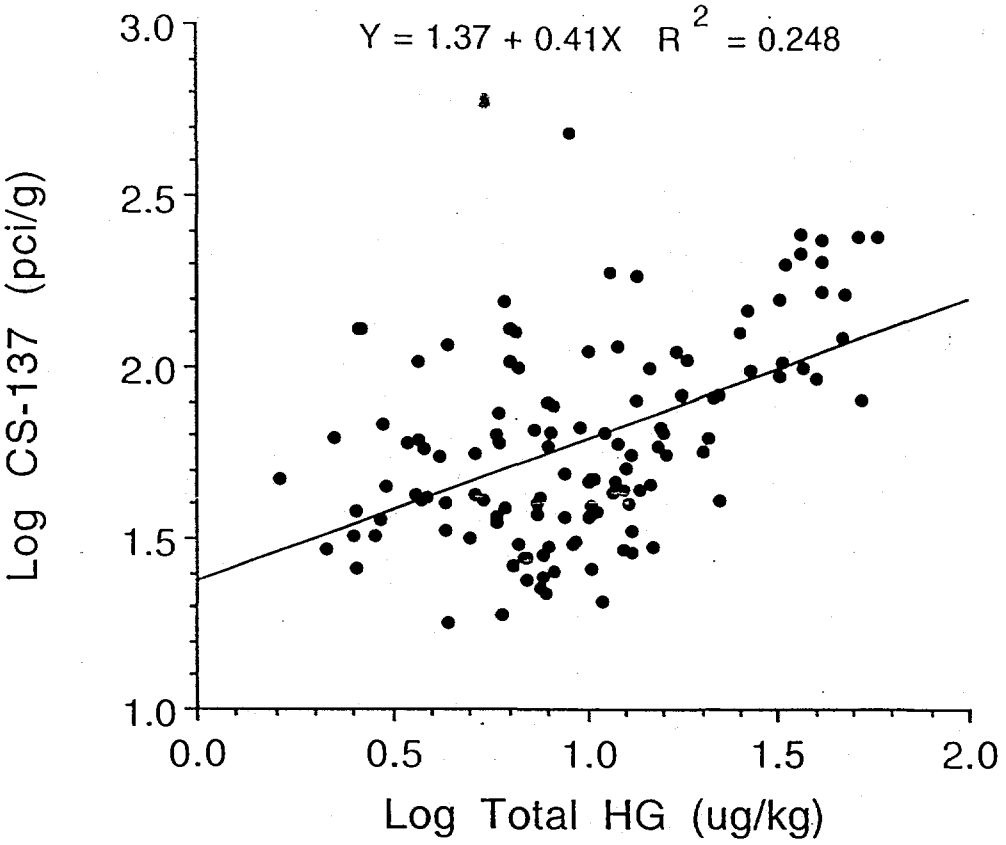

Figure 2. Relationship between cesium-137 and total mercury concentrations in Par Pond exposed sediments.

Nine radionuclides plus gross alpha and nonvolatile beta were present in detectable concentrations in tissue samples from Par Pond, and six radionuclides plus gross alpha and nonvolatile beta were present in detectable concentrations in tissue samples from the reference sites (note that strontium and plutonium were only analyzed for in the lake arm composite samples; Table 6). Three of the radionuclides in the Par Pond cotton rats (lead-212, manganese-54, and radium-226) were detected infrequently and barely exceeded detection limits (Table 5). Potassium-40 and thorium-234 were detected more frequently or in slightly higher concentrations in the tissue composites from the reference sites than in those from Par Pond. Gross alpha exceeded the detection limit in approximately 50% of the samples from both Par Pond and the reference sites but occurred in higher concentrations in Par Pond (Table 5). Reasons for this difference are uncertain, although the small number of reference site samples renders this comparison problematical. Of specific alpha-emitting radionuclides measured in Par Pond and reference site soils, plutonium-238 concentrations were slightly higher in Par Pond than at the reference sites and plutonium-239/240 concentrations were approximately comparable in both areas. Concentrations of strontium-90, a beta-emitting radionuclide, were also comparable between the Par Pond and reference sites.

Only two radioactive constituents were present in Par Pond cotton rat tissues in concentrations well in excess of detection limits and much higher than in reference site cotton rat tissues: cesium-137 and nonvolatile beta. The geometric mean cesium-137 specific activity in Par Pond cotton rats (57 pCi/g) was more than 100 times higher than in reference site cotton rats (0.38 pCi/g). The geometric mean

Table 6. Concentrations of radionuclides (pCi/g), mercury (μg/kg) and other metals (mg/kg) in composite tissue samples from Par Pond lake arm and reference locations.

	Par Pond								Reference locations[1]							
Constituent	Average DL[2]	Percent defects (n=3 or 4)	Max	Arithmetic mean	SE	Geometric mean	LCI[3]	UCI[4]	Average DL	Percent detects (n=2)	Max	Arithmetic mean	SE	Geometric mean	LCI	UCI
Actinium-228	0.56	0	0.36	0.28		0.28			0.66	0	0.39	0.33		0.32		
Antimony-124	2.5	0	1.55	1.25		1.22			1.95	0	1.16	0.98		0.97		
Antimony-125	0.92	0	0.61	0.46		0.45			0.39	0	0.23	0.2		0.2		
Barium-133	0.32	0	0.21	0.16		0.16			0.16	0	0.1	0.08		0.08		
Cerium-144	1.6	0	0.99	0.8		0.79			1.08	0	0.6	0.54		0.54		
Cesium-134	0.2	0	0.12	0.1		0.1			0.16	0	0.1	0.08		0.08		
Cesium-137	0.18	100	115	83	24.88	73.29	13.58	377.6	0.14	50	0.78	0.42		0.38		
Cobalt-57	0.21	0	0.13	0.1		0.1			0.14	0	0.08	0.07		0.07		
Cobalt-58	1.06	0	0.73	0.53		0.52			1.37	0	0.83	0.68		0.68		
Cobalt-60	0.15	0	0.09	0.07		0.07			0.18	0	0.1	0.09		0.09		
Europium-152	0.67	0	0.44	0.34		0.33			0.37	0	0.21	0.19		0.18		
Europium-154	1.24	0	0.82	0.62		0.61			1.5	0	0.87	0.76		0.76		
Europium-155	0.51	0	0.3	0.25		0.25			0.35	0	0.19	0.17		0.17		
Gross alpha	2.07	33	2.21	1.47		1.41			2.17	50	1.39	1.13		1.11		
Lead-212	0.43	33	0.62	0.35		0.34			0.27	50	0.53	0.33		0.32		
Manganese-54	0.21	0	0.15	0.1		0.1			0.21	0	0.13	0.11		0.11		
Neptunium-239	0.86	0	0.53	0.43		0.43			0.59	0	0.34	0.29		0.29		
Nonvolatile Beta	2.58	100	123	79.2	28.43	65.88	8.05	493.42	2.55	100	13.4	12.64	0.76	12.62	5.71	26.67
Plutonium-238	0.05	25	0.09	0.04		0.04			0.06	0	0.03	0.03		0.03		
Plutonium-239/240	0.02	50	0.01	0.01	0	0.01	0.01	0.02	0.01	100	0.01	0.01	0	0.01	-0.07	0.1
Potassium-40	1.29	100	11.9	11.27	0.35	11.26	9.86	12.84	1.2	100	12.5	11.98	0.52	11.96	6.73	20.74
Promethium-144	0.2	0	0.13	0.1		0.1			0.21	0	0.12	0.1		0.1		
Promethium-146	0.44	0	0.3	0.22		0.22			0.17	0	0.11	0.09		0.09		
Ruthenium-106	2.44	0	1.51	1.22		1.19			1.65	0	1	0.85		0.85		
Sodium-22	0.16	0	0.11	0.08		0.08			0.19	0	0.1	0.1		0.1		
Strontium-90	0.07	100	2.19	1.21	0.42	1.09	-0.1	3.87	0.04	100	1.99	1.42	0.57	1.35	-0.89	49.87
Thorium-234	4.57	67	8.62	5.64	1.64	5.23	1.06	17.8	3.25	50	6.04	4.19		3.85		
Tin-113	1.25	0	0.85	0.62		0.61			0.63	0	0.35	0.3		0.3		
Yttrium-88	0.62	0	0.43	0.31		0.31			0.77	0	0.46	0.39		0.39		
Zinc-65	0.5	0	0.32	0.25		0.25			0.61	0	0.37	0.31		0.31		
Zirconium-95	2.63	0	1.65	1.31		1.29			2.77	0	1.56	1.39		1.38		
										(n=1)						
Total silver	1153	0	600	577		576			1110	0	555					
Total aluminum	8470	100	18500	12447	4255	10463	1466	74657	6670	100	5640					

1 These data are repeated in Table 5.

2 DL = average detection limit.

3 LCI = lower confidence interval.

4 UCI = upper confidence interval.

Table 6 (continued). Concentrations of radionuclides (pCi/g), mercury (µg/kg) and other metals (mg/kg) in composite tissue samples from Par Pond lake arm and reference locations.

	Par Pond								Reference locations[1]							
Constituent	Average DL[2]	Percent defects (n=3 or 4)	Max	Arithmetic mean	SE	Geometric mean	LCI[3]	UCI[4]	Average DL	Percent detects (n=2)	Max	Arithmetic mean	SE	Geometric mean	LCI	UCI
Total arsenic	15567	0	8550	7783		7755			15800	0	7900					
Total barium	598	100	28600	23933	3623	23322	11439	47548	306	100	9800					
Total beryllium	366	0	232	183		180			306	0	153					
Total calcium	4538	100	5.70E+07	5.30E+07	300E+0	5.00E+07	4.00E+07	7.00E+07	972	100	3.00E+07					
Total cadmium	1054	0	765	527		396			1420	0	710					
Total cobalt	2404	100	1370	1273	61	1270	1032	1564	3260	0	1630					
Total chromium	4637	33	3325	2592		2422			6160	0	3080					
Total copper	5757	100	5630	4903	368	4877	3565	6672	7780	0	3890					
Total iron	2407	100	191000	162333	18774	160043	95108	269314	1250	100	44000					
Total mercury	20	33	35.9	15.81		12.56			15.65	0	8.45					
Total potassium	56933	100	8310000	7923333	225192	8.00E+06	7.00E+06	9.00E+06	37800	100	2.00E+06					
Total magnesium	3653	100	1470000	1333333	71259	1.00E+06	1.00E+06	2.00E+06	3060	100	576000					
Total manganese	2744	100	12500	7883	2315	7290	2267	23434	3750	100	1950					
Total sodium	30000	100	3910000	3690000	110151	4.00E+06	3.00E+06	4.00E+06	21100	100	1.00E+06					
Total nickel	4127	33	2925	2110		1783			5420	0	2710					
Total lead	4587	67	3170	2665	259	2641	1760	3962	4410	0	2205					
Total antimony	3950	0	2315	1975		1960			3490	0	1745					
Total selenium	44900	0	31500	22450		18496			58300	0	29150					
Total thallium	10480	0	6950	5240		5109			8470	0	4235					
Total vanadium	1394	0	970	697		585			1800	0	900					
Total zinc	510	100	70900	67100	1901	67048	59445	75622	292	100	25800					

1 These data are repeated in Table 5.

2 DL = average detection limit.

3 LCI = lower confidence interval.

4 UCI = upper confidence interval.

specific activity of nonvolatile beta-emitting radionuclides in Par Pond cotton rat tissue (61 pCi/g) was approximately five times higher than in reference site cotton rat tissues (13 pCi/g). The relatively high level of cesium-137 in Par pond cotton rats probably accounts for most of their nonvolatile beta activity.

Geometric mean cesium-137 specific activity in Par pond cotton rats (57 pCi/g) was approximately eight times higher than in Par Pond soils (7.2 pCi/g; Table 1), reflecting bioaccumulation of this constituent. Bioaccumulation of cesium-137 has been observed in cotton rats from Oak Ridge (TN) as a result of consumption of cesium-137 contaminated vegetation (Garten 1979) and in large herbivorous mammals (moose, sheep, etc.) in areas contaminated by Chernobyl fallout (Rosen et al. 1995; Johanson et al. 1994). Comparison of soil to tissue ratios for the other radionuclides indicated that only potassium-40 exhibited similar tendencies to bioaccumulate (although definite conclusions were impossible for radionuclides that were below detection levels). However, potassium-40 specific activity was as high in reference site soils as in Par Pond soils (Table 1), suggesting that its occurrence in Par Pond was unrelated to releases of contaminated water from P or R Reactors.

Cesium-137 specific activity is generally as high or higher in the forage of terrestrial herbivores than in the herbivores themselves (Rosen et al. 1995; Johanson et al. 1994). Whicker (1993) reported relatively high cesium-137 specific activity levels (approximately 60 pCi/g) in vegetation (species unknown) collected from the exposed sediments of Par Pond. Consumption of contaminated vegetation was undoubtedly responsible for the cesium-137 body burdens observed in cotton rats, which are largely herbivorous.

Because cesium-137 in the plants consumed by herbivores is derived from the soil, cesium-137 levels in cotton rat tissue may be related to cesium-137 levels in the soil. To test this hypothesis, the average cotton rat cesium-137 concentration at each sample site (for which there was at least one rat tissue sample) was regressed on the average soil cesium-137 concentration at each corresponding sample site (n = 12, including a control sample station). The R^2 for this relationship was 0.90 ($P<0.0001$) (Figure 3).

The average cotton rat tissue cesium-137 concentration at each transect within each sample site was regressed on the average soil cesium-137 concentration at each transect within each sample site. The R^2 for this relationship was lower, 0.57, but still significant ($P<0.0001$) (Figure 4). Because cotton rats are mobile, they integrate cesium-137 concentrations over their entire foraging range. Therefore, cesium-137 concentrations in rat tissues should be more strongly correlated with the average cesium-137 soil concentrations in their foraging range than with cesium-137 soil concentrations in areas smaller than their foraging range (approximately 1 hectare [2.5 acres] L. D. Wike, personal communication). It is likely that the scale represented by the sample sites rather than the scale represented by the transects within the sample sites was nearer to the size of the cotton rat foraging range, resulting in the higher R^2 for the regression at the sample station scale.

The tendency of cotton rats to bioaccumulate cesium-137 and the strong relationship between cesium-137 concentrations in cotton rat tissues and the ambient soil suggest that this species is an appropriate sentinel for detecting environmental cesium-137 contamination. Other advantages of the cotton rat in this respect are its commonness in a wide range of habitats and its restrictive home range. Because of a restrictive home range, cesium-137 contamination in cotton rats is indicative of local soil contamination; identifying the source of contamination in a more wide-ranging animal is difficult. Also, cotton rats are relatively short-lived (approximately one year on average) and the biological half-life of cesium-137 in cotton rats is relatively short (Garten 1979). Therefore, cesium-137 levels in cotton rat tissue should

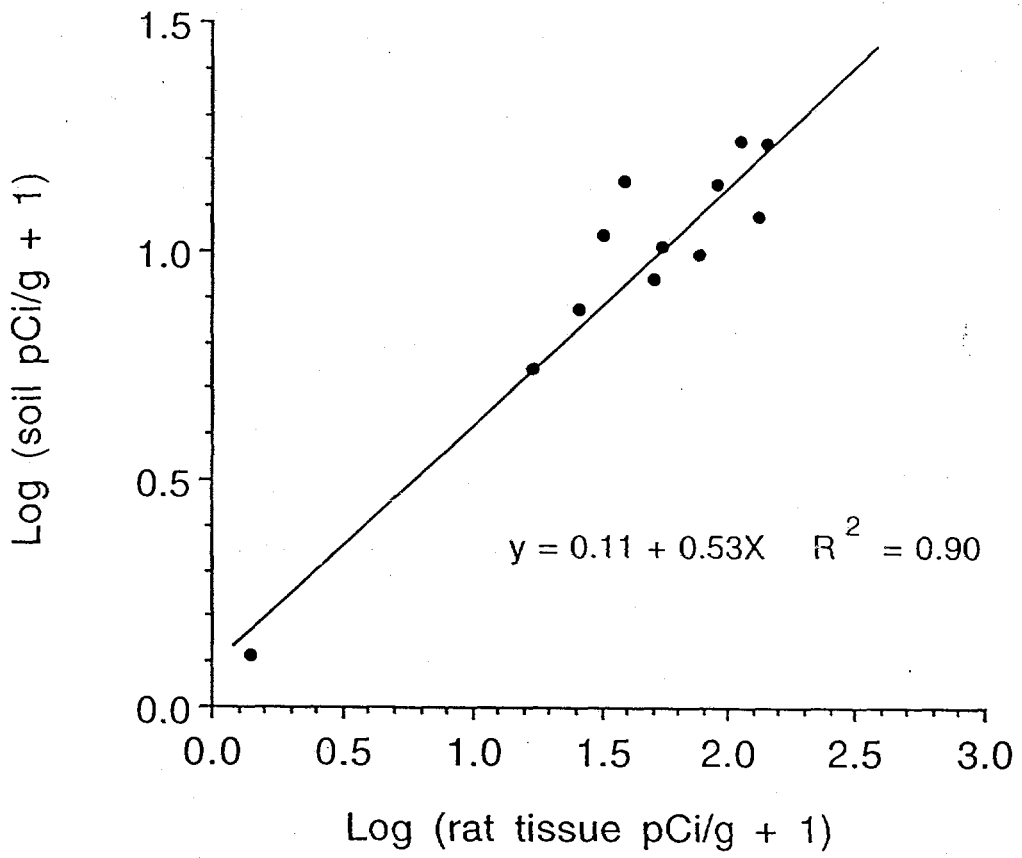

Figure 3. Relationship between cesium-137 levels in Par Pond sediments and in cotton rat tissues.

be indicative of current soil contamination rather than contamination levels associated with past conditions.

Radiation Dose to Small Mammals

The preceding analyses indicate that cesium-137 probably poses the greatest threat to terrestrial organisms residing on the exposed sediments of Par Pond. To determine the magnitude of this threat, the radiation dose to a cotton rat residing on the sediments was calculated. The cotton rat is common, representative of small organisms that live close to the substrate, and has a limited home range. Small organisms with a limited home range may spend all of their time in a contaminated area of limited size (e.g., the exposed sediments); hence they may be more likely to suffer detrimental effects than larger animals that wander over a large area. The total dose (internal and external) was 0.003 rad/day. This estimate was based on the maximum cesium-137 concentration in Par Pond sediments (57 pCi/g) and the maximum body burden in cotton rats (181 pCi/g). This level is well below the 1 rad/day limit for native organisms set by the U.S. Department of Energy suggesting that cesium-137 levels in the Par pond sediments between the elevations of 58 and 61 m (190 and 200 feet) above msl are unlikely to have detectable population-level effects on terrestrial organisms.

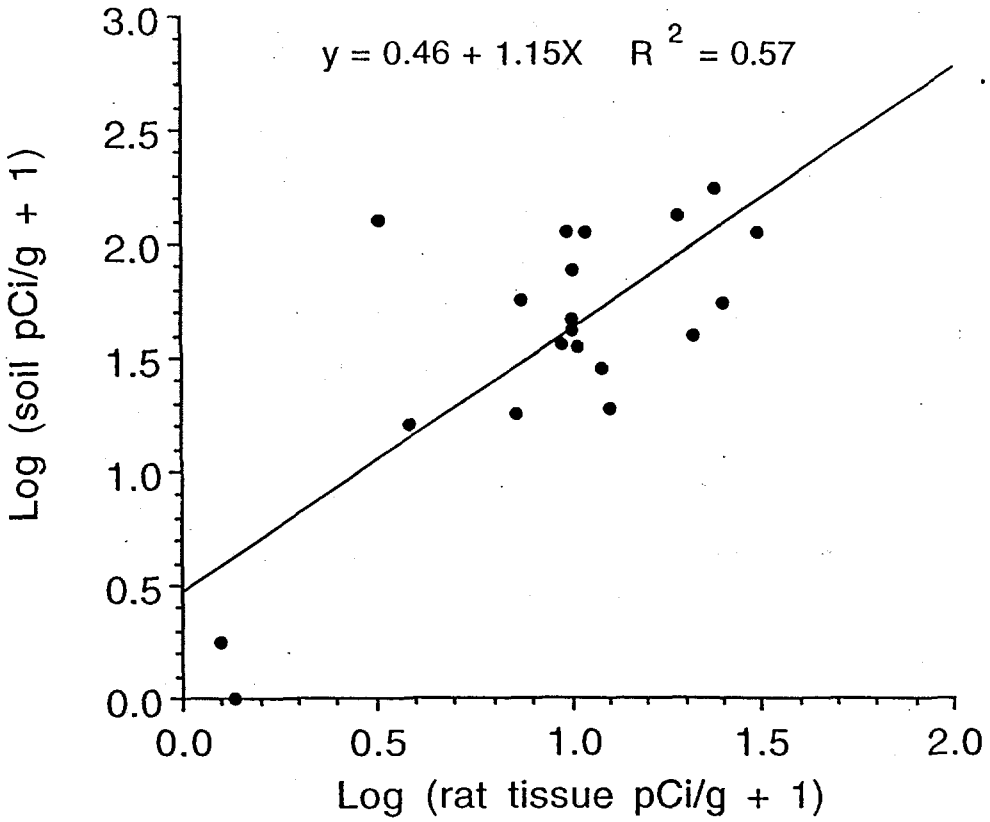

Figure 4. Relationship between cesium-137 levels in Par Pond sediments and in cotton rat tissues. Average data from each transect are shown.

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Appendix A

Elevation-Related Differences in Radionuclide (pCi/g) and Mercury (µg/kg) Concentrations in Par Pond Sediments, 1995

Constituent	Average detection limit (pCi/g)	Percent above DL (n=74)	Max	Average	SE	Geometric mean	Confidence limit Lower	Confidence limit Upper
Downslope: 58-59 m (190-195 feet) above mean sea level								
Actinium-228	0.033	100	1.98	0.99	0.038	0.963	0.89	1.04
Antimony-124	0.022	0	0.025	0.011		0.012		
Antimony-125	0.067	0	0.084	0.033		0.033		
Barium-133	0.025	0	0.03	0.013		0.012		
Cerium-144	0.113	0	0.116	0.057		0.057		
Cesium-134	0.015	1	0.018	0.008		0.007		
Cesium-137	0.016	100	56.7	13.771	1.445	9.965	8.173	12.106
Cobalt-57	0.015	0	0.015	0.007		0.007		
Cobalt-58	0.012	3	0.011	0.006		0.007		
Cobalt-60	0.009	84	0.303	0.052	0.007	0.05	0.036	0.063
Europium-152	0.057	0	0.067	0.029		0.028		
Europium-154	0.085	0	0.087	0.042		0.042		
Europium-155	0.058	38	0.163	0.053		0.052		
Gross alpha	3.201	97	25.7	9.188	0.536	8.29	7.407	9.265
Lead-212	0.031	100	2.06	1.04	0.039	1.014	0.938	1.092
Manganese-54	0.01	85	0.039	0.018	0.001	0.019	0.017	0.02
Neptunium-239	0.102	14	0.185	0.061		0.062		
Nonvolatile beta	6.529	92	71.3	20.768	1.67	16.906	14.45	19.752
Potassium-40	0.087	54	4.38	0.622	0.09	0.486	0.354	0.63
Promethium-144	0.01	0	0.009	0.005		0.005		
Promethium-146	0.035	0	0.042	0.017		0.016		
Ruthenium-106	0.154	1	0.23	0.078		0.076		
Sodium-22	0.009	0	0.009	0.005		0.005		
Thorium-234	0.66	82	2.14	1.027	0.052	0.977	0.875	1.085
Tin-113	0.033	0	0.039	0.017		0.016		
Yttrium-88	0.012	0	0.011	0.006		0.007		
Zinc-65	0.02	0	0.019	0.01		0.009		
Zirconium-95	0.026	26	0.058	0.021		0.021		
Mercury (µg/kg)	225.53	93	244	70.43	6.85	54.38	46.23	63.94
Upslope: 59-61 m (195-200 feet) above mean sea level								
Actinium-228	0.03353	100	2.35	0.99495	0.057	0.935	0.828	1.049
Antimony-124	0.01903	0	0.03765	0.00961		0.01		
Antimony-125	0.05764	0	0.124	0.02891		0.029		

Appendix A (continued)

Constituent	Average detection limit (pCi/g)	Percent above DL (n=74)	Max	Average	SE	Geometric mean	Confidence limit Lower	Confidence limit Upper
Barium-133	0.02212	0	0.04485	0.01119		0.011		
Cerium-144	0.10217	0	0.1475	0.05052		0.05		
Cesium-134	0.01381	0	0.0271	0.00693		0.007		
Cesium-137	0.01552	100	51.7	8.091	1.181	5.196	4.15	6.454
Cobalt-57	0.01295	0	0.01895	0.00649		0.006		
Cobalt-58	0.01176	3	0.0323	0.00659		0.007		
Cobalt-60	0.00964	55	0.319	0.02716	0.006	0.026	0.015	0.037
Europium-152	0.05072	0	0.098	0.02543		0.025		
Europium-154	0.08278	0	0.099	0.04116		0.041		
Europium-155	0.05281	43	0.138	0.0542		0.054		
Gross alpha	4.44267	89	18.7	8.57469	0.495	7.561	6.637	8.597
Lead-212	0.02702	100	2.4	1.04447	0.059	0.983	0.873	1.1
Manganese-54	0.01024	77	0.047	0.01787	0.001	0.018	0.015	0.02
Neptunium-239	0.09116	5	0.134	0.04878		0.049		
Nonvolatile beta	7.07107	77	53.8	13.63216	1.361	10.439	8.775	12.387
Potassium-40	0.08688	35	1.26	0.26365		0.222		
Promethium-144	0.0104	0	0.01105	0.0052		0.005		
Promethium-146	0.0294	1	0.0645	0.01475		0.015		
Ruthenium-106	0.1364	0	0.281	0.0687		0.068		
Sodium-22	0.00944	0	0.00995	0.00472		0.005		
Thorium-234	0.61231	81	2.41	1.04176	0.057	0.981	0.871	1.098
Tin-113	0.0291	0	0.0575	0.01436		0.014		
Yttrium-88	0.01198	0	0.0126	0.00622		0.006		
Zinc-65	0.02005	0	0.0256	0.01007		0.01		
Zirconium-95	0.02489	37	0.0701	0.02193		0.022		
Mercury (µg/kg)	237.23	77	484.8	82.99	6.81	70.35	61.99	79.82