WSRC-TR-95-0272

Measurements of Radionuclides in Pond C with an Underwater HPGe Detector(U)

Westinghouse Savannah Technology Center
Savannah River Site
Aiken, SC 29808

Prepared for the U.S. Department of Energy under contract no. DE-AC09-89SR18035

DISCLAIMER

Portions of this document may be illegible electronic image products. Images are produced from the best available original document.

WSRC-TR-95-0272
Rev 0
August 1995

Measurements of Radionuclides in Pond C with an Underwater HPGe Detector(U)

W. G. Winn

Prepared for the U.S. Department of Energy under contract no. DE-AC09-89SR18035

Contents

Tables

Figures

Executive Summary

This study on Pond C is part of a broader effort to appraise Savannah River Site (SRS) waterways impacted by the Par Pond Dam remediation program that commenced in 1991. In addition, the results were sought to provide a more complete appraisal of the status of historical radioactive releases that remain in the Lower Three Runs system.

Gamma-emitting radionuclide concentrations in Pond C sediment were measured with an underwater HPGe detector. The predominant radionuclide was Cs-137 and the only other radionuclide detected was Co-60, which was only 1% as intense as the Cs-137. At the time of the measurements (November 1992), the total Pond C inventory of ^{137}Cs was 4.5 ± 0.8 Ci, of which 0.30 ± 0.09 Ci was exposed during a 6-ft drawdown for Par Pond Dam repairs.

The Pond C inventory of Cs-137 is only 10% of that of Par Pond, primarily because of the much larger area of Par Pond. However, Pond C has a larger average sediment concentration of 8.1 $\mu Ci/m^2$ compared to 4.5 $\mu Ci/m^2$ for Par Pond, which is consistent with Pond C being closer to the origins of the earlier SRS reactor releases. The maximum Cs-137 concentration observed for Pond C was 55 $\mu Ci/m^2$, which is about 10% higher than the maximum observed for Par Pond.

Study of Pond C Radionuclides

Introduction

The present study reports 1992 underwater gamma assays of radionuclides in Pond C sediments.[1] These Pond C measurements evolved following similar 1991 studies conducted on Par Pond when a depression was discovered on the downstream side of Par Pond Dam.[2,3] Subsequent dam repairs required Par Pond be lowered 19 ft, meaning that radioactive sediment would become exposed; thus, the earlier study sought to estimate the amount of radioactivity to be exposed, before lowering Par Pond. Pond C empties into Par Pond through a spillway under the causeway separating the two ponds. Accordingly, Pond C was lowered by 6 ft to lessen the pressure difference across the causeway; thus, some of the Pond C sediment activity became exposed as well.

In addition to the safety and regulatory concerns implied above, the Pond C measurements would also help refine the characterization of Cs-137 in the Lower Three Runs system.[3,4] This system is known to contain about 80 Ci of Cs-137 from R Reactor releases from 1954 through 1964. Thus, it is important to understand how this Cs-137 is distributed.

Methods

The overall equipment has been described in detail in a report on the Par Pond study.[3] Briefly, the operations platform was a pontoon boat from which the underwater detector (30%-efficient HPGe) was lowered by an electrical winch to the bottom sediment. Basic electric power was provided by a 5 kVA gasoline generator, which powered the winch, an uninterruptable power supply, and the detector electronics. (Some of this equipment could be operated by rechargeable battery power).

In the present study, a compact EG&G NOMAD™ replaced the NIM bin detector electronics of the earlier work, and a small rugged DOLCH computer replaced the larger COMPAQ portable computer for emulating the multichannel analyzer (MCA). The resulting smaller detector operating system was more appropriate for field work. A further upgrade following this study was replacing the DOLCH computer with a Lite/253 (COMPAQ) notebook computer that fits into the NOMAD case, resulting in a "briefcase" system for the computer and electronics.

Position measurements utilized a Magellan™ global positioning system unit and a Lowrance™ depth finder. These measurements provided data for developing the Pond C depth contours in Figure 1 where points along each transect identify the depth measurement locations.

Measurements and Analysis

Measurements of sediment radioactivity were conducted along the transects identified in Figure 1. Initial measurements were made on October 22,1992, (transects 1, 2, . . . 5) and supplemented with additional measurements on November 11, 1992 (transects 1A, 2A, . . . 5C). Figure 2 illustrates the data collected for a typical transect, while Appendix A tabulates the measurements for all transects.

All HPGe spectra of bottom sediment were counted for one minute and saved on disk. Measurements at 101 locations were made. The count rates of the 662 keV gamma of Cs-137 were determined and recorded in the field by utilizing the MAESTRO™ peak-fitting capability of the MCA software. As in the Par Pond study, the only other man-made isotope detected was Co-60, which again only had activity of about 1% of that for Cs-137. For each spectral count, the depth and position were read and recorded. All field results were reviewed and refined as appropriate at the laboratory. Following the approach of the earlier work[3], a scatter plot of Cs-137 gamma count rate vs. sediment depth for all the measurements was developed (Figure 3).

The detector had been calibrated for Cs-137 in sediment during the Par Pond study, which includes a detailed description.[2,3] A protective screen-mesh can over the bottom of the detector defined the counting geometry. The calibration modeled the average Cs-137 distribution within the sediment, addressed the attenuation by the sediment and water, and normalized these results with measurements using a NIST-traceable point source of Cs-137. The activity/count rate conversion was 0.0171 ± 0.0027 $\mu Ci/m^2/cpm$ or 632 ± 98 $Bq/m^2/cpm$.

Estimates for Cs-137 Inventories in Pond C

Two methods were used to estimate the Cs-137 inventories for Pond C. One method yielded a total Cs-137 inventory of 4.52 Ci by utilizing the depth contour data of Figure 1 and the activity vs. depth results of Figure 3. A second method yielded an inventory of 4.50 Ci whereby the activity contour plot of Figure 4 was developed using the data of Appendix A and then integrated over the pond areas. Although the two values are in excellent agreement, each has a common systematic error due to the activity/count rate calibration. Including this error, a value of 4.5 ± 0.8 Ci was deduced for the effective average date (November 1, 1992) of the measurements.

The estimation method based on the depth contours is identical to the approach used in the Par Pond study.[2,3] In particular, the average activities (per cpm to μCi/m² conversion) for measurements within areas defined by the depth contours were integrated relative to these areas, as summarized in Table 1. A linear extrapolation was used to estimate the exposed area between of 201 ft and 195 ft above mean sea level (msl).

The estimation method based on the activity contours utilized a similar area integration approach, as summarized in Table 2. Note that the area averages for Cs-137 (μCi/m²) are not averages for the contours bounding the areas. For example, the average for the 0.0-2.7 μCi/m² region is 1.21 μCi/m², which is lower than the contour average of 1.35 μCi/m². This is due to the fact that the average is corrected for the larger integration areas associated with the outer perimeter, which have the lower activities. The correction assumes that, as an area is integrated from its outer perimeter p_o to its inner perimeter p_i, the differential area about an intermediate perimeter p is given by kpdp, which weights the activity A(p) to yield an average activity of

$$A_{avg} = \frac{\int_{p_o}^{p_i} A(p)\, p\, dp}{\int_{p_o}^{p_i} p\, dp}$$

where the constant k has been cancelled. In the present analysis, A(p) was assumed to change linearly between p_o and p_i.

The amount of Cs-137 exposed by the 6 ft drawdown is also of interest. Unfortunately, the measurements were conducted while the drawdown condition existed, making it impossible for direct appraisal with the underwater HPGe detector. However, based on the results obtained in the Par Pond study, it appeared reasonable to extrapolate a value based on an effective zero level for Cs-137 activity at the normal shoreline of 201 ft msl.

The depth contour analysis of Table 1 predicts 0.30 Ci for the drawdown area of 17.59 hectares between the 201 ft and 195 ft contours. The activity contour data of Table 2 indicates 0.31 Ci for a somewhat larger area of 25.15 hectares, which proportionally yields 0.22 Ci for the 17.59 hectare area of interest. The value of 0.30 Ci is considered more reliable as it is based on an extrapolation of the actual counting data of Figure 3, whereas the 0.22 Ci value depends on the accuracy of the inner contour perimeter inferred for the exposed area. At the same time, their difference of 0.08 Ci may be used as an estimate of the overall extrapolation error, which when coupled with the error due to the activity/count-rate calibration yields an exposed Cs-137 activity of 0.30 ± 0.09 Ci.

Discussion of Results

The Pond C results reported here are not significantly different from those given in a preliminary report.[1] The total Cs-137 activity of 4.5 Ci was only 10% of that for Par Pond, which is not surprising since the area of Pond C is only about 6% of that of Par Pond proper.[4] By contrast, the average sediment concentration of Cs-137 for Pond C was 8.1 μCi/m² as compared to only 4.5 μCi/m² for Par Pond. This is consistent with Pond C being upstream of Par Pond and thus closer to the origins of earlier radioactive releases. The maximum concentration for Pond C was 55 μCi/m², occurring near the center of transect 2A (see Figure 1 and Appendix A); this was only about 10% higher than the maximum observed for Par Pond. These pond comparisons for Cs-137 concentrations update those of the preliminary report[1], which predated the final results of both Par Pond and Pond C.

Similar to the results for Par Pond, the Cs-137 count rate tends to monotonically increase with depth as shown in Figure 3; however, some deviation from this is noted at the deepest depths, although significant scatter is seen in the count rates. Pond C exhibits a dip in count rate near a depth of 15 ft. In the Par Pond study[3], such a dip was associated with the depth "barrier" beyond which underwater vegetation ceased to be abundant. The dip for the Pond C data is not as obvious, probably because the pond had been lowered for a year before the measurements were made, allowing time for the vegetation to extend to lower depths and "smear out" the historical imprint of the dip. By contrast, the Par Pond dip was measured before significant lowering of its level.

The data of Table 1 are plotted in Figure 5 as a guide to the exposed Cs-137 in Pond C for different drawdown levels. Although the pond levels have been restored to normal levels at present so that no pond Cs-137 is exposed, this information could guide future environmental remediation actions concerning Pond C. Similar information was also reported for Par Pond.[3] Figure 6 reproduces a contour map of the activities for both ponds.[5]

The present measurements for Pond C updates the information on the Cs-137 in the Lower Three Runs system, as shown in Table 3. Here the Cs-137 for Pond C has a slight decay correction for comparison to the other data, which apply for the third quarter of 1991. The earlier result for Par Pond[3] has also been refined for a small area correction based on information discussed in Appendix B. Earlier estimates for the Cs-137 in the Lower Three Runs system are also given in the Table for comparison. With the Pond C data of the present work, a fairly definitive distribution for the Cs-137 in the system results. The only Cs-137 that has not been measured directly is that in the Lower Three Runs areas below Par Pond Dam; however, a value of 21.4 Ci is inferred from the total Cs-137 of 83 Ci, which was known to be released to the system[3], although the error in this estimate as rather large, being at least 35%. Overflight gamma mappings for Cs-137 have shown consistency with the above results, relative to the exposed sediments[6]; thus, although beyond the scope of the present study, an improved estimate for Cs-137 might be made using the widely exposed flood plain areas of Lower Three Runs below Par Pond Dam.

Acknowledgments

The author wishes to thank C. D. Ouzts, H. T. Wilson, R. W. Johnson, and H. L. Hayes for assisting with the field measurements. Also D.W. Hayes is thanked for the use of his GPS and depth gauge systems.

References

1. Winn, W. G., "Preliminary Summary - Pond C Measurements with Underwater HPGe Detector", SRTC-ETS-93-040 (February 9, 1993).

2. Winn, W. G. "Evaluation of ^{137}Cs in Pond Sediment with an Underwater HPGe Detector", *Trans. Am. Amer. Nuc. Soc.*, 66, pp 32-34 (1992).

3. Winn, W.G., *Measurements of Radionuclides in Par Pond Sediments with an Underwater HPGe Detector*, WSRC-TR-93-0209 (1993).

4. Carlton, W. H., L. R. Bauer, A. G. Evans, L. A. Geary, C. E. Murphy, Jr., J. E. Pinder, and R. N. Strom, *Cesium in the Savannah River Site Environment*, WSRC-RP-92-250 (March 1992).

5. Winn, W. G., "Environmental Measurements at the Savannah River Site with Underwater Gamma Detectors", WSRC-MS-93-437 (February 1994), to be published in *Journal of Radioanalytical and Nuclear Chemistry*.

6. Feimster, E. L., *An Aerial Radiological Survey of Par Pond and Associated Drainage Pathways of the Savannah River Site*, EG&G Energy Measurements Report EGG-10617-1227/UC-702 (December 1992).

Table 1. Pond C Inventory Analysis for Cs-137 using Depth Contours

Depth Range		Area[a]	Cs-137		
(msl-ft)	(ft)	(hectare)	(avg cpm)	(Ci)[b]	(Accum Ci)
201-195	0-6	17.59	99.0[c]	0.30	0.30
195-190	6-11	11.18	280.7	0.53	0.83
190-185	11-16	8.58	358.0	0.53	1.36
185-180	16-21	9.44	630.9	1.02	2.38
180-175	21-26	7.27	1531.0	1.90	4.28
175-168	26-33	1.73	811.3	0.24	4.52

a) Areas determined from contour map of Figure 1. (1 hectare = 10^4 m^2)

b) Cs-137 (Ci) = 0.000171 (Ci/hectare/cpm) × Cs-137 (cpm) × Area (hectare)
NOTE: 0.000171 Ci/hectare/cpm = 0.0171 μCi/m^2/cpm

c) Extrapolated value

Table 2. Pond C Inventory Analysis for Cs-137 using Activity Contours

Activity Range		Area[a]	Cs-137		
(Mbq/m^2)	(μCi/m^2)	(hectare)	(avg μCi/m^2)[b]	(Ci)[c]	(Accum Ci)
0.0-0.1	0.0-2.7	25.15	1.21	0.31	0.31
0.1-0.2	2.7-5.4	5.49	4.04	0.22	0.53
0.2-0.4	5.4-10.8	12.08	7.74	0.94	1.47
0.4-0.8	10.8-21.6	6.15	15.49	0.95	2.42
0.8-1.6	21.6-43.2	6.48	29.05	1.88	4.30
1.6-3.2	43.2-86.4	0.44	46.64	0.2	4.50

a) Areas determined from contour map of Figure 3. (1 hectare = 10^4 m^2)

b) Values averaged as discussed in text.

c) Cs-137 (Ci) = 0.01 Cs-137 (μCi/m^2) × Area (hectare)
NOTE: 0.01 Ci = 1 μCi/m^2 hectare

Table 3. Comparison of Cs-137 Estimates for Lower Three Runs System [Effective date: third quarter of 1991]

Location	Cs-137 Estimates for Sediments[a]					
	History	Prediction[b]	Cs Report[c]	SREL[d]	Par Pond Report[b]	Present
Pond B	12.0	12.0	12.0	12.0*	12.0	12.0
Pond C	-	2-7	~2.4	~3.5	~3.9	4.6
Par Pond	-	35-59	42.8	~44.0	46.6	45.0
LTR Areas	-	5-34	~25.8	~23.5	~20.5	21.4
Total	83.0*	83.0	83.0	83.0	83.0	83.0

a) Underlined entries are based on direct pond measurements. The "~" denotes preliminary estimates. For entries with identical values, the one denoted "*" identifies the estimate from which it originated.

b) See reference 3.

c) See reference 4.

d) F. W. Whicker et al. - direct communications and *Ecological Monographs*, 60, pp 471-476 (1990).

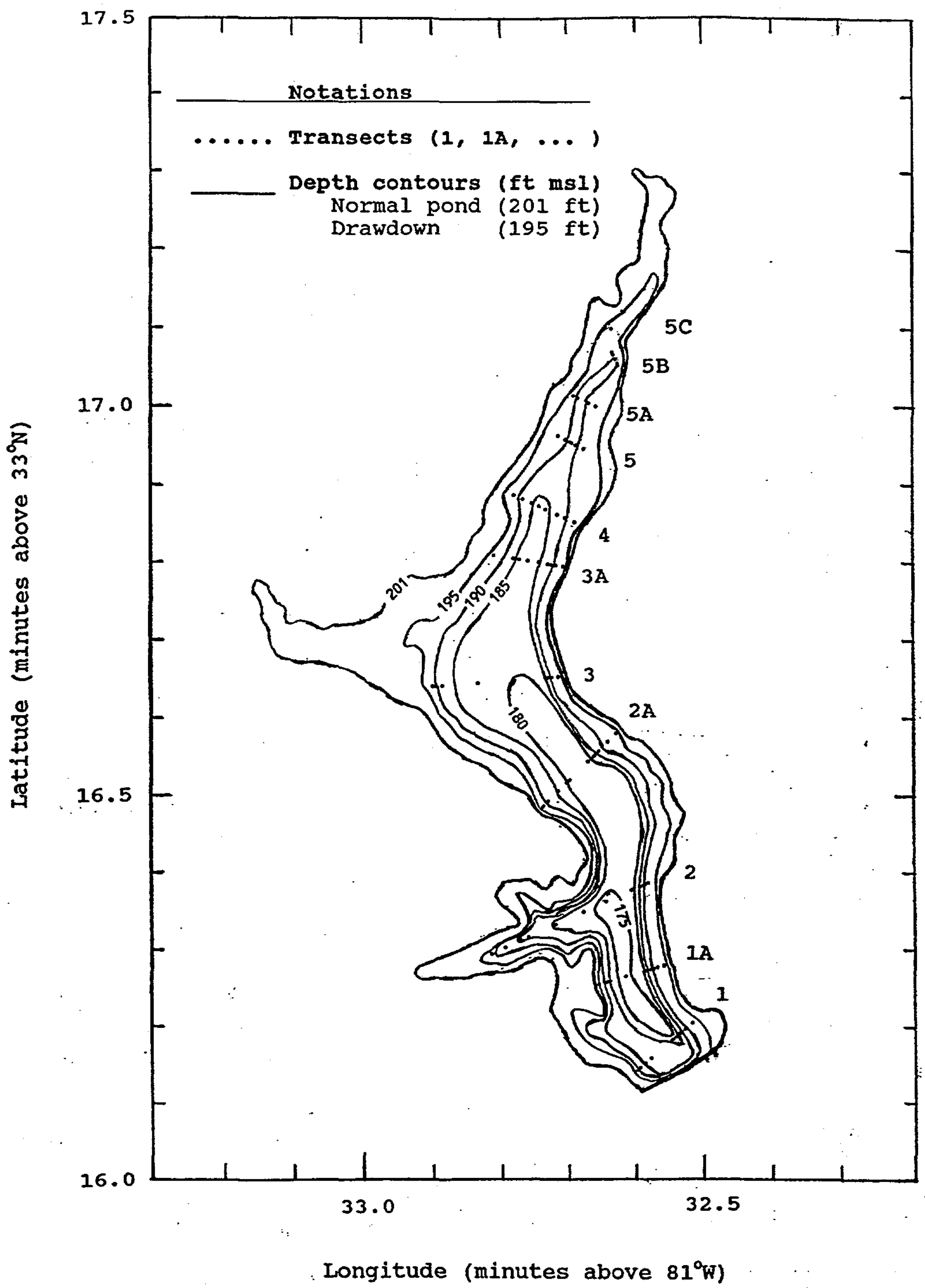

Figure 1. Pond C Depth Contours and Measurement Transects

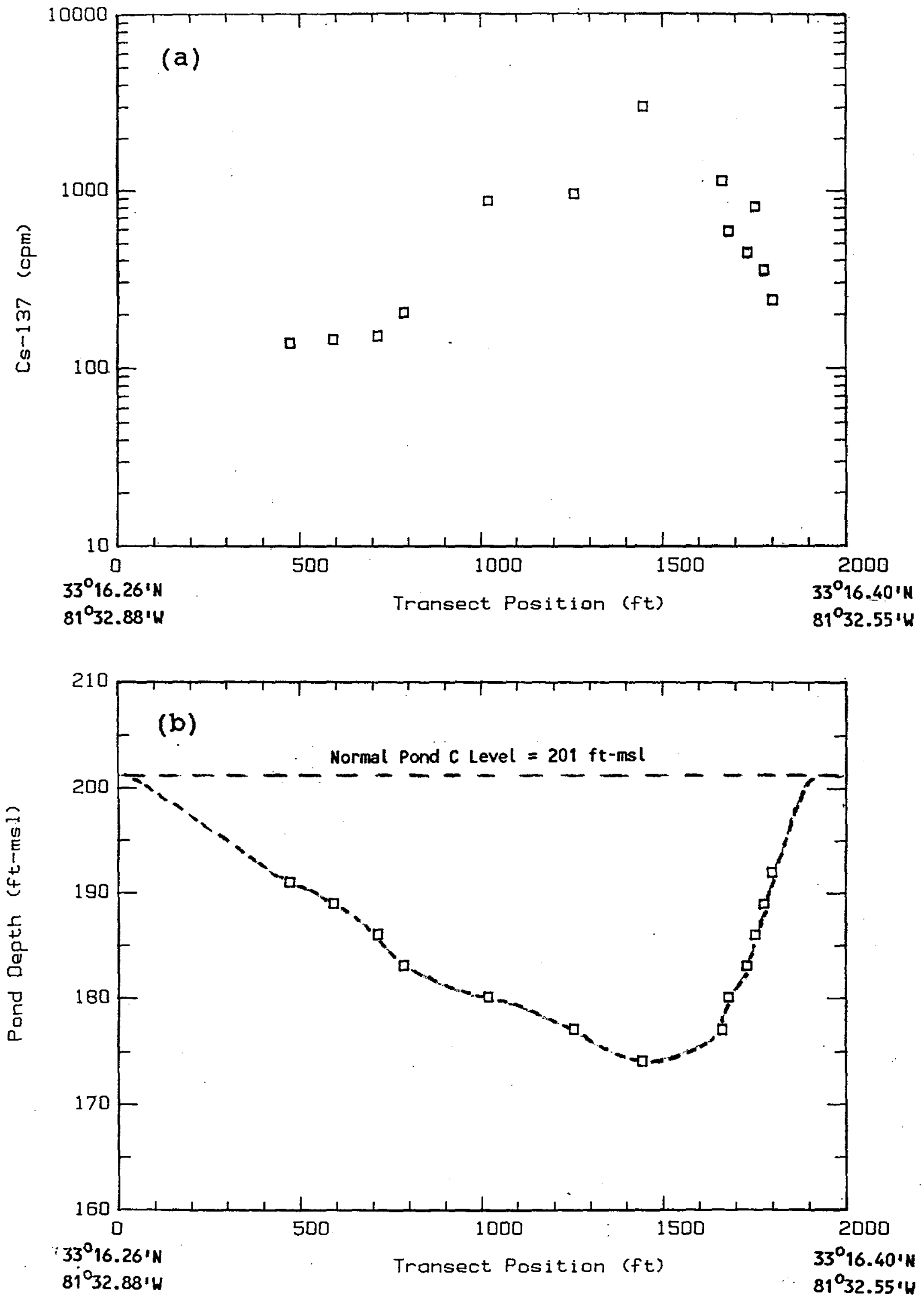

Figure 2. **Data Collected for a Typical Transect**
Transect 2: (a) Cs-137 and (b) pond depth

95x02852

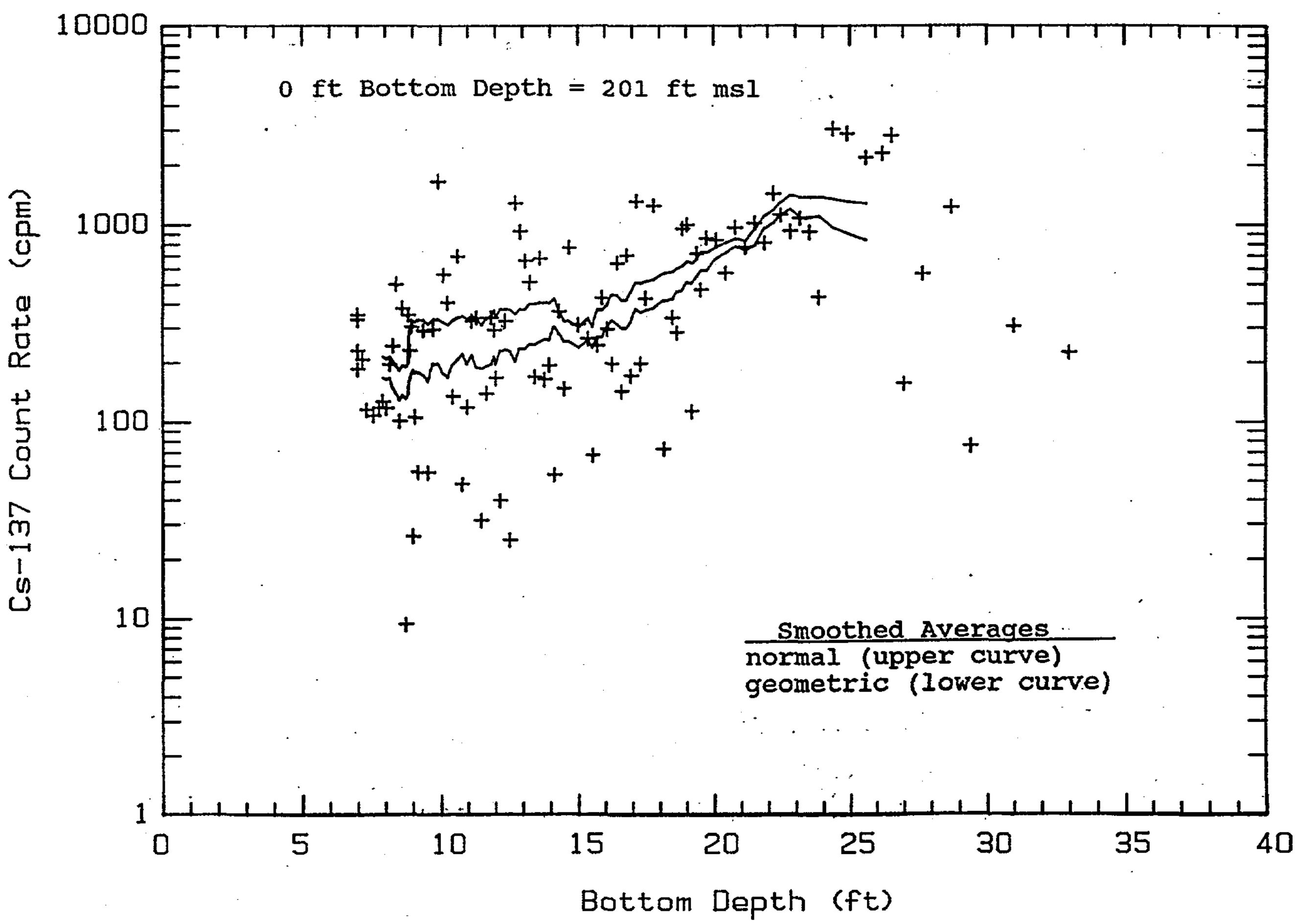

Figure 3. Cs-137 Count Rate of Sediment vs. Pond Depth
Curves plot cpm average of point and 16 adjacent points (8 above and 8 below) as a function of corresponding average depth

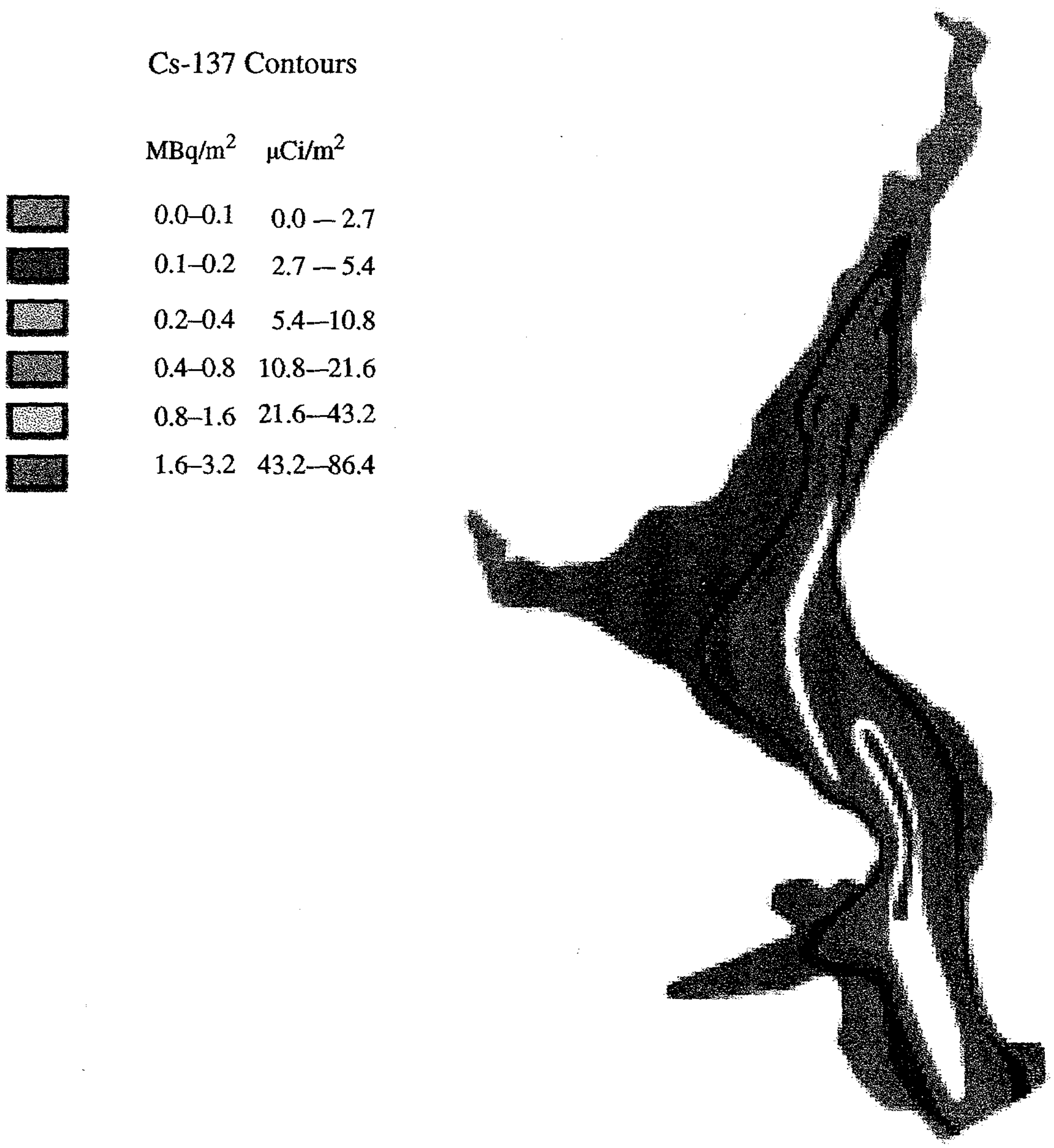

Figure 4. Cs-137 Activity Contours for Pond C

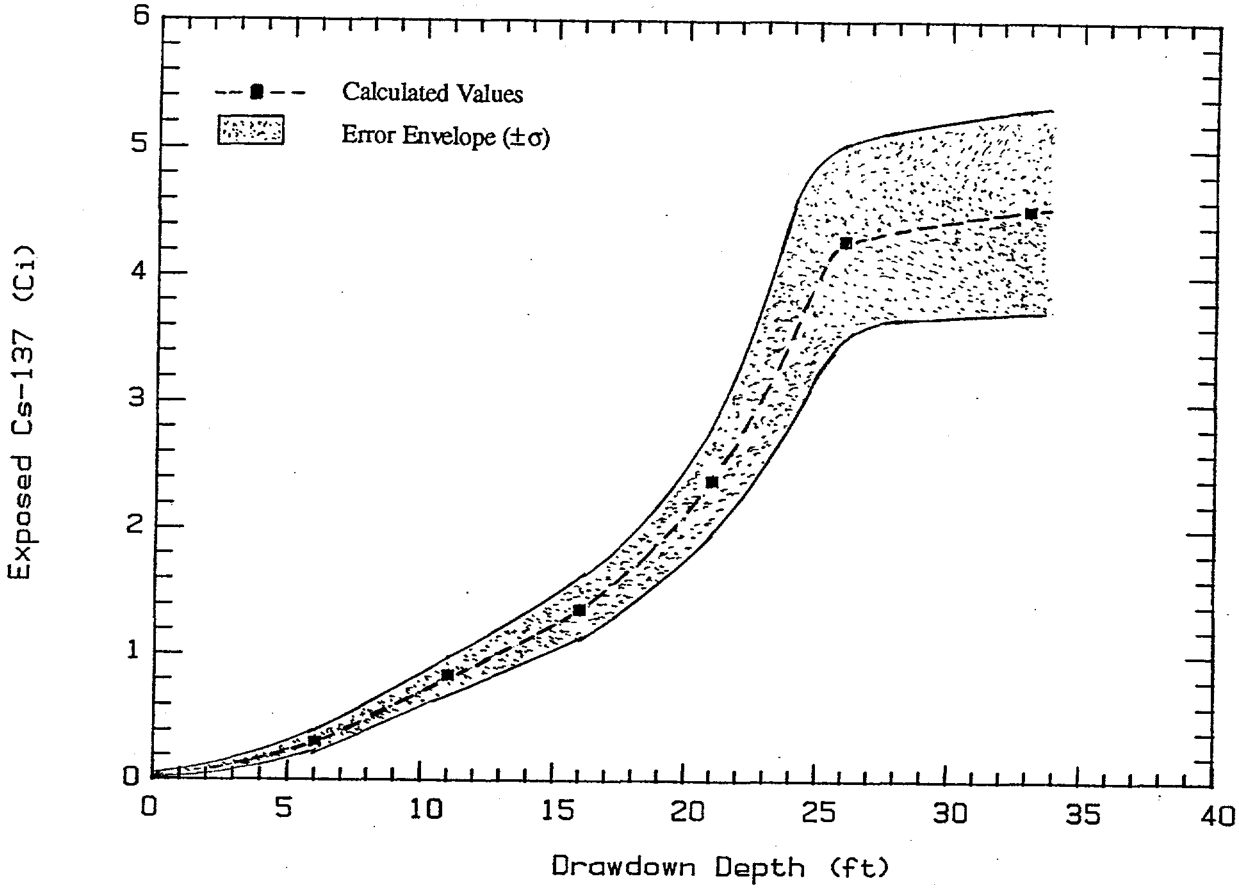

Figure 5. Exposed Cs-137 vs. Drawdown Depth for Pond C

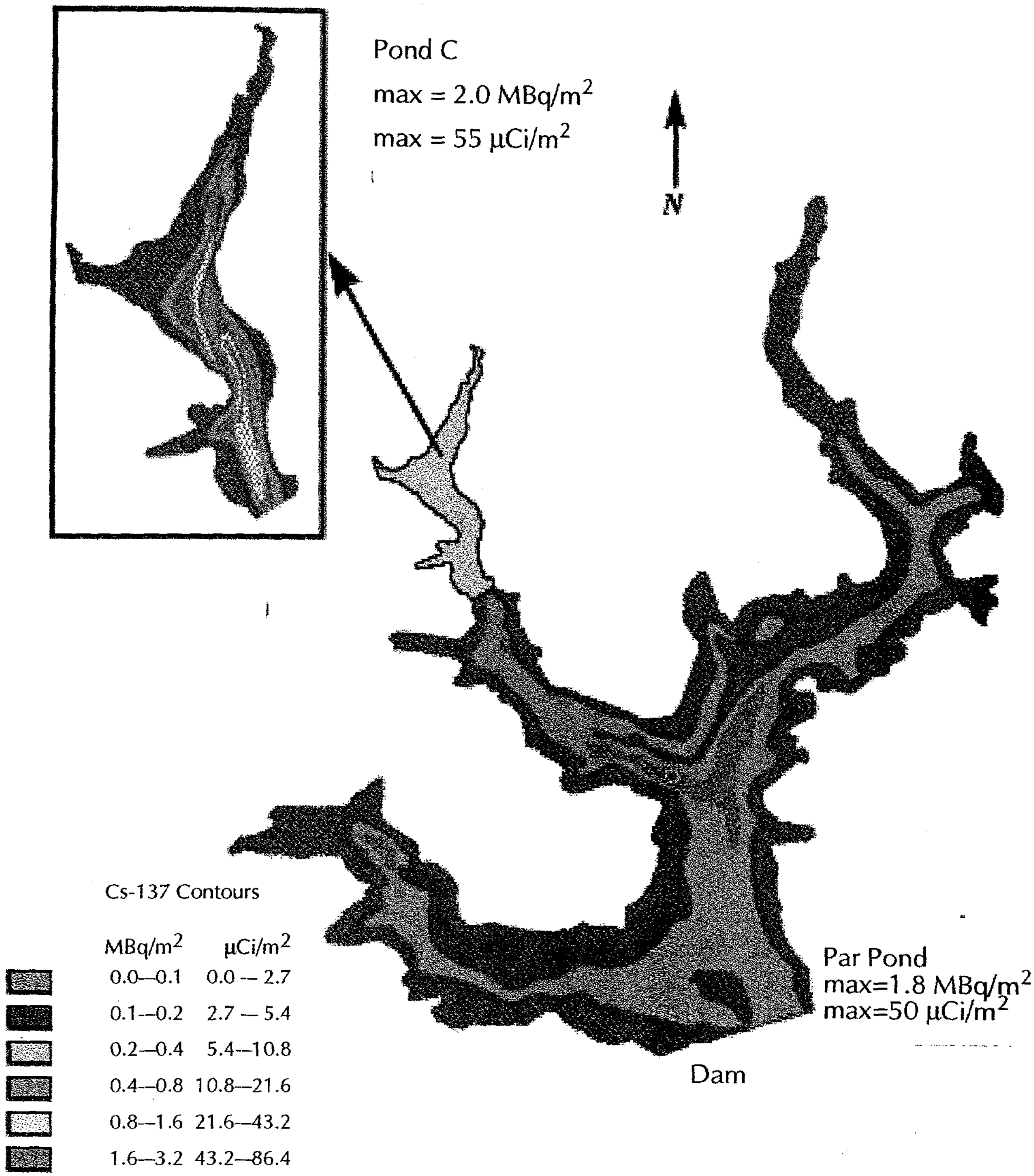

Figure 6. Cs-137 Activity Contours for Pond C and Par Pond

Appendix A. Raw Data–Pond C HPGe Measurements

The raw data for the underwater HPGe measurements of Pond C are summarized in Table A. The data are characterized according to their transects as identified in Figure 1. (Note that the transects IDs are listed in reverse numerical order to facilitate their correlation with Figure 1). The table gives the following for each measurement:

- Transect identification
- Latitude and longitude
- Sediment depth
- Cs-137 count rate
- Cs-137 activity concentration
- Date of measurement

The relative latitude and longitudes are estimated to be somewhat better than ± 0.01 min (± 15 m) based on the combination techniques used for positioning. GPS bench points defined the beginning and end points of each transect, and Lowrance depth chart profiles were used to interpolate the positions between these benchmarks. The other entries are self-explanatory.

Table A. Raw Data - Pond C HPGe Measurements

Transect	Lat33N (min)	Lon81W (min)	Depth (ft msl)	Cs-137 Rate (cpm)	Cs-137 Activity (uCi/m2)	Data Date
5C	17.098	32.634	193.5	123 +/- 14	2.09 +/- 0.24	11/11/92
5B	17.068	32.633	194.0	238 +/- 30	4.06 +/- 0.50	11/11/92
	17.065	32.631	192.0	110 +/- 11	1.87 +/- 0.19	11/11/92
	17.059	32.628	189.0	41 +/- 7	0.69 +/- 0.12	11/11/92
	17.053	32.625	192.0	57 +/- 8	0.97 +/- 0.14	11/11/92
	17.051	32.624	193.0	132 +/- 16	2.25 +/- 0.27	11/11/92
5A	17.013	32.692	192.0	307 +/- 30	5.23 +/- 0.50	11/11/92
	17.010	32.684	189.0	343 +/- 29	5.85 +/- 0.50	11/11/92
	17.003	32.668	192.0	57 +/- 9	0.96 +/- 0.15	11/11/92
	16.999	32.658	194.0	192 +/- 15	3.28 +/- 0.26	11/11/92
5	16.961	32.713	194.0	342 +/- 25	5.84 +/- 0.43	10/22/92
	16.956	32.702	192.0	256 +/- 16	4.36 +/- 0.27	10/22/92
	16.953	32.696	189.0	49 +/- 7	0.84 +/- 0.12	10/22/92
	16.952	32.693	186.0	714 +/- 33	12.19 +/- 0.56	10/22/92
	16.949	32.686	189.0	123 +/- 15	2.11 +/- 0.26	10/22/92
	16.944	32.675	192.0	526 +/- 27	8.98 +/- 0.47	10/22/92
4	16.885	32.780	192.0	104 +/- 15	1.78 +/- 0.26	10/22/92
	16.880	32.767	189.0	342 +/- 22	5.84 +/- 0.37	10/22/92
	16.875	32.753	186.0	170 +/- 14	2.90 +/- 0.23	10/22/92
	16.871	32.742	183.0	148 +/- 14	2.52 +/- 0.25	10/22/92
	16.867	32.732	183.0	740 +/- 33	12.63 +/- 0.56	10/22/92
	16.860	32.714	186.0	203 +/- 20	3.46 +/- 0.35	10/22/92
	16.856	32.703	189.0	356 +/- 26	6.08 +/- 0.44	10/22/92
	16.851	32.689	192.0	398 +/- 27	6.79 +/- 0.47	10/22/92
3A	16.808	32.810	193.0	122 +/- 18	2.08 +/- 0.30	11/11/92
	16.804	32.780	189.0	26 +/- 6	0.44 +/- 0.09	11/11/92
	16.803	32.777	186.0	70 +/- 9	1.19 +/- 0.15	11/11/92
	16.803	32.772	183.0	355 +/- 25	6.06 +/- 0.43	11/11/92
	16.801	32.759	181.0	489 +/- 33	8.34 +/- 0.56	11/11/92
	16.799	32.743	183.0	297 +/- 25	5.07 +/- 0.42	11/11/92
	16.797	32.729	186.0	257 +/- 17	4.39 +/- 0.28	11/11/92
	16.796	32.724	189.0	1364 +/- 43	23.29 +/- 0.73	11/11/92
	16.795	32.717	192.0	310 +/- 21	5.29 +/- 0.35	11/11/92
	16.794	32.706	194.0	367 +/- 26	6.27 +/- 0.44	11/11/92

Table A. (Continued)

Transect	Lat33N (min)	Lon81W (min)	Depth (ft msl)	Cs-137 Rate (cpm)	Cs-137 Activity (uCi/m2)	Data Date
3	16.639	32.899	192.0	10 +/- 3	0.16 +/- 0.05	10/22/92
	16.639	32.894	189.0	32 +/- 6	0.55 +/- 0.10	10/22/92
	16.640	32.885	186.0	55 +/- 6	0.94 +/- 0.10	10/22/92
	16.644	32.832	183.0	178 +/- 12	3.04 +/- 0.21	10/22/92
	16.647	32.780	180.0	904 +/- 34	15.44 +/- 0.57	10/22/92
	16.651	32.730	183.0	1391 +/- 47	23.75 +/- 0.80	10/22/92
	16.651	32.728	186.0	383 +/- 20	6.55 +/- 0.35	10/22/92
	16.651	32.724	190.0	731 +/- 32	12.49 +/- 0.55	10/22/92
	16.652	32.714	192.0	367 +/- 26	6.27 +/- 0.45	10/22/92
2A	16.484	32.738	194.0	216 +/- 19	3.68 +/- 0.32	11/11/92
	16.485	32.736	192.0	1745 +/- 49	29.80 +/- 0.83	11/11/92
	16.491	32.729	189.0	971 +/- 39	16.58 +/- 0.66	11/11/92
	16.504	32.714	186.0	449 +/- 27	7.66 +/- 0.46	11/11/92
	16.515	32.702	183.0	1013 +/- 42	17.30 +/- 0.71	11/11/92
	16.516	32.700	180.0	1073 +/- 41	18.32 +/- 0.70	11/11/92
	16.519	32.697	177.0	3213 +/- 68	54.86 +/- 1.15	11/11/92
	16.542	32.670	177.0	3045 +/- 70	52.00 +/- 1.20	11/11/92
	16.549	32.662	180.0	847 +/- 31	14.47 +/- 0.52	11/11/92
	16.550	32.661	183.0	1055 +/- 39	18.01 +/- 0.67	11/11/92
	16.551	32.660	186.0	309 +/- 25	5.27 +/- 0.43	11/11/92
	16.556	32.654	189.0	690 +/- 34	11.78 +/- 0.57	11/11/92
	16.568	32.641	192.0	584 +/- 32	9.97 +/- 0.54	11/11/92
	16.579	32.628	194.0	119 +/- 12	2.02 +/- 0.20	11/11/92
2	16.293	32.815	191.0	139 +/- 21	2.37 +/- 0.36	10/22/92
	16.301	32.794	189.0	146 +/- 13	2.48 +/- 0.21	10/22/92
	16.310	32.773	186.0	153 +/- 16	2.61 +/- 0.27	10/22/92
	16.315	32.760	183.0	205 +/- 24	3.50 +/- 0.41	10/22/92
	16.331	32.719	180.0	882 +/- 37	15.05 +/- 0.63	10/22/92
	16.348	32.677	177.0	967 +/- 36	16.52 +/- 0.62	10/22/92
	16.361	32.644	174.0	2980 +/- 67	50.89 +/- 1.15	10/22/92
	16.376	32.605	177.0	1138 +/- 38	19.43 +/- 0.65	10/22/92
	16.378	32.602	180.0	593 +/- 32	10.13 +/- 0.55	10/22/92
	16.381	32.593	183.0	447 +/- 28	7.63 +/- 0.48	10/22/92
	16.383	32.589	186.0	815 +/- 34	13.91 +/- 0.58	10/22/92
	16.384	32.585	189.0	355 +/- 22	6.07 +/- 0.37	10/22/92
	16.386	32.581	192.0	240 +/- 20	4.10 +/- 0.34	10/22/92

Table A. (Continued)

Transect	Lat33N (min)	Lon81W (min)	Depth (ft msl)	Cs-137 Rate (cpm)	Cs-137 Activity (uCi/m2)	Data Date
1A	16.253	32.655	193.0	206 +/- 24	3.51 +/- 0.41	11/11/92
	16.256	32.645	189.0	536 +/- 28	9.15 +/- 0.48	11/11/92
	16.256	32.643	186.0	206 +/- 21	3.51 +/- 0.36	11/11/92
	16.257	32.640	183.0	117 +/- 19	1.99 +/- 0.32	11/11/92
	16.257	32.639	180.0	1519 +/- 60	25.94 +/- 1.02	11/11/92
	16.258	32.638	177.0	2286 +/- 64	39.04 +/- 1.09	11/11/92
	16.264	32.614	174.0	1303 +/- 45	22.25 +/- 0.77	11/11/92
	16.271	32.587	177.0	2416 +/- 62	41.26 +/- 1.06	11/11/92
	16.272	32.585	180.0	1177 +/- 45	20.09 +/- 0.77	11/11/92
	16.273	32.582	183.0	758 +/- 34	12.94 +/- 0.57	11/11/92
	16.274	32.578	186.0	675 +/- 34	11.52 +/- 0.57	11/11/92
	16.275	32.573	189.0	176 +/- 18	3.01 +/- 0.31	11/11/92
	16.277	32.568	192.0	421 +/- 28	7.18 +/- 0.47	11/11/92
	16.279	32.558	194.0	112 +/- 16	1.90 +/- 0.27	11/11/92
1	16.142	32.598	192.0	320 +/- 29	5.46 +/- 0.50	10/22/92
	16.146	32.593	189.0	306 +/- 18	5.22 +/- 0.31	10/22/92
	16.152	32.585	186.0	325 +/- 24	5.55 +/- 0.40	10/22/92
	16.159	32.577	183.0	1323 +/- 43	22.59 +/- 0.73	10/22/92
	16.181	32.546	180.0	1021 +/- 41	17.44 +/- 0.69	10/22/92
	16.182	32.546	177.0	964 +/- 38	16.46 +/- 0.65	10/22/92
	16.183	32.545	174.0	163 +/- 13	2.78 +/- 0.22	10/22/92
	16.184	32.544	171.0	78 +/- 14	1.33 +/- 0.24	10/22/92
	16.186	32.540	168.0	235 +/- 27	4.00 +/- 0.45	10/22/92
	16.188	32.537	171.0	324 +/- 26	5.53 +/- 0.45	10/22/92
	16.190	32.536	174.0	598 +/- 34	10.20 +/- 0.58	10/22/92
	16.190	32.535	177.0	449 +/- 26	7.67 +/- 0.45	10/22/92
	16.191	32.534	180.0	811 +/- 39	13.84 +/- 0.67	10/22/92
	16.192	32.533	183.0	75 +/- 9	1.28 +/- 0.15	10/22/92
	16.193	32.532	186.0	276 +/- 19	4.71 +/- 0.32	10/22/92
	16.196	32.527	189.0	174 +/- 13	2.96 +/- 0.22	10/22/92
	16.205	32.516	192.0	27 +/- 6	0.45 +/- 0.10	10/22/92

Appendix B. Refinements of Par Pond Results

This appendix refines the results of the earlier Par Pond study[3] by making a small correction associated with the pond area. During the analysis of Pond C, it was noted that its area was given as 5.7% of "Par Pond proper" in an earlier report.[4] The Pond C area estimated in the present study was 55.8 hectares, and an area of 1057 hectares was used for the Par Pond study.[3] This would imply that Pond C area is only 5.3% of that of Par Pond. Interpreting "Par Pond" to be composed of "Par Pond proper" plus "Pond C", Par Pond proper would have an area of 1001 hectares, and Pond C would have an area that is 5.6% of this, which agrees reasonably with the purported 5.7%. Accordingly, the Par Pond results[3] should be corrected by using the area for Par Pond proper.

The Par Pond Cs-137 inventory analysis (Ref 3, Table 3) has been revised in Table B. Here, the "Par Pond proper" areas are calculated by subtracting the "Pond C" areas from the "Par Pond" areas. The appropriate Pond C areas were determined using graphical interpolation of the depth vs. area data of Table 1. The table gives both the earlier analysis[3] and the revised one.

The revised analysis yields 45.03 ± 7.00 Ci for the Par Pond inventory of Cs-137. This is only about 3% lower than the earlier value and is small relative to the dominant calibration error of 16%. The refined analysis gives 8.62 ± 1.34 Ci for the sediment exposed upon drawdown, which is 8% lower than the earlier value but still significantly smaller than the overall error. Thus the overall results and conclusions of the earlier report are essentially unaffected.

Table B. Refined Par Pond Cs-137 Inventory Analysis

Depth Range		Area	Cs-137		
m	ft	hectare[a]	Avg Cpm	Ci[b]	Accum Ci
Earlier Analysis (Reference 3)					
0-3	0.0-9.8	317.29	60.8	3.29	3.29
3-6	9.8-19.7	226.66	169.6	6.57	9.86
6-9	19.7-29.5	219.52	387.7	14.53	24.39
9-12	29.5-39.4	166.78	395.1	11.30[c]	35.70
12-15	39.4-49.2	85.15	436.8	7.14[c]	42.84
15-18	49.2-59.1	41.11	534.2	3.75[d]	46.59
Revised Analysis (present work)					
0-3	0.0-9.8	291.29	60.8	3.02	3.02
3-6	9.8-19.7	207.66	169.6	6.02	9.04
6-9	19.8-29.5	209.02	387.7	13.84	22.88
9-12	29.5-39.4	166.48	395.1	11.26[c]	34.14
12-15	39.4-49.2	85.15	436.8	7.14[c]	41.28
15-18	49.2-59.1	41.11	534.2	3.75	45.03

a) hectare = 10^4 m^2

b) Cs-137 (Ci) = 0.000171(Ci/hectare/cpm) Cs-137 (cpm) × Area (hectare)

NOTE: 0.000171 Ci/hectare/cpm = 0.0171 $\mu Ci/m^2/cpm$

95x02852