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Environmental Radiological Studies in 1989 Near the Rancho Seco Nuclear Power Generating Station

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Contents

Abstract

Cesium-137 is the most significant radionuclide still observed downstream from the Rancho Seco Nuclear Power Plant. Only occasionally is ^{134}Cs or ^{60}Co observed. In 1989, the concentration of ^{137}Cs in the water and fish decreased with distance from the plant to the same level that it was in 1987, and was lower than it had been from 1984 through 1986. The concentration ratio (C.R.) for ^{137}Cs in fish is between 1000 and 1500, which is below the NRC default value of 2000. Physical mixing in the creek environment has moved the ^{137}Cs deeper into the sediment column, thereby reducing the concentration in the top 12 cm relative to that in previous years.

Introduction

In December 1988, the Sacramento Municipal Utilities District (SMUD) asked the Lawrence Livermore National Laboratory's (LLNL) Environmental Sciences Division (ENV) to collect sediment, water, and fish samples downstream from the Rancho Seco Nuclear Power Generating Station for analysis of radionuclides to compare with results from earlier surveys in 1984 through 1987 (1–8). ENV was, however, asked to reduce the total number of sample collections to a minimum in this study because of financial constraints. The proposal ENV submitted for the 1989 Environmental Radiological Studies downstream of the Rancho Seco Nuclear Power Generating Station reflected this reduction, but we believe, nevertheless, the 1989 efforts do allow us to make some meaningful comparisons with the previous studies.

Initially, the samples were to be collected in the spring, summer, and fall of 1989 to compare with similar seasonal collections in the earlier surveys. We were also initially asked to take soil samples from other sites around the plant. However, due to budget limitations, the final program consisted of collecting only samples downstream from the Rancho Seco Station in April and June 1989; the fall collection was cancelled by SMUD. In addition, there was a limited, special collection in January of 1989, at the request of SMUD, to determine if there had been an accidental release of activity to the retention ponds and the creek, and no elevated activity was found in that survey.

In this report we present the results of the analyses for several radionuclides in the sediment, water, and fish samples collected in 1989 and compare the results with those from the previous surveys conducted by LLNL at Rancho Seco.

Sample Collection

In general, the sampling plans and methods used in this study follow those of the previous studies in 1984 through 1986 (1–7).

A brief description of the sample collection procedure is as follows:

1. Creek Surface-Sediment Samples.

A 12-cm long (by 6-cm diameter) stainless steel tube equipped with a handle, similar to the one used in previous studies (1–7), was used for the collection of the 0- to 12-cm surface-sediment samples. Four to five subsamples were pooled from each sample location to make one composited sample.

We collected 14 composited surface-sediment samples in January 1990 from the point of the plant effluent discharge to 4.8 km downstream. In April 1989, we collected 32 more samples and extended the sampling sites to a distance of 26.7 km downstream.

2. Creek Sediment-Core Samples.

A modified sediment-core sampler was developed and used for this study. The hand-driven plastic sediment corer which was adequate in previous studies did not have sufficient penetration for deeper sampling of creek sediments required for the 1989 study. With the new impact-driven coring tool, shown in Figure 1, we collected sediment cores to depths in excess of 30 cm to check for any migration of radionuclides since the last study.

The core samples were frozen immediately in dry ice after collection and transported to LLNL for processing and analysis. A total of 35 deep-sediment core samples were collected in April 1989, and 44 were collected in June 1989.

Background core samples were also collected from Rancho Seco Lake, Cosumnes River, Mokelumne River, and Hadselville Creek north of the confluence of Clay Creek.

3. Fish Samples.

Valid "Scientific Collectors Permits" for 1989 were obtained by all participating personnel involved with fish collection in the study. Rod and reel fishing equipment and live bait or artificial lures, the same methods used by typical local fishermen catching fish for consumption, were used for the collection of fish samples in this study. Normally, three species of fish (bass, *Micropterus salmoides*; bluegill, *Lepomis macrochirus*; and catfish, *Ictalurus nebulosus*) were sought from each sample station; however, at some locations not all species were caught. On some occasions, a substituted species such as carp had to be used. The fish samples were placed on dry ice and transported to LLNL for processing.

Seven stations ranging from 0.7 to 19.5 km from the plant effluent discharge were selected for fish collection. Several fish of each species were usually pooled from each sample location and processed as a composited sample. A total of 40 composited fish samples were collected in April and June of 1989. Background fish samples were also collected from Rancho Seco Lake and the Mokelumne River.

4. Water Sampling.

Fifty-liter water samples were obtained at stations in conjunction with the fish collections. Water was pumped through 1-μm cartridge filters into a 15-gal polyethylene container, acidified with 100 mL of 4 *N* HCl, and returned to LLNL for processing.

A summary listing of all the samples collected for the 1989 study is tabulated in Table 1.

Sample Preparation and Analytical Procedures

All samples that arrived at LLNL from the field collections were processed as soon as possible or stored in the freezers for later analysis. We expected most of these samples to be very low in activity, and they were processed in the Low-Level Environmental Lab at LLNL to minimize contamination. Because we have records of the relative activities of the sample stations from previous studies, we were able to improve our analytical procedure by arranging and analyzing the samples in increasing order of radioactivity to further minimize cross-contamination among the samples.

For low-level-activity samples, we also optimized the sample size, counting geometry, and counting time to maximize the analytical sensitivity. For example, sediments were counted in the largest container for which our detector systems are calibrated; we reduced the fish sample size by dry ashing to obtain maximum counting efficiency; we used all 15 gallons of each water sample collected to obtain the maximum sensitivity; and, we analyzed low-level samples for 2500 minutes or longer to obtain better counting statistics.

As part of the general procedure, each sample was assigned a unique analytical reference number and logged into a bound laboratory notebook together with all the pertinent sampling data, such as sample location, collection date, weights, and volume. These preliminary data entries are always checked by a second analyst against the original records on the samples and field notebooks.

These data are then transcribed into the computer for data reduction and reports.

The procedures for processing surface sediments, sediment cores, fish, and water samples are briefly described below.

1. Surface Sediments.

The composited surface-sediment samples were transferred to new, unused 1-gal paint cans and dried at 100°C. The clay particles were broken up and homogenized by shaking, and the samples sieved through 2-mm mesh screen to remove large rocks. Depending on the sample density, 300 to 350 g of the fine fraction was transferred to a standardized container for analysis on Ge(Li) gamma spectrometers. The total wet, dried, sieved, and aliquot weights were recorded.

2. Sediment-Core Samples.

The frozen sediment-core samples collected in June 1989, together with the polycarbonate sample tube, were cut into 6-cm sections. Each 6-cm section was extruded and processed as a separate sample in a manner similar to the procedure outlined for surface sediment given above. A typical counting aliquot of a 6-cm section of sediment core was about 150 g dried weight.

In the April 1989 collection, most core samples were less than 30 cm in depth and only 2 to 3 sections were obtained from each core for analysis.

3. Fish Samples.

The fish samples were frozen in the field and initially stored in freezers at LLNL. Processing began by partially thawing the fish samples and determining the standard length of each individual fish. The fish were then dissected to obtain the edible flesh without the skin. The edible flesh from each species at the same sampling site was pooled together as one sample. The samples were dried in ovens at 90°C to constant weight and then ashed in a muffled furnace at 450°C. The wet, dried, and ashed weights were recorded. The ashed samples were homogenized, transferred to the proper-sized counting vials, and analyzed by gamma spectrometry.

4. Water Samples.

The 1-µm prefilters containing the particulate material were ashed at 450°C, transferred to counting vials, and analyzed by gamma spectrometry.

Only samples analyzed for ^{134}Cs and ^{137}Cs were preconcentrated from the filtered water samples by adsorption onto ammonium molybdophosphate (AMP) micro-crystals. A known amount of standardized stable cesium carrier was added to each water sample and allowed to equilibrate before processing. Then, 15 g of AMP was added to each acidified 55-L sample; the AMP was allowed to settle overnight, the supernates were discarded, and the AMP was separated from the slurry by centrifuge. The AMP was decomposed by heating in diluted sodium hydroxide solution; the cesium was precipitated as cesiumchloroplatinate, Cs_2PtCl_6; and the cesium radioactivity was determined by gamma spectrometry. The weight of the Cs_2PtCl_6 was used to correct for the chemical recovery of the cesium activities in the water sample.

Results

The locations of the various sampling sites established in 1984 are shown in Figure 2. Every site was not sampled in 1989, but an adequate number were sampled to permit comparison with previous data. The sampled sites are identified in the tables. They start at the Rancho Seco Nuclear Power Station boundary and follow Clay Creek to its intersection with Hadselville Creek, then follow Hadselville Creek to its confluence with Laguna Creek and then follow Laguna Creek toward the Cosumnes river. The last sampling station is about 27 km from the Rancho Seco Nuclear Power Station boundary.

The number and type of samples collected in 1989 are listed in Table 1. Water, creek sediments, sediment cores, and several species of fish were collected during the 1989 field trips.

The concentration of radionuclides in filtered water, prefilters, and combined total water are listed in Table 2 for collections made in January, April, and June 1989 downstream of the Rancho Seco Nuclear Power Station. The concentrations of ^{60}Co and ^{134}Cs were below detection limits for all but a few prefilter samples. Consequently, the significant radionuclide is ^{137}Cs and the total concentration of ^{137}Cs in water is shown in Figure 3 by collection period and distance downstream from the plant.

The highest concentration of ^{137}Cs found was less than 0.5 fCi/L near the plant in April 1989. The ratio of ^{137}Cs in filtered water and total water, at stations more than 0.7 km from the power plant to station RS17 located 0.7 km from the plant, is plotted in Figure 4.

The concentration of ^{137}Cs in the water is very low in all three time periods at all locations, but a definite reduction in the concentration of ^{137}Cs is observed as the distance away from the plant increases.

The results of the analysis of fish muscle-tissue samples collected in April and June 1989 are listed in Tables 3 and 4, and shown graphically in Figures 5 and 6. The results are very similar to those for the water samples; the concentration of ^{137}Cs is very low in all samples and decreases with increasing distance from the plant. The highest concentration of ^{137}Cs observed was near the plant in April and was only 0.4 pCi/g wet weight.

Figures 7, 8, and 9 show the ^{137}Cs concentration in bass, bluegill, and catfish, respectively, for the April and June collections. The ^{137}Cs concentration is essentially the same for both time periods for each of the species.

The concentration of ^{137}Cs found in fish muscle tissue from 1984 through 1989 is shown respectively in Figures 10, 11, and 12 for four stations: RS17 (0.7 km downstream), T1 (3.0 km downstream), R5 (4.8 km downstream), and R8 (12.8 km downstream). The data are decay-corrected to 1989 for easy comparison. The decrease in the ^{137}Cs concentration in all three species since 1984 is much greater than can be accounted for by radioactive decay alone.

If we then look at results from the sediment samples, we find that the concentrations of ^{137}Cs, ^{60}Co, and ^{134}Cs in creek sediments in January and April 1989 are shown in Figures 13 and 14 for the 0- to 12-cm depth at various distances from the Rancho Seco plant. Samples were only collected to a distance of 5 km from the plant in January, but to a distance of 27 km in April. The concentrations of the radionuclides in the 0- to 12-cm portion of the sediment column were very similar for the two time periods. The data are also listed in Tables 5 and 6, along with the ratios of some of the radionuclides.

Creek sediment cores were collected in April and June; the results are listed in Tables 7 and 8. The distribution of ^{137}Cs with depth varies at different locations down the streams; in general, the concentration decreases with depth, although there are locations (RS17B, T2) where higher concentrations were observed below the surface layer (0 to 6 cm). The mean fraction of the ^{137}Cs inventory found below 12-cm depth was about 45%.

In Figure 15, we show the ^{137}Cs concentration in the 0- to 12-cm sediments for 1984, 1985, 1986, 1987, and 1989. The top line of the graph is a regression for the 1984 data, the next line is the 1985 data, the third line is the 1986 data, the fourth line is 1987 data, and the bottom line the 1989 data. The regression equations are listed from top to bottom as 1984 through 1989. The calculated ^{137}Cs concentration at the effluent outfall (0 km; y-intercept of the equations) was 18.2 pCi/g in 1984 and has dropped to about 3 or 4 pCi/g in the 1987 to 1989 time period. The slope for each set of data is slightly different, but each shows a definite reduction in the ^{137}Cs concentration with distance from the plant.

Figure 16 shows the ratio of ^{137}Cs in fish to that in the 0- to 12-cm sediments for seven locations from 1984 through 1989. The ratio has decreased since 1984, but seems to be about the same since 1987.

The correlation of the ^{137}Cs concentration between fish and sediments, and fish and water, are shown in Figures 17 and 18, respectively.

Discussion

Water

In 1989, ^{137}Cs was the only radionuclide found in creek water samples except for four samples in which very low concentrations of ^{60}Co and ^{134}Cs were observed. The ^{137}Cs concentration in the water decreased with distance from the plant and was close to background levels at 8 to 12 km from the plant effluent outfall. Excluding the first 4-km zone, the ^{137}Cs concentration decreases rapidly with distance from the plant (Figure 3).

Data from previous years showed that the ^{137}Cs concentration in filtered water at stations between 0.7 and 10 km was equal to or greater than that at station RS17 at 0.7 km. However, the ^{137}Cs concentration in filtered water in April 1989 showed no such relationship and decreased consistently with distance from the plant as shown in Figure 4. In January 1989, ^{137}Cs was only detected at RS17 and was below our detection limit at all other stations. The water samples collected in June 1989 did show the ^{137}Cs slightly higher at 3 km than at 0.7 km, but this is not conclusive because all other samples were below our detection limit.

The concentration of ^{137}Cs in water at all periods sampled in 1989 was below that observed in previous years, and is in most cases approaching our detection limit of a few hundreths of a pCi per liter.

An analysis of the ^{137}Cs concentration in water from 1984 through 1989 indicates an exponential decrease at each of our stations according to the formula $y = a\,e^{bt}$, where y is the ^{137}Cs concentration at time t, a is the calculated ^{137}Cs concentration on August 1, 1984, and b is the depletion, or loss, rate constant. The half-depletion time for stations RS17 through R-11, based on measured data and a regression analysis with the above equation, ranges from 0.5 to 1.0 y. The depletion half-time based on data through 1987 was used to estimate the 1989 results; the predictions were that the ^{137}Cs concentration would be below our detection limit at all stations greater than 3 km downstream. This is precisely what we did observe when samples were collected and measured in 1989.

Fish

In 1989, the concentration of ^{137}Cs in fish decreased rapidly with distance from the plant boundary and was around background levels at 8 to 12 km from the plant effluent outfall. This rapid decrease in the ^{137}Cs concentration with distance from the plant was also observed in all of the previous studies (1–6).

However, the concentration of ^{137}Cs in fish is well below the concentration observed in 1984 through 1986, and is about the same as levels observed in 1987 (Figures 10 to 12). There was no statistically significant difference between the ^{137}Cs concentration observed in fish for April and June 1989.

The ^{137}Cs concentrations in bass, bluegill, and catfish were very similar to each other at any given station; consequently, we pooled the data for all fish species to improve the data base for correlating the ^{137}Cs concentration in fish to that in water and sediment. We will discuss this comparison under the Concentration-Ratio (or Concentration Factor) (C. R.) section.

Sediment

The concentration of ^{137}Cs in the sediments decreased in a very gradual way over the first 4 to 5 km from the plant effluent outfall, and then decreased very rapidly thereafter to about background levels at 8 to 12 km from the plant. A major observation is that about 45% of the sediment column inventory is now below 12 cm, whereas this fraction was only about 15% in earlier years. Consequently, the ^{137}Cs is being distributed deeper in the sediment column and is less available for exchange with the water. As a result, the amount of ^{137}Cs available for transfer from the water to fish, or the amount of ^{137}Cs ingested along with surface sediments by fish is less in 1989 than 1984 due to the ^{137}Cs being removed from the surface deeper into the sediments.

A comparison of the ratio of the ^{137}Cs *concentration in fish to that in the 0- to 12-cm* sediments (Figure 16) shows a reduction with time since 1984, and confirms the lesser availability of ^{137}Cs as it moves deeper in the sediment column.

In addition, the rainfall has been very light in 1987, 1988, and 1989. There has been little runoff and no turbulent water flow or flooding in the creeks with the concurrent massive movement of the sediment further downstream. During any rainstorm condition in the creek, the ^{137}Cs concentration in surface sediments may change by dilution or reconcentration, which could give different results from observations which were made in drought years.

Concentration Ratio (C. R.)

The C. R. calculated from the 1989 data by a regression analysis of the correlation between the ^{137}Cs concentration in water and fish is about 1030 (Figure 18). When calculated for each individual fish sample, the average is 1560 (Table 9). This range of possible C.R.'s for ^{137}Cs is less than the default value of 2000 used in the NRC Regulatroy Guide 1.109. There also was no observed significant difference in the C.R. with distance or concentration of ^{137}Cs.

The correlation between fish and 0- to 12-cm surface sediments is also quite good as shown in Figure 17; the correlation with sediments would probably be even better if made with only the top 5 cm of the sediment column, which is the major source of sediments ingested by fish and remobilized ^{137}Cs in the water column.

Recommendation

Most of the Rancho Seco Effluent Stream Radiological studies completed since 1986 have been made during abnormally low rainfall years. Deeper penetration of ^{137}Cs and ^{134}Cs has been noted in the creek sediments in 1989 compared to 1984: however, no significant change in the inventory of the creek sediments were observed, other than from radioactive decay. The effect of redistribution of radionuclides from the creek sediment during heavy runoff from an abnormally high rainfall year, or even a normal rainfall year, has so far not been evaluated due to the low rainfall cycle of the past four years. Such redistribution of radionuclides from the sedimentary source during heavy, stormy, runoff would spread radioactivity to a wider area, both downstream *and on adjacent land, which might change* their availability for uptake by the biota.

The most probable effect of heavy runoff would be a decrease in the over all radionuclide concentrations in the creek sediments because of dilution from the lower activity soils in the surroundings. Likewise, we do not anticipate any significant effect on the dose assessment related to the creek sediments; nevertheless, we recommend such a study be done when the opportunity permits to assess quantitatively the effect of runoff on the redistribution of radionuclides in the Ranch Seco effluent stream from a normal or from an abnormally high rainfall year.

If this type of study is desired by Rancho Seco, it should be planned as soon as possible and put in place before the rainy season so that the right opportunity would not be missed.

References

1. V. E. Noshkin, R. J. Eagle, J. M. Dawson, J. L. Brunk, and K. M. Wong, *Concentration of Radionuclides in Fresh Water Fish Downstream of Rancho Seco Nuclear Generating Plant*, Lawrence Livermore National Laboratory, Livermore, CA, UCID-20295 (1984).

2. K. M. Wong, R. J. Eagle, J. M. Dawson, J. L. Brunk, and V. E. Noshkin, *Radionuclides in Sediments Collected Downstream from the Rancho Seco Nuclear Power Generating Station*, Lawrence Livermore National Laboratory, Livermore, Ca, UCID-20298 (1985).

3. V. E. Noshkin, K. M. Wong, R. J. Eagle, J. W. Dawson, J. L. Brunk, and T. A. Jokela, *Environmental Radiological Studies Downstream from the Rancho Seco Nuclear Power Generating Station*, Lawrence Livermore National Laboratory, Livermore, CA, UCID-20367 (1985).

4. V. E. Noshkin, K. M. Wong, R. J. Eagle, J. L. Brunk, and T. A. Jokela, *Environmental Radiological Studies Downstream from the Rancho Seco Nuclear Power Generating Station - 1985*, Lawrence Livermore National Laboratory, Livermore, CA, UCID-20641, Part 1 (1986).

5. V. E. Noshkin, K. M. Wong, R. J. Eagle, J. L. Brunk, and T. A. Jokela, *Environmental Radiological Studies Downstream from the Rancho Seco Nuclear Power Generating Station - 1985*, Appendices, Lawrence Livermore National Laboratory, Livermore, CA, UCID-20641, Part II (1986).

6. V. E. Noshkin, R. J. Eagle, J. M. Dawson, J. L. Brunk, and K. M. Wong, *Environmental Radiological Studies Conducted During 1986 in the Vicinity of the Rancho Seco Nuclear Power Generating Station*, Lawrence Livermore National Laboratory, Livermore, CA, UCID-20963, Part 1 (1987).

7. V.E. Noshkin, K. M. Wong R. J. Eagle, J. L. Brunk, and T. A. Jokela, *Environmental Radiological Studies Conducted During 1986 in the Vicinity of the Rancho Seco Nuclear Power Generating Station*, Appendices, Lawrence Livermore National Laboratory, Livermore, CA, UCID-20963, Part II (1987).

8. 1987 data from Vic Noshkin, private communication.

GMG/rb

Table 1. Number and Type of Samples Collected in 1989.

	January	April	June	Total
Water	6	13	6	25
Sediment (0–12 cm)	14	32	--	46
Sediment cores	--	35	44	79
Fish[a]				
Bass	--	8	5	13
Bluegill	--	6	7	13
Carp	--	4	--	4
Catfish	--	5	5	10
Background water				
Rancho Seco Lake	--	1	--	1
Mokelumne River	--	1	--	1
Cosumnes River	--	1	--	1
Background fish				
Bass, Rancho Lake	--	1	--	1
Carp, Mokelumne River	--	1	--	1
Background sediment (0–12 cm)				
Mokelumne River	--	1	--	1
Hadselville Creek	--	1	--	1
Rancho Seco Lake	--	1	--	1
Cosumnes River	--	1	--	1

(a) Number of locations; several fish were pooled for each location.

Table 2. Radionuclide Concentrations in Creek Water Downstream of Rancho Seco Nuclear Power Generating Station, in January, April, and June 1989.

Date	Station No.	Distance, km (b)	Radionuclide concentration in filters and water, pCi/L(a) — Prefilter ^{60}Co	Prefilter ^{134}Cs	Prefilter ^{137}Cs	Filtrate ^{137}Cs	Total water ^{134}Cs	Total water ^{137}Cs
Jan-89	RS–24	0			0.012(12)	0.04(42)		0.052(35)
Jan-89	RS–17	0.7			0.059(18)	bd		0.059(18)
Jan-89	RS–9	1.5			0.039(12)	bd		0.039(12)
Jan-89	RS–1	2.3			0.04(17)	bd		0.04(17)
Jan-89	T–1	3.0			0.015(18)	bd		0.015(18)
Jan-89	R–5	4.8			0.012(25)	bd		0.012(25)
Apr-89	RS–24	0.0						
Apr-89	RS–17	0.7	0.055(9)		0.14(4)	0.29(13)		0.43(9)
Apr-89	RS–1	2.3	0.078(15)	0.05(25)	0.4(5)	0.06(39)	0.05(25)	0.46(5)
Apr-89	T–1	3.0	0.025(26)		0.18(7)	0.1(26)		0.28(9)
Apr-89	R–5	4.8			0.14(11)	bd		0.14(11)
Apr-89	T–2	7.5		0.013(40)	0.071(7)	0.06(36)	0.013(40)	0.13(17)
Apr-89	R–8	12.8			0.026(20)	bd		0.026(20)
Apr-89	R–22	15.4			0.047(9)	bd		0.047(9)
Apr-89	R–11	19.5			0.021(17)	bd		0.021(17)
Apr-89	R–9	26.7			0.005(39)	0.007(38)		0.012(38)
Apr-89	R–53	(c)			bd	bd		bd
Apr-89	R–100	(d)			0.021(23)	bd		0.021(23)
Apr-89	R–18	(e)			bd	bd		bd
Jun-89	RS–17	0.7			0.039(27)	bd		0.039(27)
Jun-89	T–1	3.0			0.1(14)	0.06(37)		0.16(23)
Jun-89	R–5	4.8	0.02(42)		0.1(15)	bd		0.1(15)
Jun-89	R–8	12.8			0.076(16)	bd		0.076(16)
Jun-89	R–22	15.4			bd	bd		bd
Jun-89	R–11	19.5			bd	bd		bd

Note: bd Below detection limit.

(a) Values in parenthesis are one-sigma standard deviation counting errors expressed as percent of activity.

(b) Distance from plant effluent discharge.

(c) Rancho Seco Lake, upstream of plant effluent discharge.

(d) Mokelumne River background sample.

(e) Cosumnes River background sample.

Table 3. Radionuclide Concentrations in Fish Muscle Tissue Collected Downstream of Rancho Seco Nuclear Power Generating Station in April 3–7, 1989.

Station No.	Distance, km (b)	Fish name	Dry/wet Wt.	pCi/g wet weight (a) ^{40}K	^{134}Cs	^{137}Cs	Activity Ratio 134/137
RS–17	0.7	Bass	0.2000	bd	bd	0.41(2)	
T–1	3.0	Bass	0.2043	bd	bd	0.21(3)	
R–5	4.8	Bass	0.2008	3.5(2)	0.018(17)	0.18(3)	0.10
T–2	7.5	Bass	0.2090	3.3(6)	bd	0.077(11)	
R–8	12.8	Bass	0.2260	2.7(9)	bd	0.011(27)	
R–22	15.4	Bass	0.2171	3.7(14)	bd	bd	
R–11	19.5	Bass	0.1983	4.4(12)	bd	bd	
T–1	3.0	Bluegill	0.2047	3.2(4)	bd	0.084(9)	
R–5	4.8	Bluegill	0.1965	4.1(12)	bd	0.14(8)	
T–2	7.5	Bluegill	0.2136	3.9(8)	bd	0.081(19)	
R–8	12.8	Bluegill	0.2150	3.7(3)	bd	0.026(20)	
R–22	15.4	Bluegill	0.3390	3.7(4)	bd	0.017(38)	
R–11	19.5	Bluegill	0.2038	3.7(5)	bd	0.016(36)	
T–1	3.0	Carp	0.2051	bd	bd	0.13	
R–5	4.8	Carp	0.1973	4.9(5)	bd	0.049(19)	
R–11	19.5	Carp	0.2005	3.1(5)	bd	bd	
T–1	3.0	Catfish	0.1884	3.5(5)	0.014(25)	0.15(3)	0.093
R–5	4.8	Catfish	0.1895	3.4(4)	bd	0.13(4)	
T–2	7.5	Catfish	0.1904	5.7(6)	bd	0.072(30)	
R–8	12.8	Catfish	0.1963	4.6(4)	bd	0.055(14)	
R–11	19.5	Catfish	0.2279	4(3)	bd	bd	
R–53	(c)	Bass	0.3427	3.7(2)	bd	0.023(9)	
R–100	(d)	Carp	0.2292	3.3(9)	bd	0.039(39)	

Note: bd Below detection limit.

(a) Values in parentheses are the one sigma standard deviation of counting errors expressed as percent of activity.

(b) Distance from plant effluent discharge.

(c) Rancho Seco Lake, upstream of effluent discharge.

(d) Mokelumne River background sample.

Table 4. Radionuclide Concentrations in Fish Muscle Tissue Collected Downstream of Rancho Seco Nuclear Power Generating Station in June 28–29, 1989.

Station No.	Distance km (b)	Fish name	Dry/wet Wt.	pCi/g wet weight (a) ^{40}K	^{134}Cs	^{137}Cs	Activity Ratio 134/137
RS–17	0.7	Bass	0.217	3.4(3)	0.037(14)	0.31(3)	0.12
R–5	4.8	Bass	0.204	3.9(8)	bd	0.31(7)	
T-2	7.5	Bass	0.203	3.3(4)	bd	0.073(10)	
R–8	12.8	Bass	0.205	2.1(38)	bd	bd	
R–11	19.5	Bass	0.213	3.7(5)	bd	bd	
RS–30(c)	0.7	Bluegill	0.188	2.9(5)	0.013(34)	0.22(4)	0.06
T–1	3.0	Bluegill	0.199	3.0(3)	0.012(26)	0.12(3)	0.10
R–5	4.8	Bluegill	0.205	3.4(6)	bd	0.15(6)	
T–2	7.5	Bluegill	0.193	3.1(4)	bd	0.03(7)	
R–8	12.8	Bluegill	0.196	3.3(7)	bd	0.07(19)	
R–22	15.4	Bluegill	0.188	2.6(6)	bd	0.018(32)	
R–11	19.5	Bluegill	0.192	3(5)	bd	bd	
R–5	4.8	Catfish	0.190	3.2(5)	bd	0.091(11)	
T–2	7.5	Catfish	0.187	9(11)	bd	bd	
R–8	12.8	Catfish	0.193	3.5(7)	bd	0.0085(42)	
R–22	15.4	Catfish	0.182	3.6(10)	bd	0.084(20)	
R–11	19.5	Catfish	0.186	3.4(5)	bd	bd	

Note: bd Below detection.

(a) Values in parentheses are the one sigma standard deviation counting errors expressed as percent of activity.

(b) Distance from plant effulent discharge.

(c) Irrigation pond adjacent to Sta. RS-17.

Table 5. **Radionuclide Concentration in 0- to 12-cm Creek Sediments Downstream of the Rancho Seco Nuclear Power Generating Plant, Collected January 26, 1989.**

Station	Distance	pCi/g dry sediment(a)				Activity Ratios	
No.	km (b)	^{40}K	^{60}Co	^{134}Cs	^{137}Cs	134/137	60/137
RS–24	0	6.9 (8)	0.77 (4)	0.44 (11)	4.24 (2)	0.10	0.18
RS–23	0.1	6.4 (6)	0.40 (4)	0.48 (7)	4.57 (2)	0.10	0.09
RS–23 (c)	0.3	7.5 (7)	0.71 (4)	0.30 (12)	3.08 (5)	0.10	0.23
RS–21	0.3	6.4 (7)	0.82 (3)	1.20 (3)	11.0 (1)	0.11	0.07
RS–17	0.7	5.7 (6)	0.39 (5)	0.21 (10)	1.89 (2)	0.11	0.21
RS–13	1.1	4.2 (8)	0.59 (4)	0.44 (8)	4.05 (1)	0.11	0.15
RS–9	1.5	3.4 (8)	0.28 (4)	0.30 (8)	2.70 (2)	0.11	0.10
RS–4	1.9	4.7 (14)	0.63 (6)	0.72 (8)	6.24 (1)	0.12	0.10
RS–1	2.2	3.5 (12)	0.16 (9)	0.18 (14)	1.86 (3)	0.09	0.09
R–45	2.4	4.6 (17)	0.70 (8)	0.51 (13)	4.69 (3)	0.11	0.15
R–44	2.6	9.5 (5)	0.46 (6)	0.30 (13)	3.08 (3)	0.10	0.15
T–1	3.0	10.1 (9)	0.34 (11)	0.39 (12)	3.68 (3)	0.11	0.09
R–4	4.0	14.2 (5)	0.22 (15)	0.27 (22)	2.51 (3)	0.11	0.09
R–5	4.8	14.1 (5)	0.09 (39)	0.29 (13)	2.35 (7)	0.12	0.04
				Mean ratio (Collection)=		0.107	0.124
				Std. dev. =		0.007	0.053

(a) Value in parentheses are the one sigma standard deviation counting errors expressed as percent of activity.
(b) Distance from plant effluent discharge.
(c) Soil from embankment of RS-23.

Table 6. Radionuclide Concentrations in 0- to 12 -cm Creek Sediments Downstream of Rancho Seco Nuclear Power Generating Plant, Collected April 1989.

Station No.	Date Collected	Distance Down Stream, km (b)	pCi/g dry weight(a)				Activity Ratios	
			^{40}K	^{60}Co	^{134}Cs	^{137}Cs	134/137	60/137
RS–24	04-04-89	0.0	6.8 (4)	0.21 (4)	0.30 (8)	3.15 (2)	0.10	0.07
RS–19	04-04-89	0.5	4.6 (10)	1.47 (2)	0.52 (7)	6.50 (3)	0.08	0.23
RS–18	04-04-89	0.6	4.7 (4)	0.49 (2)	0.57 (3)	5.74 (1)	0.10	0.09
RS–17	04-04-89	0.7	3.9 (3)	0.32 (2)	0.20 (4)	2.10 (2)	0.10	0.15
RS–30	04-04-89	c	5.2 (7)	0.035 (15)	0.04 (51)	0.39 (4)	0.10	0.09
RS–12	04-04-89	1.2	4.1 (8)	0.24 (3)	0.27 (7)	2.66 (3)	0.10	0.09
RS–9	04-04-89	1.5	3.6 (9)	0.38 (2)	0.41 (5)	4.36 (2)	0.09	0.09
RS–5	04-04-89	1.9	3.6 (6)	0.32 (2)	0.22 (9)	2.25 (2)	0.10	0.14
RS–4	04-04-89	2.0	5.3 (5)	0.67 (2)	0.61 (6)	6.00 (2)	0.10	0.11
RS–1	04-04-89	2.3	4.5 (5)	0.07 (9)	0.15 (10)	1.55 (2)	0.10	0.05
K–61	04-03-89	2.5	7.2 (4)	0.36 (5)	0.59 (6)	5.70 (2)	0.10	0.06
K–60	04-03-89	2.7	13.1 (3)	0.136 (5)	0.25 (7)	2.52 (2)	0.10	0.05
T-1	04-03-89	3.0	11.9 (4)	0.11 (10)	0.27 (10)	2.68 (3)	0.10	0.04
R–54	04-04-89	d	8.1 (5)	bd	bd	0.095 (14)		
K–59	04-03-89	3.2	13.7 (4)	0.07 (15)	0.13 19)	1.34 (2)	0.10	0.05
R–37	04-03-89	4.0	16.8 (2)	0.064 (15)	0.25 (6)	2.42 (2)	0.10	0.03

Note: bd Below detection

(a) Values in parentheses are the one sigma standard deviation counting errors expressed as percent of activity.

(b) Distance from plant effluent discharge.

(c) Irrigation pond connected to RS-17.

(d) Holding pond located 200 m from Station T-1.

(e) Background sample, Cosumnes River.

(f) Bkg sample from Mokelumne River.

(g) Bkg sample from Hadselville Ck 2.5 km north of confluence of Clay Ck.

(h) Bkg sample from Rancho Seco Lake.

Table 6 continued. Radionuclide Concentrations in 0- to 12-cm Creek Sediments Downstream of Rancho Seco Nuclear Power Generating Plant, Collected April 1989.

Station No.	Date Collected	Distance Down Stream, km (b)	pCi/g dry wt. at collection (a)				Activity Ratios	
			^{40}K	^{60}Co	^{134}Cs	^{137}Cs	134/137	60/37
R–36	04-03-89	4.1	13.0 (3)	0.16 (6)	0.30 (8)	3.02 (2)	0.10	0.05
R–4	04-03-89	4.2	13.9 (2)	0.07 (12)	0.15 (14)	1.60 (3)	0.09	0.04
R–35	04-03-89	4.3	13.8 (4)	0.33 (5)	0.29 (7)	2.93 (3)	0.10	0.11
R–33	04-03-89	4.6	14.8 (2)	0.125 (7)	0.18 (11)	1.94 (2)	0.09	0.06
R–5	04-03-89	4.8	12.3 (4)	0.032 (18)	0.10 (18)	0.95 (2)	0.11	0.03
T–2	04-02-89	7.5	8.3 (2)	0.03 (16)	0.09 (10)	0.88 (3)	0.11	0.03
R–8	04-02-89	12.8	9.3 (3)	bd	0.03 (41)	0.39 (3)	0.07	
R–21	04-02-89	13.7	7.1 (5)	bd	bd	0.03 (29)		
T–4	04-02-89	17.2	8.3 (2)	bd	bd	0.04 (9)		
R–11	04-02-89	19.5	8.9 (4)	bd	bd	0.04 (20)		
R–9	04-02-89	26.7	11.0 (3)	bd	bd	0.03 (23)		
R–18	04-03-89	e	10.0 (4)	bd	bd	0.03 (30)		
R–100	04-06-89	f	8.4 (5)	bd	bd	0.024 (73)		
R–1	04-04-89	g	16.9 (2)	bd	bd	0.05(14)		
R–53	04-04-89	h	6.4 (3)	bd	bd	0.03 (24)		

Note: bd Below detection

(a) Values in parentheses are the one sigma standard deviation counting errors expressed as percent of activity.

(b) Distance from plant effluent discharge.

(c) Irrigation pond connected to RS-17.

(d) Holding pond located 200 m from Station T-1.

(e) Background sample, Cosumnes River.

(f) Bkg sample from Mokelumne River.

(g) Bkg sample from Hadselville Ck 2.5 km north of confluence of Clay Ck.

(h) Bkg sample from Rancho Seco Lake.

Table 7. Radionuclide Concentrations in Sediment Cores Downstream of the Rancho Seco Nuclear Power Generating Plant, Collected April 1989.

Station No.	Distance from Plant, km (c)	Core Section cm	Dry Wt. g	pCi/g dry weight (a,b) ^{40}K	^{226}Ra	^{228}Ra	^{60}Co	^{134}Cs	^{137}Cs	Activity Ratio 134/137	Fraction Cs-137 Below 12 cm
RS-19	0.5	0-10	398	4.2(6)	0.31(5)	0.27(12)	2.30(2)	0.32(7)	5.66(2)	0.06	0.52
RS-19	0.5	10-17	247	4.9(10)	0.30(11)	0.34(24)	3.30(1)	0.35(10)	7.22(1)	0.05	
RS-19	0.5	17-31	355	4.3(5)	0.46(3)	0.38(8)	0.51(2)	0.10(18)	1.76(1)	0.06	
RS-30	0.7	0-9	250	8.1(6)	0.93(4)	0.6(10)			0.07(20)		0.46
RS-30	0.7	9-19	214	6.1(10)	0.89(4)	0.58(11)			0.03(33)		
RS-30	0.7	19-26	102	2.4(41)	0.30(26)	0.55(46)			0.08(37)		
RS-17	0.7	0-13	325	5.6(6)	0.42(11)	0.45(5)			0.18(11)		0.59
RS-17	0.7	13-16	92	4.9(8)	0.32(26)	0.52(18)			0.16(11)		
RS-17	0.7	16-26	249	7.5(6)	0.66(5)	0.57(11)			0.28(7)		
RS-12	1.2	0-11	294	3.1(13)	0.18(20)	0.20(26)	0.53(4)	0.59(5)	5.95(4)	0.10	0.24
RS-12	1.2	11-20	166	3.7(8)	0.28(11)	0.38(17)	0.14(8)	0.33(8)	3.36(2)	0.10	
RS-12	1.2	20-28	195	1.8(24)	0.14(21)	0.19(36)			0.03(28)		
R-5	4.8	0-16	473	13.1(3)	0.47(5)	0.56(8)		0.036(26)	0.43(8)	0.08	0.38
R-5	4.8	16-25	200	9.5(9)	0.84(11)	0.85(9)			0.0826)		
R-5-B	4.8	0-11	401	15.4(2)	0.43(4)	0.40(21)	0.05(13)	0.22(7)	2.05(1)	0.11	0.17
R-5-B	4.8	11-16	119	12.6(6)	0.42(11)	0.35(30)		0.15(16)	1.44(4)	0.10	
T-2	7.5	0-11	135	9.2(6)	0.45(15)	0.42(12)		0.1(19)	1.07(4)	0.09	0.58
T-2	7.5	11-20	16	6.6(10)	0.4(11)	0.46(24)		0.1(39)	0.97(5)	0.10	
T-2	7.5	20-28	110	6.4(11)	0.32(10)	0.32(11)		0.09(31)	0.80(2)	0.11	

Note: bd Below detection limit.
(a) Decay corrected to date of collection.
(b) Values in parentheses are the one sigma standard deviation counting errors expressed as percent of activity.
(c) Distance from plant effluent discharge.

Table 7 continued. Radionuclide Concentrations in Sediment Cores Downstream of the Rancho Seco Nuclear Power Generating Plant, Collected April 1989.

Station No.	Distance from Plant, km (c)	Core Section cm	Dry Wt. g	pCi/g dry weight (a,b) ^{40}K	^{226}Ra	^{228}Ra	^{60}Co	^{134}Cs	^{137}Cs	Activity Ratio 134/137	Fraction Cs-137 Below 12 cm
R-8	12.8	0-9	126	5.8(4)	0.25(24)	0.14(38)			0.21(10)		0.76
R-8	12.8	9-27	377	9.2(5)	0.45(5)	0.46(10)		0.093(13)	0.74(4)	0.13	
R-8-B	12.8	0-10	355	9.8(4)	0.53(6)	0.48(13)		0.2(15)	1.7(2)	0.12	0.24
R-8-B	12.8	10-26	344	9.9(5)	0.63(4)	0.56(7)	0.25(43)	0.025(77)	0.44(5)	0.06	
R-8-B	12.8	26-40	456	10.3(6)	0.42(5)	0.42(8)			0.084(17)		
R-21	13.7	0-15	375	9.5(4)	0.62(3)	0.65(5)			bd		1.00
R-21	13.7	15-24	277	7.3(8)	0.53(9)	0.65(13)			bd		
R-21	13.7	24-30	211	8.3(2)	0.66(2)	0.68(8)			0.02(23)		
R-22	15.4	0-12	411	9.2(5)	0.53(3)	0.51(5)			0.077(14)		
R-22	15.4	12-24	325	7(8)	0.57(8)	0.68(10)			bd		
R-22	15.4	24-35	229	8.9(6)	0.73(4)	0.7(9)			bd		
R-11	19.5	0-13	576	10.5(3)	0.42(4)	0.40(8)			0.06(11)		0.19
R-11	19.5	13-18	251	11.7(2)	0.34(5)	0.29(12)			0.03(22)		
R-11	19.5	18-23	196	6.7(7)	0.50(5)	0.51(9)			bd		
R-53	RSL	0-10	261	6.7(11)	0.86(4)	0.69(8)			bd		
R-53	RSL	10-23	312	8.2(5)	0.86(3)	0.71(12)			bd		
										------	------
							Mean			0.098	0.43
							Std.			0.027	0.27

Note: RSL Rancho Seco Lake
bd Below detection limit.
(a) Decay corrected to date of collection.
(b) Values in parentheses are the one sigma standard deviation counting errors expressed as percent of activity.
(c) Distance from plant effluent discharge.

Table 8. Radionuclide Concentrations in Sediment Cores Downstream of the Rancho Seco Nuclear Power Generating Plant, Collected June 1989.

Station No.	Distance Down Stream, km (c)	Core Section cm	Total Dry Wt. g	pCi/g dry weight (a,b) ^{40}K	^{60}Co	^{134}Cs	^{137}Cs	Activity Ratio 134/137	Fraction Cs-137 Below 12cm
RS–17A(d)	0.7	0–6	92	5.5(12)	0.57(7)	0.43(10)	4.60(2)	0.09	0.47
RS–17A	0.7	6–12	164	2.9(29)	0.23(10)	0.31(20)	2.52(3)	0.12	
RS–17A	0.7	12–18	175	3.9(10)	bd	0.13(24)	1.28(3)	0.10	
RS–17A	0.7	18–24	131	2.5(19)	bd	0.19(13)	1.94(3)	0.10	
RS–17A	0.7	24–30	103	3.9(15)	bd	0.13(28)	1.56(3)	0.08	
RS–17A	0.7	30–40	159	2.4(31)	bd	0.05(65)	0.60(5)	0.08	
RS–17B(d)	0.7	0–6	127	3.9(5)	0.32(4)	0.18(11)	1.86(2)	0.10	0.83
RS–17B	0.7	6–12	127	bd	0.30(11)	bd	1.91(4)		
RS–17B	0.7	12–18	117	3.9(16)	0.98(4)	0.55(9)	6.31(2)	0.09	
RS–17B	0.7	18–24	52	bd	0.45(23)	0.61(15)	7.06(2)	0.08	
RS–17B	0.7	24–30	82	3.2(26)	0.18(19)	0.54(12)	6.54(2)	0.08	
RS–17B	0.7	30–37	93	3.2(17)	0.22(15)	0.73(8)	7.30(2)	0.10	
RS–17S(e)	0.7	0–6	208	5.6(9)	0.12(13)	0.06(55)	1.04(3)	0.06	0.48
RS–17S	0.7	6–12	222	6.5(5)	0.11(15)	0.03(53)	0.97(3)	0.03	
RS–17S	0.7	12–18	249	7.4(8)	0.05(35)	0.04(81)	0.47(5)	0.09	
RS–17S	0.7	18–24	211	4.8(12)	0.06(36)	bd	0.48(6)		
RS–17S	0.7	24–30	203	6.5(11)	bd	bd	0.23(11)		
RS–17S	0.7	30–41	428	5.9(5)	0.03(36)	bd	0.31(5)		

Note: bd Below detection limit.
(a) Decay corrected to date of sampling.
(b) Values in parentheses are the one sigma standard deviation of counting errors expressed as percent of activity.
(c) Distance from plant effluent discharge.
(d) RS-17A and B are duplicate samples taken 10 m apart at Station RS-17.
(e) RS-17S is a horizonal core taken from the side of the bank below stream water.

Table 8 continued. Radionuclide Concentrations in Sediment Cores Downstream of the Rancho Seco Nuclear Power Generating Plant, Collected June 1989.

Station No.	Distance Down Stream, km (c)	Core Section cm	Total Dry Wt. g	pCi/g dry weight (a,b) ^{40}K	^{60}Co	^{134}Cs	^{137}Cs	Activity Ratio 134/137	Fraction Cs-137 Below 12cm
T-1	3.0	0–6	166	12.6(6)	bd	bd	0.12(44)		0.34
T-1	3.0	6–12	199	14.3(5)	bd	bd	bd		
T-1	3.0	12–18	208	14.0(4)	bd	bd	0.05(29)		
T-1	3.0	18–24	296	15.0(4)	bd	bd	bd		
T-1	3.0	24–30	269	14.8(5)	bd	bd	bd		
T-1	3.0	30–37	211	15.6(5)	bd	bd	bd		
R-5	4.8	0–6	202	15.6(5)	bd	0.11(29)	1.44(3)	0.08	0.10
R-5	4.8	6–12	225	11.7(7)	bd	bd	0.30(12)		
R-5	4.8	12–18	246	10.4(4)	bd	bd	0.07(33)		
R-5	4.8	18–24	221	13.5(5)	bd	bd	0.06(43)		
R-5	4.8	24–30	109	8.4(11)	bd	bd	bd		
R-5	4.8	30–36	86	8.4(17)	bd	bd	bd		
R-5	4.8	36–43	152	9.4(8)	bd	bd	0.05(29)		
T-2	7.5	0–6	148	7.1(9)	bd	bd	0.61(5)		0.81
T-2	7.5	6–12	1[illegible]8	9.3(6)	0.18(94)	0.06(41)	0.80(4)	0.08	
T-2	7.5	12–18	366	7.9(7)	3.40(11)	0.16(21)	1.60(3)	0.10	
T-2	7.5	18–24	110	9.6(6)	0.20(85)	0.11(42)	1.07(3)	0.10	
T-2	7.5	24–32	126	8.3(6)	bd	bd	0.62(6)		

Note: bd Below detection limit.
(a) Decay corrected to date of sampling.
(b) Values in parentheses are the one sigma standard deviation of counting errors expressed as percent of activity.
(c) Distance from plant effluent discharge.
(d) RS-17A and B are duplicate samples taken 10 m apart at Station RS-17.
(e) RS-17S is a horizonal core taken from the side of the bank below stream water.

Table 8 continued. Radionuclide Concentrations in Sediment Cores Downstream of the Rancho Seco Nuclear Power Generating Plant, Collected June 1989.

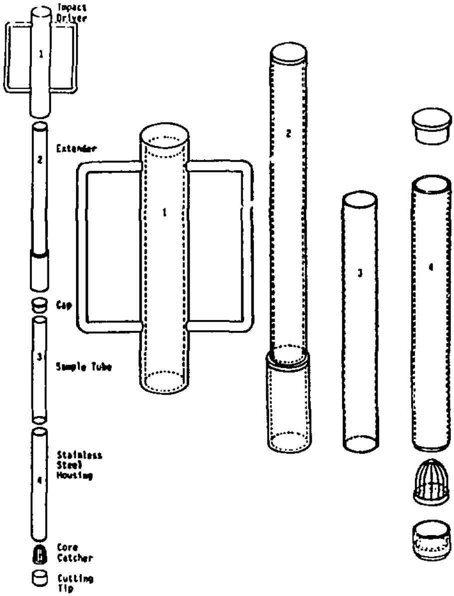
Station No.	Distance Down Stream, km (c)	Core Section cm	Total Dry wt. g	pCi g dry weight (a,b) ^{40}K	^{60}Co	^{134}Cs	^{137}Cs	Activity Ratio 134/137	Fraction Cs-137 below 12 cm
R-8	12.8	0–6	166	9.0(7)	bd	bd	0.78(6)		0.15
R-8	12.8	6–12	225	8.7(6)	bd	0.05(51)	0.78(5)	0.06	
R-8	12.8	12–18	200	7.1(9)	bd	bd	0.23(18)		
R-8	12.8	18–24	215	8.0(11)	bd	bd	bd		
R-8	12.8	24–30	24[illegible]	9.2(13)	bd	bd	bd		
R-8	12.8	30–36	229	8.6(7)	bd	bd	0.03(39)		
R-8	12.8	36–42	248	9.5(9)	bd	bd	bd		
R-8	12.8	42–48	301	7.8(11)	bd	bd	bd	------	------
					Mean Value (at collection):			0.09	0.45

Note: bd Below detection limit.
(a) Decay corrected to date of sampling.
(b) Values in parentheses are the one sigma standard deviation of counting errors expressed as percent of activity.
(c) Distance from plant effluent discharge.
(d) RS-17A and B are duplicate samples taken 10 m apart at Station RS-17.
(e) RS-17S is a horizonal core taken from the side of the bank below stream water.

Table 9. The Concentration Ratio (C.R.) for ^{137}Cs for Fish Downstream from the Rancho Seco Nuclear Power Station in 1989.

	Bass		Bluegill		Catfish	
Station No.	April	June	April	June	April	June
RS17	1.41×10^3	—	—	—	—	—
T–1	2.10×10^3	—	8.40×10^2	2.00×10^3	1.50×10^3	—
R–5	—	3.10×10^3	—	1.50×10^3	9.10×10^2	
T–2	1.28×10^3	—	1.35×10^3	—	1.20×10^3	—
Mean	1597	3100	1095	1750	1350	910
Std. Dev.	441	—	361	354	212	—

Note: Overall Weighted mean = 1563.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1
Extender
2
Cap
3
Sample Tube
Stainless Steel Housing
4
Core Catcher
Cutting Tip

Figure 1

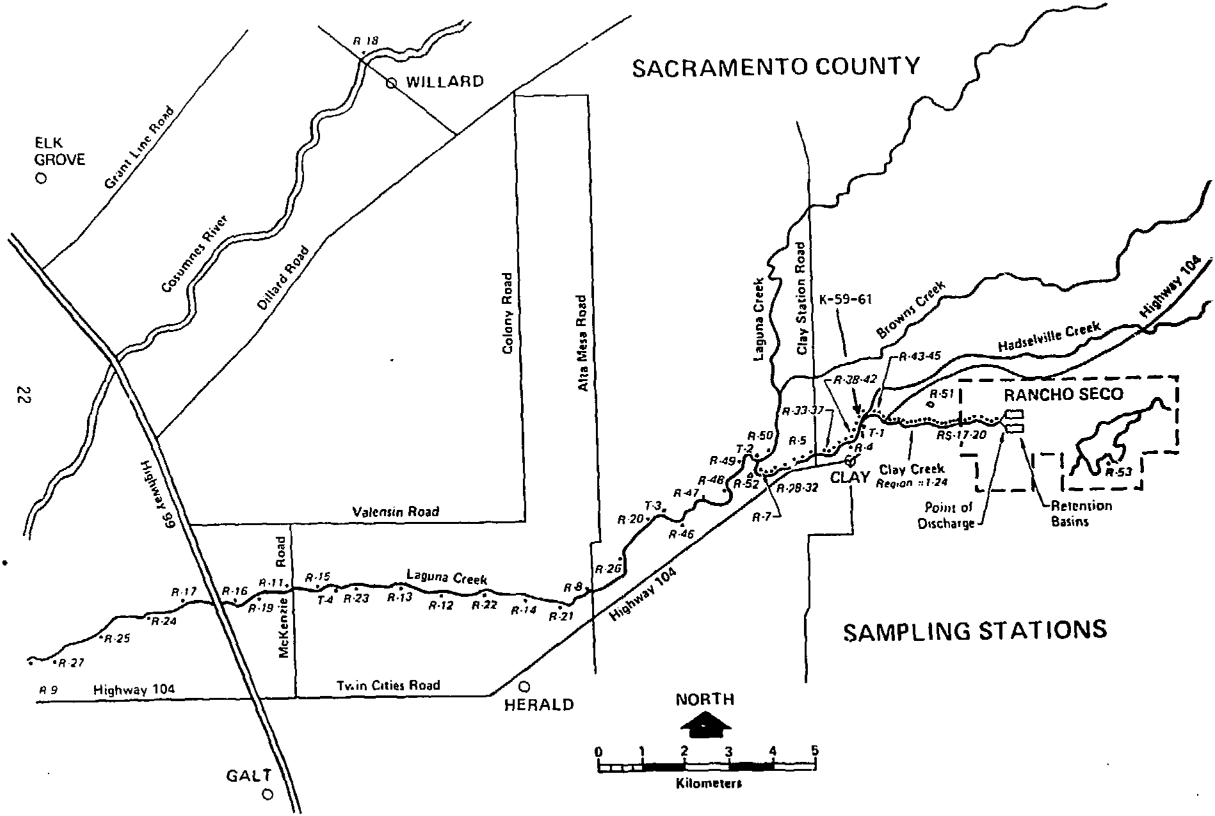

SACRAMENTO COUNTY
SAMPLING STATIONS
ELK GROVE
WILLARD
GALT
HERALD
CLAY
RANCHO SECO
Grant Line Road
Cosumnes River
Dillard Road
Colony Road
Alta Mesa Road
Valensin Road
McKenzie Road
Twin Cities Road
Highway 99
Highway 104
Laguna Creek
Clay Station Road
Browns Creek
Hadselville Creek
Clay Creek
Region :: 1-24
Point of Discharge
Retention Basins
K-59-61
R-18
R-9
R-27
R-25
R-24
R-17
R-16
R-19
R-11
R-15
T-4
R-23
R-13
R-12
R-22
R-14
R-21
R-8
R-26
R-20
T-3
R-46
R-47
R-48
R-49
T-2
R-50
R-52
R-7
R-28-32
R-5
R-33-37
R-38-42
R-43-45
R-4
T-1
R-51
RS-17-20
R-53
NORTH
0
1
2
3
4
5
Kilometers

Figure 2

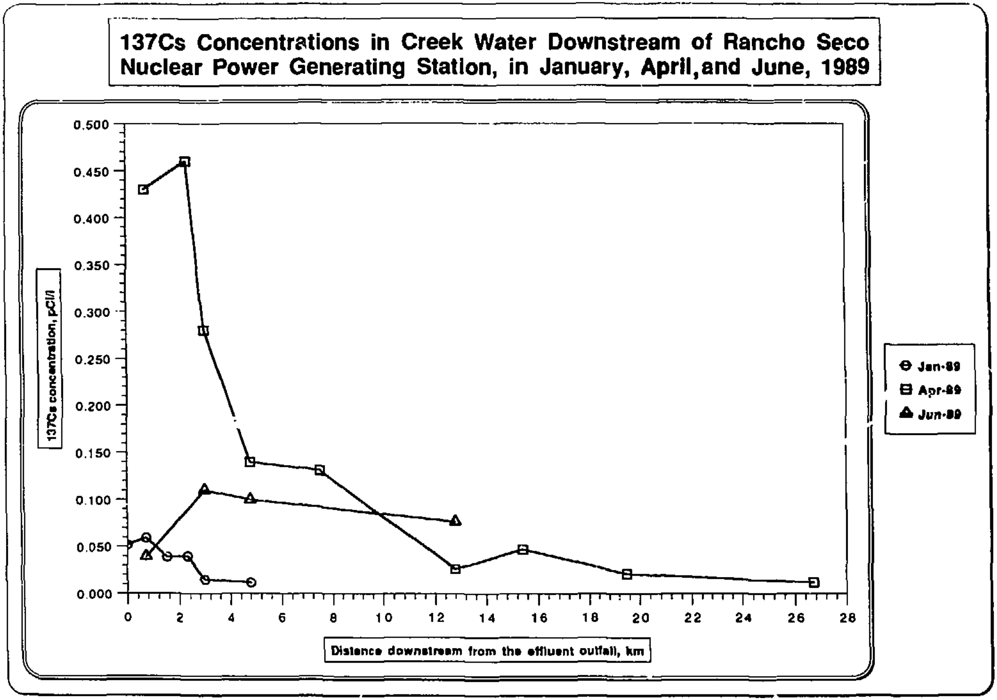

137Cs Concentrations in Creek Water Downstream of Rancho Seco Nuclear Power Generating Station, in January, April,and June, 1989
137Cs concentration, pCi/l
0.500
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
Distance downstream from the effluent outfall, km
Jan-89
Apr-89
Jun-89

Figure 3

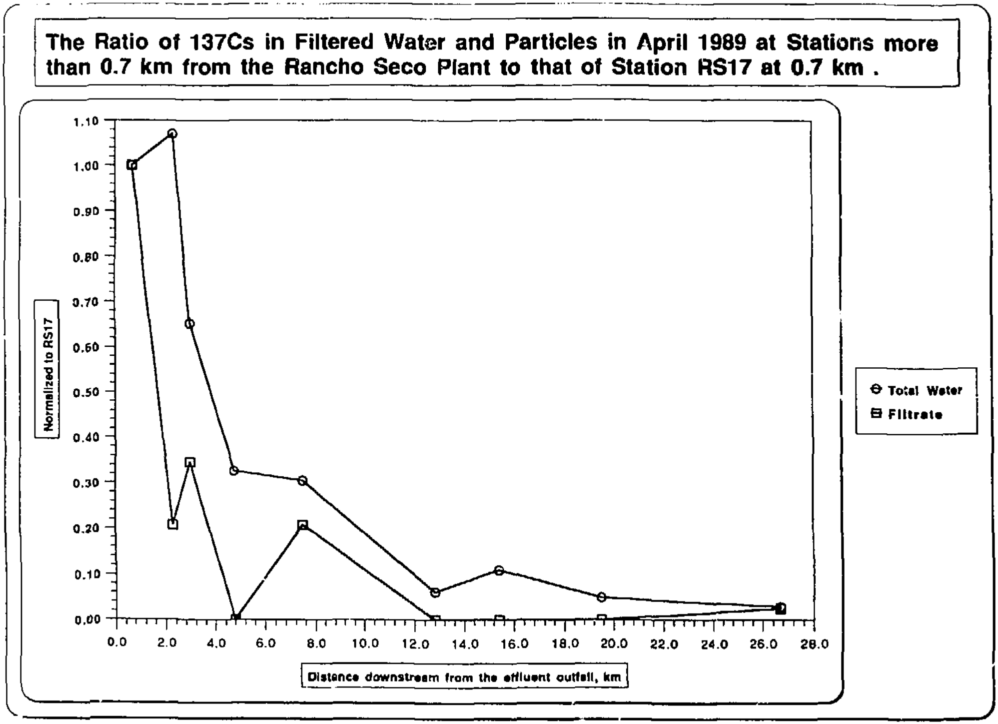

The Ratio of 137Cs in Filtered Water and Particles in April 1989 at Stations more than 0.7 km from the Rancho Seco Plant to that of Station RS17 at 0.7 km .
Normalized to RS17
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
Distance downstream from the effluent outfall, km
Total Water
Filtrate

Figure 4

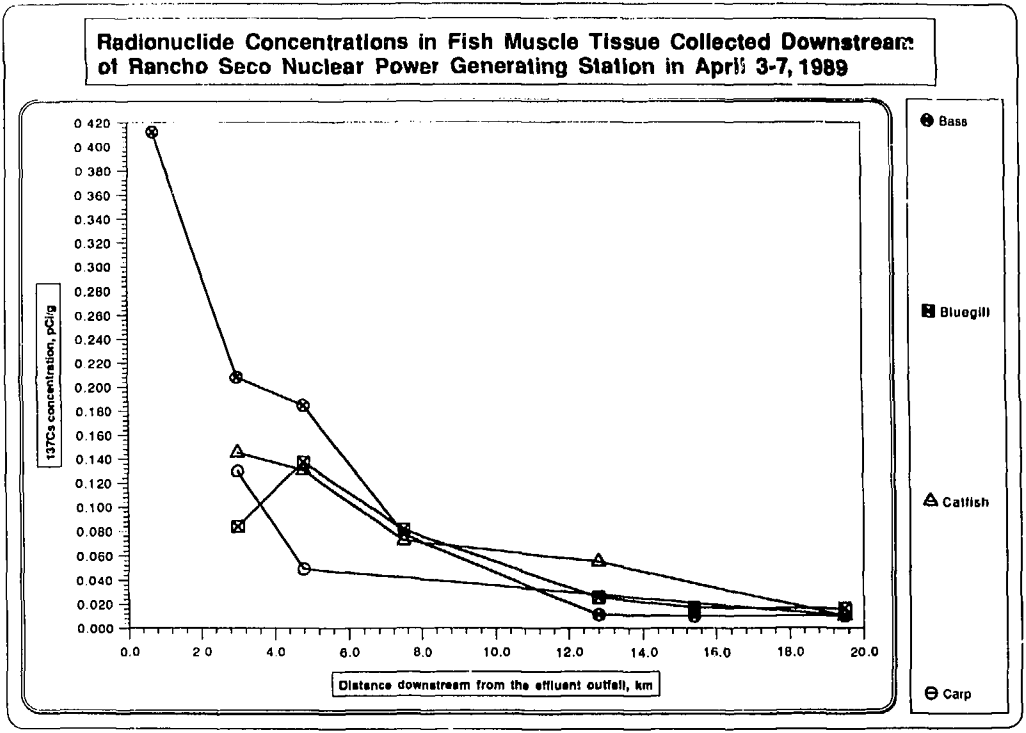

Radionuclide Concentrations in Fish Muscle Tissue Collected Downstream of Rancho Seco Nuclear Power Generating Station in April 3-7, 1989
137Cs concentration, pCi/g
0.420
0.400
0.380
0.360
0.340
0.320
0.300
0.280
0.260
0.240
0.220
0.200
0.180
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
Distance downstream from the effluent outfall, km
Bass
Bluegill
Catfish
Carp

Figure 5

Radionuclide Concentrations in Fish Muscle Tissue Collected Downstream of Rancho Seco Nuclear Power Generating Station in June 28-29, 1989

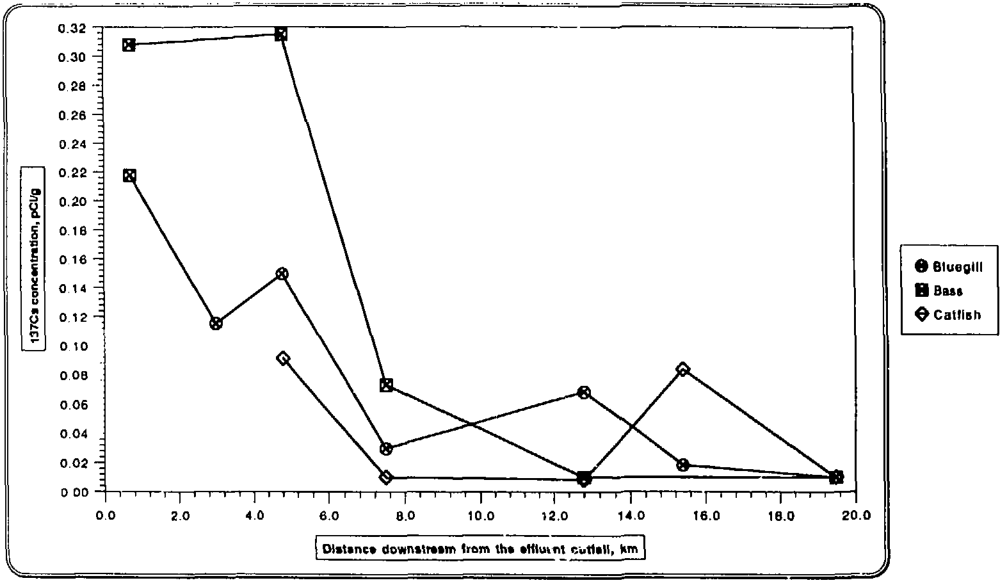


Figure 6

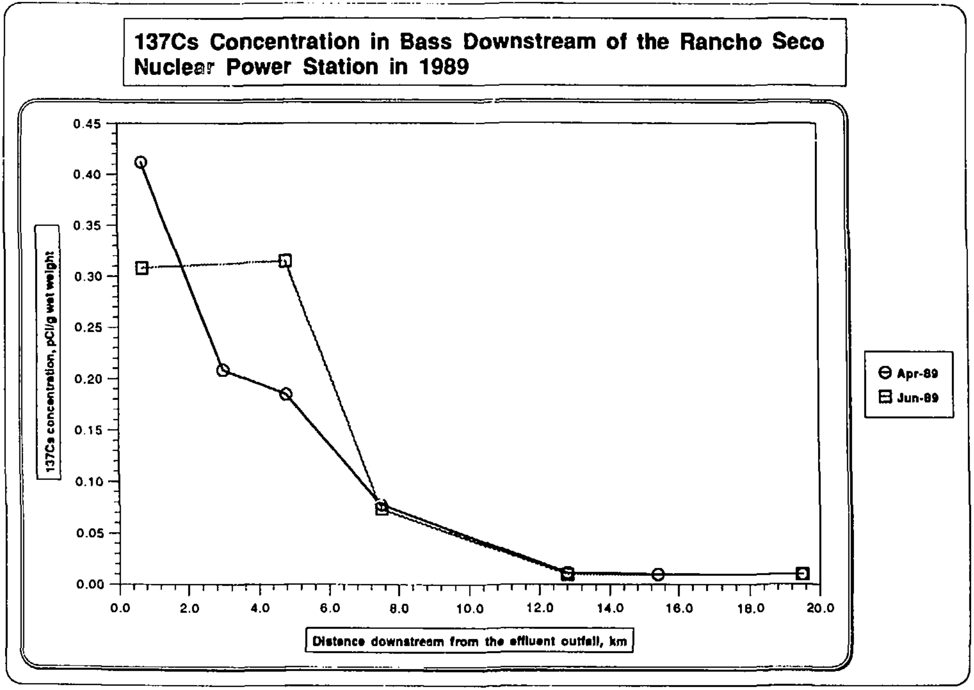

137Cs Concentration in Bass Downstream of the Rancho Seco Nuclear Power Station in 1989
137Cs concentration, pCi/g wet weight
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
Distance downstream from the effluent outfall, km
Apr-89
Jun-89

Figure 7

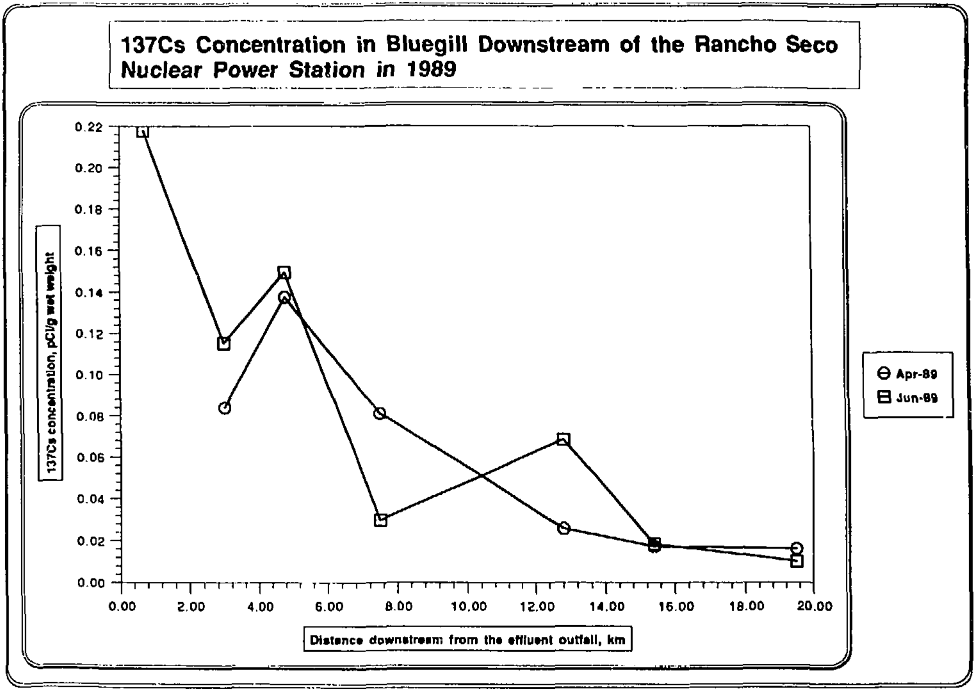
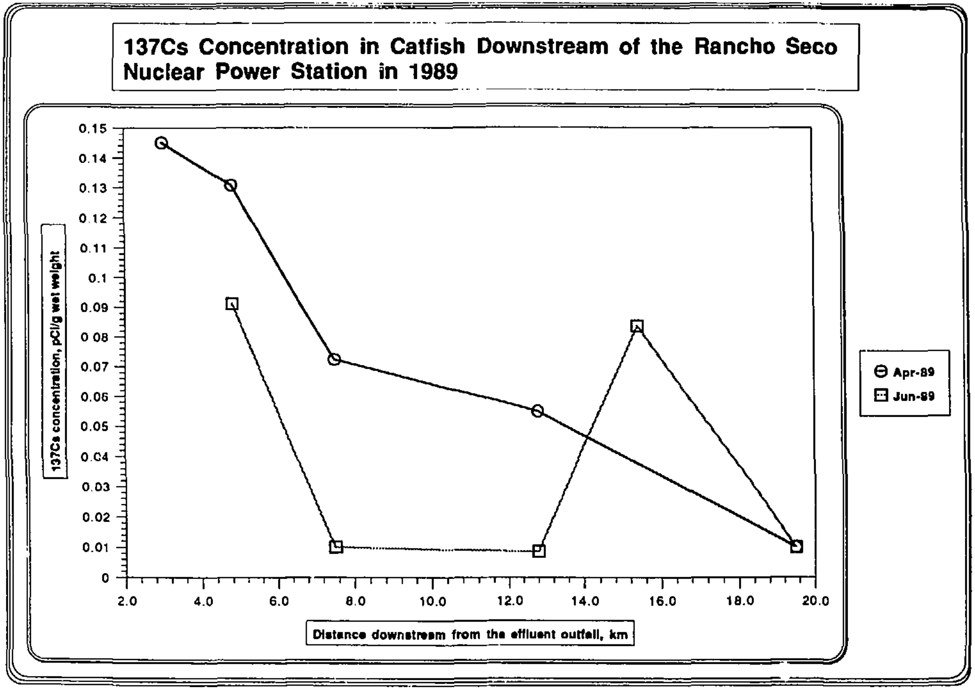

137Cs Concentration in Bluegill Downstream of the Rancho Seco Nuclear Power Station in 1989
137Cs concentration, pCi/g wet weight
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
Distance downstream from the effluent outfall, km
Apr-89
Jun-89

Figure 8



137Cs Concentration in Catfish Downstream of the Rancho Seco Nuclear Power Station in 1989
137Cs concentration, pCi/g wet weight
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0 08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
Distance downstream from the effluent outfall, km
Apr-89
Jun-89

Figure 9

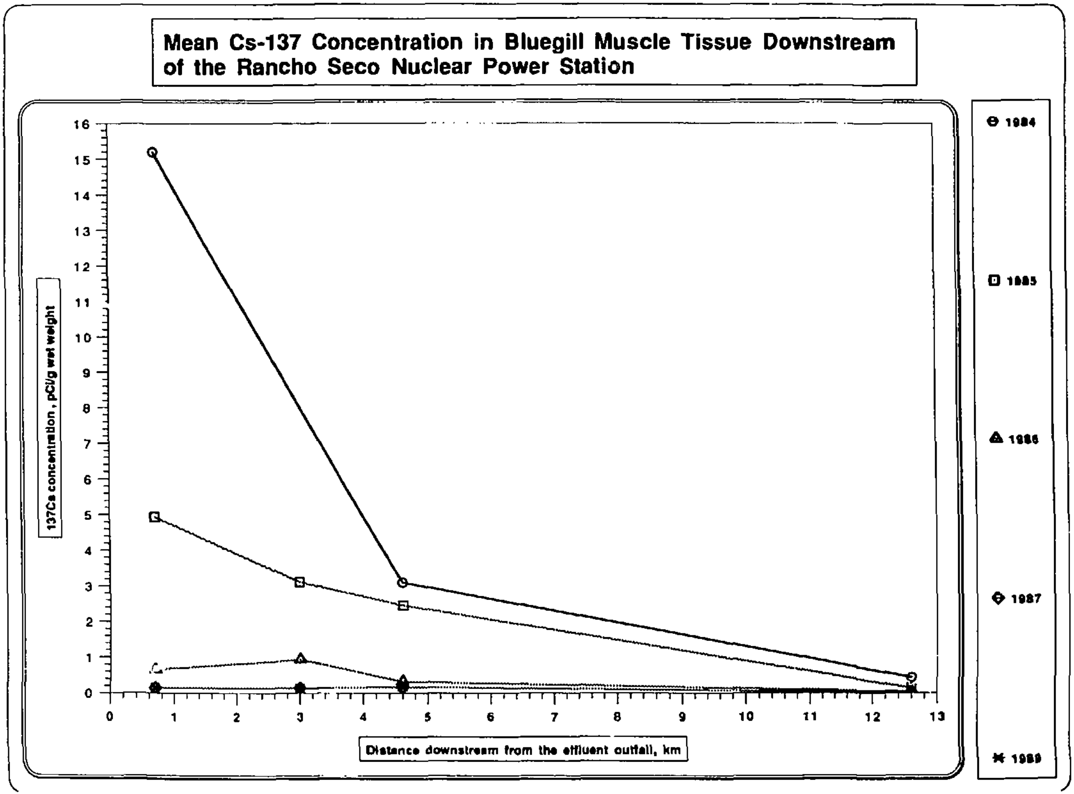
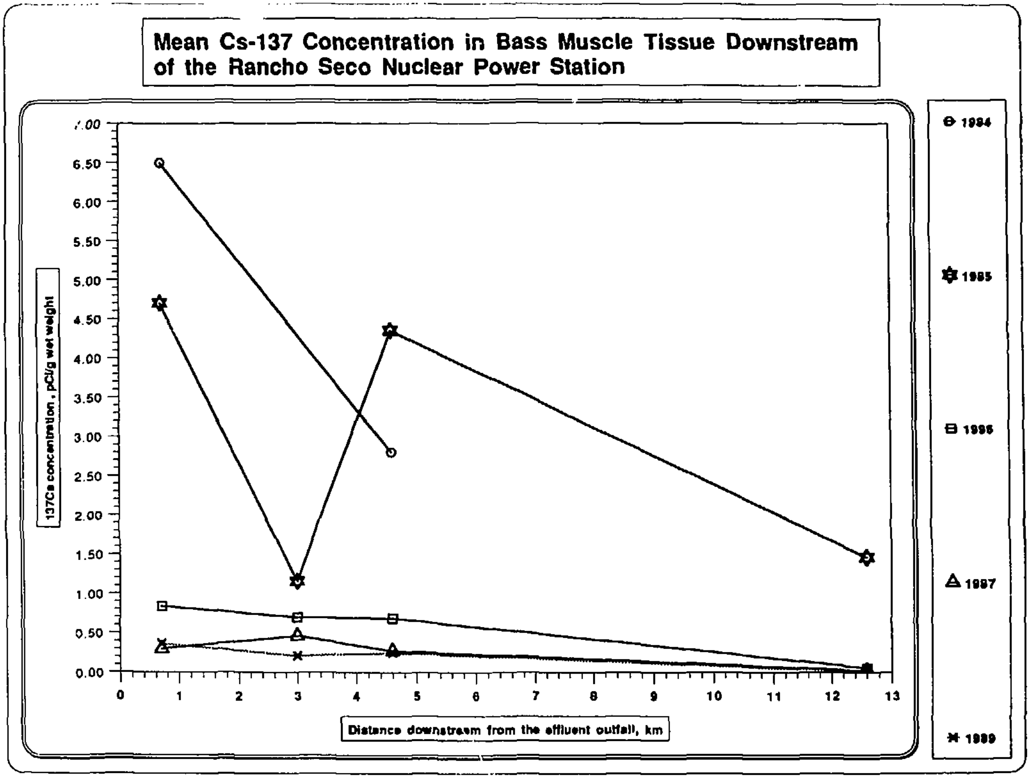

Mean Cs-137 Concentration in Bluegill Muscle Tissue Downstream of the Rancho Seco Nuclear Power Station
137Cs concentration, pCi/g wet weight
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Distance downstream from the effluent outfall, km
1984
1985
1986
1987
1989

Figure 10



Mean Cs-137 Concentration in Bass Muscle Tissue Downstream of the Rancho Seco Nuclear Power Station
137Cs concentration , pCi/g wet weight
Distance downstream from the effluent outfall, km
7.00
6.50
6.00
5.50
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
1
2
3
4
5
6
7
8
9
10
11
12
13
1984
1985
1986
1987
1989

Figure 11

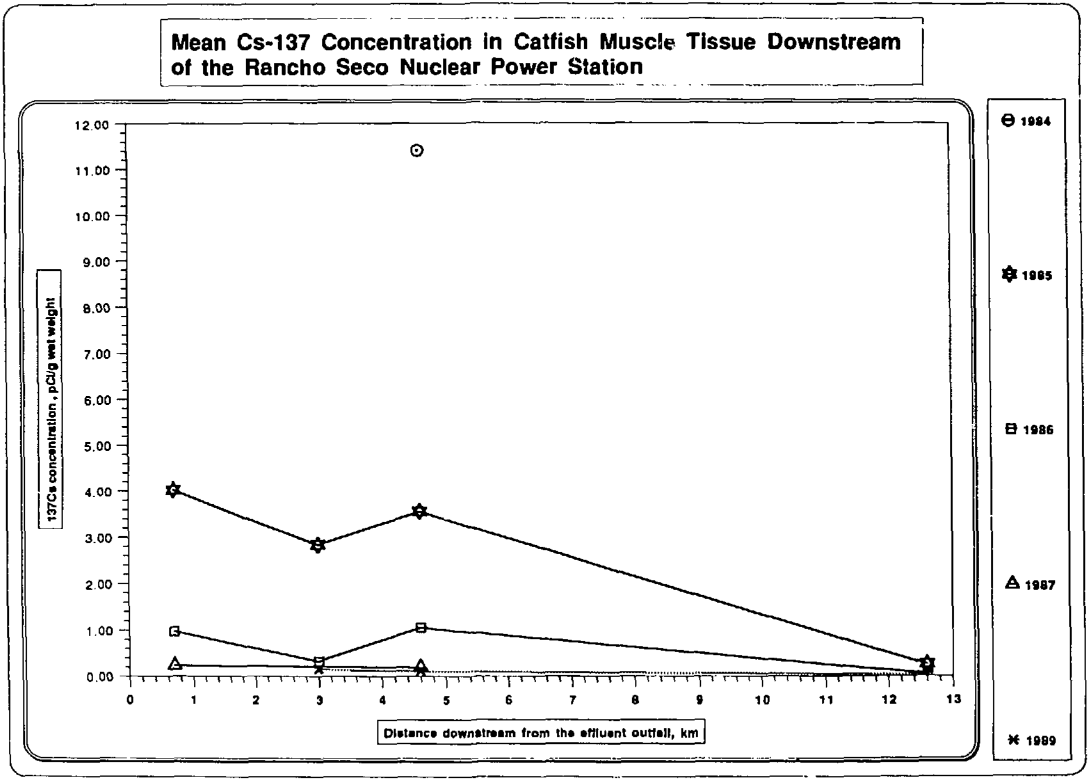
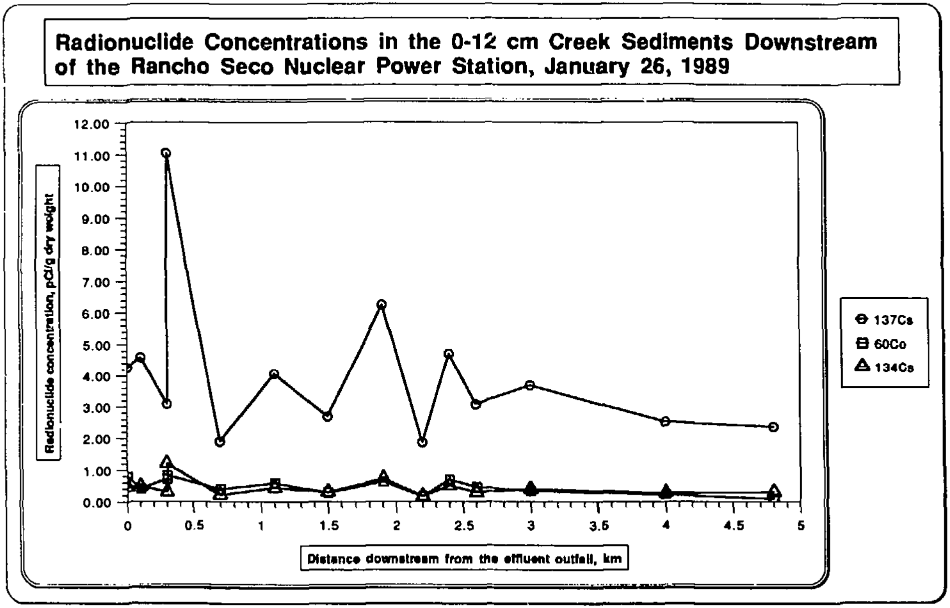

Mean Cs-137 Concentration in Catfish Muscle Tissue Downstream of the Rancho Seco Nuclear Power Station
137Cs concentration, pCi/g wet weight
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0 1 2 3 4 5 6 7 8 9 10 11 12 13
Distance downstream from the effluent outfall, km
1984
1985
1986
1987
1989

Figure 12



Radionuclide Concentrations in the 0-12 cm Creek Sediments Downstream of the Rancho Seco Nuclear Power Station, January 26, 1989
Radionuclide concentration, pCi/g dry weight
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Distance downstream from the effluent outfall, km
137Cs
60Co
134Cs

Figure 13

Radionuclide Concentrations in 0-12 Cm Creek Sediments Downstream of Rancho Seco Nuclear Power Generating Plant, Collected April,1989

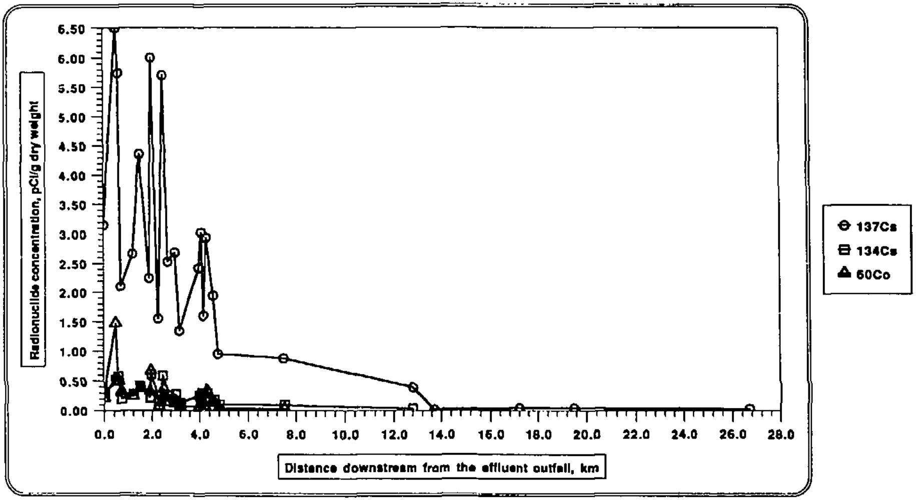


Figure 14

137Cs Concentration in the 0-12 cm Creek Sediments Downstream from the Rancho Seco Nuclear Power Station

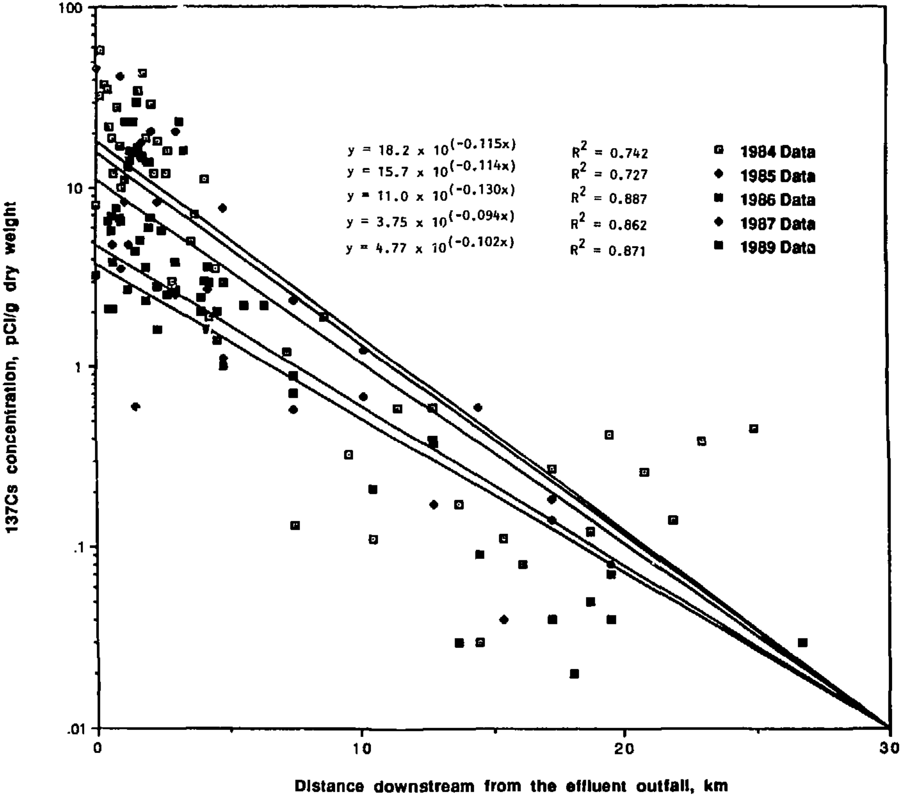


Figure 15

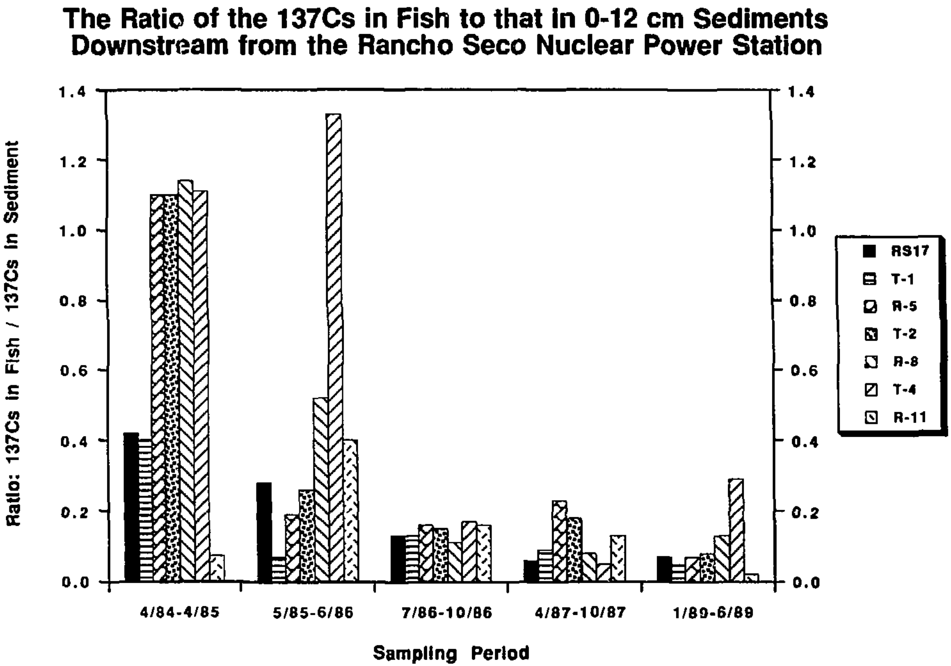

The Ratio of the 137Cs in Fish to that in 0-12 cm Sediments
Downstream from the Rancho Seco Nuclear Power Station
Ratio: 137Cs in Fish / 137Cs in Sediment
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
4/84-4/85
5/85-6/86
7/86-10/86
4/87-10/87
1/89-6/89
Sampling Period
RS17
T-1
R-5
T-2
R-8
T-4
R-11

Figure 16

The Correlation between the 137Cs Concentration in Fish and Sediment in 1989 Downstream from the Rancho Seco Nuclear Power Station

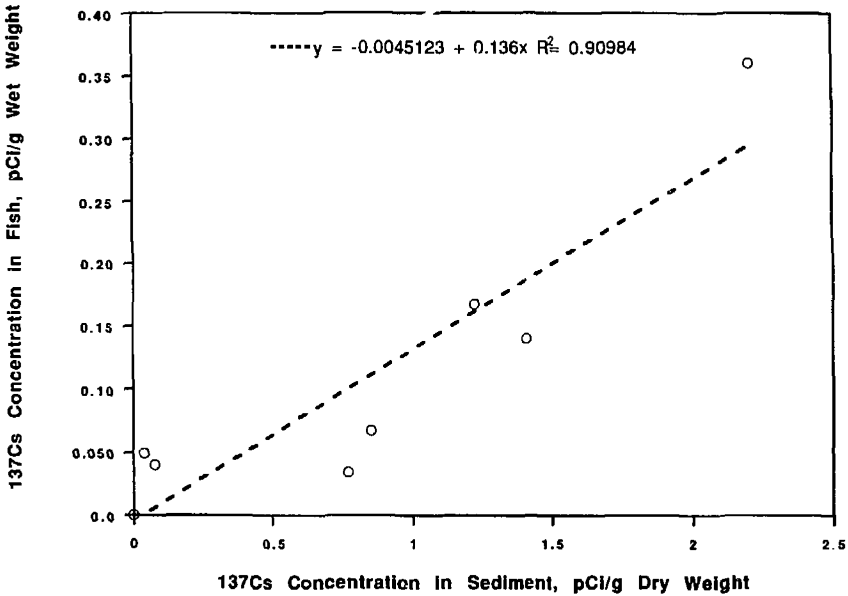


Figure 17

The Correlation between the 137Cs concentration in Fish and Water in April 1989 downstream from the Rancho Seco Nuclear Power Station

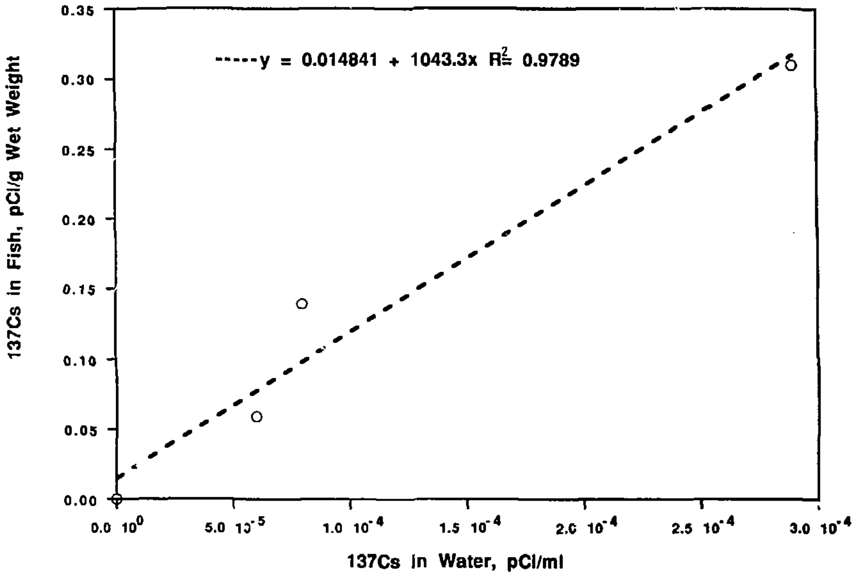


Figure 18