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Radiochemical Analyses of Game Birds Collected from the Hanford Environs 1971-1975

by
J. J. Fix
P. J. Blumer

July 1977

Prepared for the Energy Research and Development Administration under Contract EY-76-C-06-1830

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BNWL-2089

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Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151
Price: Printed Copy $_____*; Microfiche $3.00

*Pages	NTIS Selling Price
001-025	$4.50
026-050	$5.00
051-075	$5.50
076-100	$6.00
101-125	$6.50
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RADIOCHEMICAL ANALYSES OF GAME BIRDS COLLECTED FROM THE HANFORD ENVIRONS, 1971-1975

By
J. J. Fix
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INTRODUCTION

As part of the Environmental Surveillance program for the Hanford environs, game birds (coots, ducks, geese, and pheasants) have been routinely collected on the Hanford Site and along the Hanford reach of the Columbia River. Because game birds may take in radioactivity from contaminated vegetation and water at specific areas of the Hanford Site and then travel offsite, they represent a potential source of radiation exposure for hunters. Table 1 shows the number of game birds collected annually from 1971 through 1975. The total number of each type collected over the 5-year period was 80 pheasants, 90 geese, 356 ducks, and 11 coots.

Samples of game bird muscle tissue were analyzed radiochemically to assess the total contribution of radionuclides, both those originating from Hanford and those already present in the environment due to worldwide fallout or natural causes. The resulting data were evaluated using probability plotting, which provided a visual estimate of the observed radioactivity attributable to fallout and, separately, any detectable increase attributable to Hanford operations. In addition, the levels of naturally occurring ^{40}K were measured in all samples.

TABLE 1. Game Birds Collected, 1971-1975

	1971	1972	1973	1974	1975	Total
Pheasants	16	24	9	15	16	80
Geese	7	30	23	14	16	90
River Ducks	97	70	34	33	27	261
Pond Ducks	17	20	24	15	19	95
Coots	3	3	0	4	1	11

SUMMARY

Game birds -- pheasants, geese, ducks and coots -- have been collected routinely on the Hanford Site as a way of monitoring radionuclide concentrations potentially attributable to Hanford operations. In general, radionuclide concentrations attributable to Hanford operations were only slightly greater than (within a factor of 10) or indistinguishable from expected levels attributed to worldwide fallout. An exception was that ^{137}Cs concentrations, primarily in ducks and coots, were higher than levels attributable to fallout. Highlights of all observations follow:

- Pheasants-- Only two observations, a ^{90}Sr concentration of 0.08 ρCi/g and a ^{137}Cs concentration of 5.6 ρCi/g, were attributed to Hanford operations. The 50-year internal dose commitment from ingesting 500 grams of duck meat containing these concentrations would be 0.3 mrem total body (^{137}Cs-0.2, ^{90}Sr-0.1) and 0.3 mrem bone (^{90}Sr-0.3). (See pages 6-9).
- Geese -- Only ^{65}Zn activity observed in geese during 1971 and 1972 was attributed to Hanford operations. The positive data available for the other radionuclides were too few to determine any contribution attributable to Hanford operations from the expected fallout levels. However, the data do show that regardless of the origin of the activity, the concentrations observed would contribute a minor dose impact. Assuming a hunter ingested 5 kilograms of goose meat containing the maximum observed ^{65}Zn, 1.3 ρCi/g, and ^{137}Cs, 1.0 ρCi/g concentrations, a 50-year internal dose commitment to the total body of 0.05 mrem from ^{65}Zn and 0.3 mrem from ^{137}Cs would be incurred. (See pages 9-13).
- Ducks -- The duck data were separated into two components for analysis: 1) Ducks collected from the Columbia River, and 2) Ducks collected from onsite ponds. With the exception of ^{65}Zn, the maximum observed concentrations of ^{60}Co, ^{90}Sr, and ^{137}Cs were for ducks collected from onsite ponds. The maximum ^{65}Zn concentrations were for ducks collected during 1971 from near the Columbia River. Livers from ducks collected from certain

onsite ponds were analyzed for U and Pu activity. The majority of the analyses were positive. However, the contribution from Hanford is uncertain because of the lack of similar data representing the expected levels attributable to fallout. Fifty-year internal dose estimates based on consumption of 500 grams of duck meat containing the highest observed concentrations of ^{60}Co (1.8 ρCi/g), ^{65}Zn (15 ρCi/g), ^{90}Sr (0.3 ρCi/g) and ^{137}Cs (130 ρCi/g) would be 4.4 mrem total body (^{60}Co-0.004, ^{65}Zn 0.05, ^{90}Sr-0.3, ^{137}Cs-4.0) and 1.1 mrem bone (^{90}Sr-1.1). The dose impact from ingesting 60 grams of duck livers containing U or Pu would be very small, less than 0.01 mrem to any organ of the body. (See pages 14-25).

- Coots -- Only 11 coots were collected from 1971 through 1975, all from onsite ponds; but because coots are less migratory than ducks and may therefore take in more activity from Hanford process ponds, the available data were analyzed. Generally, a much larger fraction of the coots analyzed showed positive analysis for ^{90}Sr and ^{137}Cs activity as compared to ducks collected from along the Columbia River. Assuming the increased frequency of positive measurements is indicative of the impact from Hanford operations, a 50-year internal dose commitment from ingesting 500 grams of coot meat containing the maximum observed ^{90}Sr, 0.1 ρCi/g, and ^{137}Cs, 210 ρCi/g, concentrations would be 6.5 mrem total body (^{90}Sr-0.09 mrem, ^{137}Cs-6.4 mrem) and 8.4 mrem to the bone (^{90}Sr-0.4 mrem, ^{137}Cs-8.0 mrem). (See pages 26-30).

The above dose estimates may be compared to the dose of approximately 100 mrem received each year from natural background radiation or an accumulated dose of 5000 mrem (50 x 100) over a 50-year period.

DATA ANALYSIS

Interpretation of the game bird data is more difficult than most types of environmental samples because of the tenuous relationship of the location of collection with the life history of the birds being collected. For example, collection of several ducks from an onsite pond may include ducks which are migrating through southeastern Washington state, ducks which have been feeding along the Columbia River or other ponds, as well as ducks which have been feeding at the pond of collection.

All of the data analyzed were collected on the Hanford Site resulting in the need to estimate the expected levels of fallout radionuclides as well as any distinguishable increase attributable to Hanford operations from the same set of data. The availability of analogous game bird data distant from the Hanford Site would have allowed a direct estimate of the fallout radionuclide concentrations. The duck data were separated into two groups representing 1) ducks collected along the Columbia River and 2) ducks collected from onsite ponds. However the availability of ^{65}Zn and likely ^{60}Co along the river, particularly during 1971 immediately following the deactivation of the last once-through cooling production reactor, makes a determination of a net Hanford impact difficult.

However, it should be noted that the primary purpose for collecting the data was to estimate the dose to members of the public from ingesting game birds collected near the Hanford Site. The present document estimates the dose impact for each measured radionuclide/game bird association which is attributed to Hanford operations. An estimate of the expected levels of fallout radionuclides is also given. The data were evaluated using log-normal probability plots of the analytical data greater than the 2-sigma counting uncertainty. This method of analysis allows a visual evaluation of the data especially when two analogous sets of data, such as ducks from the ponds versus ducks from the river, are being compared.

Log-normal probability plotting is simply a graphical means of analysis which allows visual interpretation of the similarity of all

data, the number of results less than the detection limit (intercept of plot with the detection level), the median value expected (50 percent intercept), and the slope of a best-fit line to the data (ratio of 84% and 50% intercepts). The method is convenient because large quantities of data can be evaluated and presented in an easily understood manner. Also, all of the data are represented in the plots.

Throughout the following text, the geometric mean (50 percent intercept) and geometric standard deviation (ratio of 84% and 50% intercepts) obtained from the log-normal plots are used to estimate any net impact attributable to Hanford operations, as shown by radionuclide concentrations greater than the range expected from worldwide fallout. In some cases, the mean concentration of a radionuclide attributable to fallout is subtracted from individual results attributable to Hanford operations to provide a more realistic estimate of the Hanford impact on the environment.

GAME BIRD DATA ANALYSIS

The data from analysis of game birds collected from 1971 through 1975 have been analyzed as a function of the radionuclide concentration found in primarily muscle tissue, the species of birds collected, and, for ducks, the location of the ducks collected. Analysis for uranium and plutonium in liver tissue was done for a few ducks. The following sections will examine separately data for pheasants, geese, ducks, and coots.

PHEASANTS

Pheasants were collected each year during the period 1971 through 1975. A 5-year total of 80 pheasants was taken, with annual samplings ranging from 9 (1973) to 24 (1972). Pheasants were taken near each of the 100 Areas and along the Columbia River from 100-K to North Richland.

Table 2 summarizes the maximum, minimum and average concentrations for naturally-occurring ^{40}K and for artificially produced ^{60}Co, ^{65}Zn, ^{90}Sr and ^{137}Cs for each of the years 1971 through 1975. It is apparent from a comparison of the data between years that all of the data for each radionuclide were similar with the exception of the maximum ^{137}Cs concentration of 5.6 pCi/g observed in 1973 and possibly the maximum ^{90}Sr concentration of 0.08 pCi/g observed in 1975. All other radionuclide concentrations were similar during each year and generally near the detection limit of the analysis.

Figure 1 presents log-normal probability plots of the ^{40}K, ^{90}Sr, and ^{137}Cs data. The ^{40}K plot shows the characteristics typical of data which are very nearly equal to each other. The slope of 1.2 (ratio of 84% to 50% values) illustrates the close grouping of the data. The average ^{40}K concentration observed was 2.8 pCi/g.

The plotted results for ^{90}Sr appear to represent similar data for all of the pheasants, with the exception of the aforementioned maximum concentration of 0.08 pCi/g, during 1975. This concentration was obtained from analysis of a pheasant collected near the White Bluffs area on the Hanford Site on November 20, 1975. The majority of the 0.08 pCi/g of ^{90}Sr activity is attributed to Hanford operations. Any Hanford contribution to the ^{90}Sr

TABLE 2. Summary of Radiochemical Analyses of Pheasant Samples, 1971-1975

(Concentrations in ρCi/g of Muscle Tissue, Wet Weight)

Year	No. of Samples	^{40}K Max.	^{40}K Min.	^{40}K Avg.(a)	^{60}Co Max.	^{60}Co Min.	^{60}Co Avg.	^{65}Zn Max.	^{65}Zn Min.	^{65}Zn Avg.
1971	16	3.7	*	2.4-2.7	0.1	*	0.01-0.1	0.4	*	0.05-0.2
1972	24	3.5	*	2.6-2.7	*	*	*	0.6	*	0.05-0.2
1973	9	3.6	2.5	2.9	*	*	*	*	*	*
1974	15	3.6	*	2.7-2.8	*	*	*	*	*	*
1975	16	3.8	*	2.1-2.7	*	*	*	*	*	*

Year	No. of Samples	^{90}Sr Max.	^{90}Sr Min.	^{90}Sr Avg.	^{137}Cs Max.	^{137}Cs Min.	^{137}Cs Avg.
1971	16	0.01	*	0.003-0.006	0.1	*	0.04-0.1
1972	24	0.01	*	0.001-0.005	0.2	*	0.06-0.1
1973	9	0.02	*	0.003-0.007	5.6	*	0.6-0.7
1974	15	*	*	*	*	*	*
1975	16	0.08	*	0.007-0.01	0.1	*	0.01-0.1

*Less than detectable. The detection level for gamma spectrometric measurement of ^{40}K, ^{60}Co, ^{65}Zn and ^{137}Cs depends on the various types and quantities of radionuclides present. Approximate detection levels are: ^{40}K ∿2-, ^{60}Co ∿0.1-, ^{65}Zn ∿0.2-, ^{90}Sr ∿0.005-, and ^{137}Cs ∿0.1- ρCi/g.

(a)Range of arithmetic average shown was derived by assuming first that all "less than detectable" values are equal to zero, and then that all "less than detectable" values are equal to the detection levels.

concentration observed in the other pheasants is indistinguishable from the expected regional levels of fallout.

If a hunter were to eat 500 grams (1.1 pounds) of pheasant meat containing 0.08 ρCi/g, the highest ^{90}Sr concentration observed, a 50-year dose commitment of 0.07 mrem to the total body and 0.3 mrem to the bone would be incurred. About 5% of the dose would be received during the first year after ingestion.

The plotted results for ^{137}Cs in Figure 1 result in a similar interpretation as that for ^{90}Sr. All of the data, with the exception of the maximum concentration observed in 1973, represent a similar group of data as in-

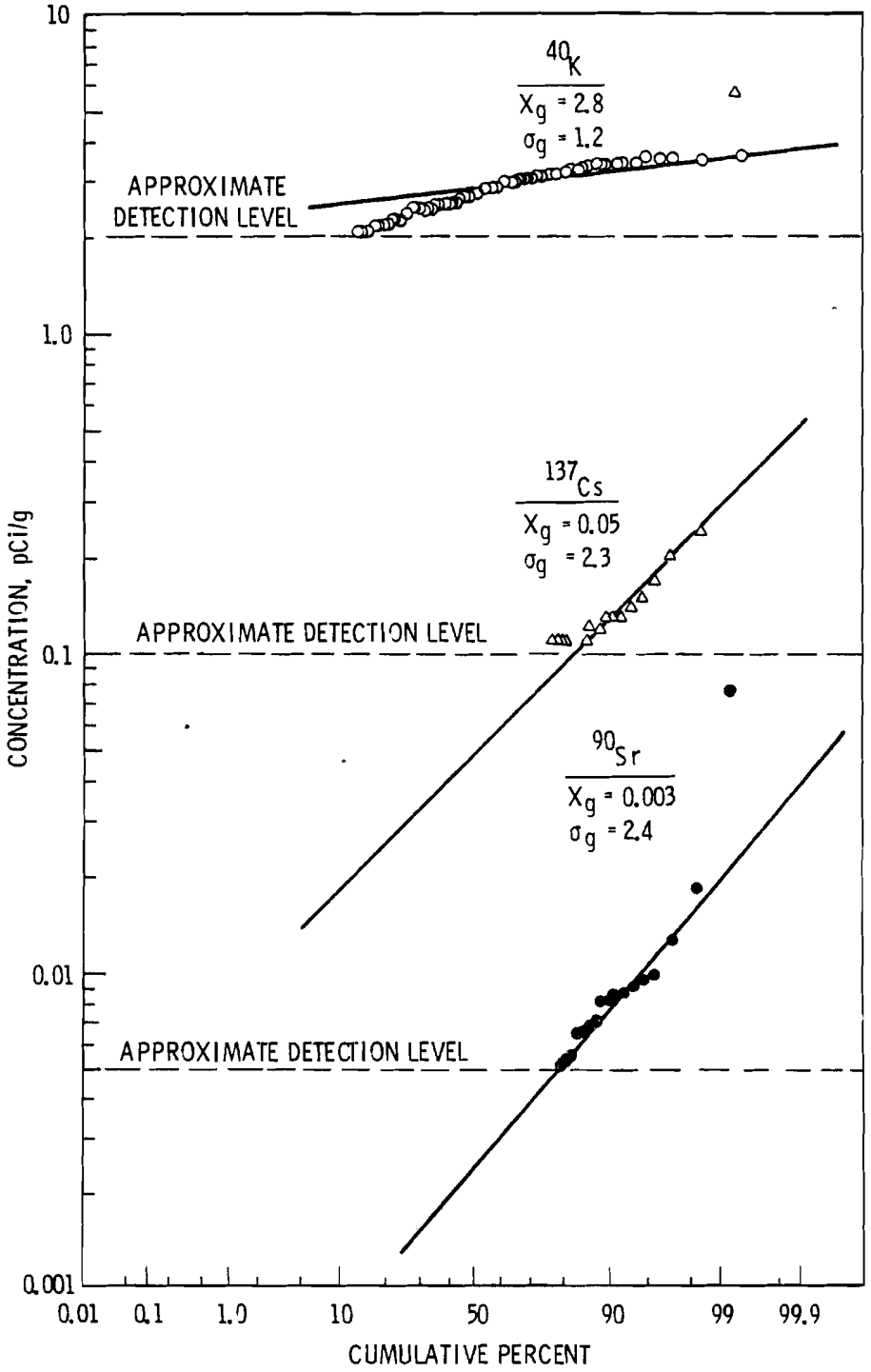

FIGURE 1. ^{40}K, ^{90}Sr, and ^{137}Cs Concentrations in Pheasant Muscle Tissue

dicated by the linearity of the data. The straight line fit to the data in Figure 1 represents the expected concentrations attributable to worldwide fallout. The maximum-plotted concentration, 5.6 pCi/g for ^{137}Cs, is at least an order of magnitude greater than expected and is attributed to Hanford operations. Hanford contributions of ^{137}Cs activity to the other points are indistinguishable from the variability in fallout levels.

Ingestion of 500 grams of pheasant meat containing the maximum ^{137}Cs concentration observed, 5.6 pCi/g, would result in a total body 50-year dose commitment of 0.2 mrem. Over 90% of this dose would be received during the first year after ingestion.

GEESE

Geese were collected from along the Columbia River between the 100-K Area and North Richland during each year of the period 1971 through 1975. A total of 90 geese were taken during this period, with the annual collection ranging from a low of 14 in 1971 and 1974 to a high of 30 in 1972. Census data* for goose populations along the Hanford reach of the Columbia River during the 1975 hunting season indicated the presence of a few hundred geese during each day of observation.

Table 3 summarizes the maximum, minimum and average concentrations for naturally-occurring ^{40}K and for artificially-produced ^{60}Co, ^{65}Zn, ^{90}Sr and ^{137}Cs for each of the years 1971 through 1975. Potassium-40 was present in the largest concentrations. Cobalt-60 was detected only occasionally and at levels very near the detection limit. It is interesting that all positive ^{65}Zn observations occurred during the years 1971 and 1972. However, the positive data are too few and too near the detection limit to conclusively attribute the positive analyses to Hanford operations even though ^{65}Zn was a major contaminant from Hanford operations during these years (the last once-through production reactor was deactivated during

*J. D. Hedlund, "Waterfowl Census," Pacific Northwest Laboratory Annual Report for 1975 to the ERDA Division of Biomedical and Environmental Research, Part 2, Ecological Sciences, BNWL-2000 PT 2, Battelle, Pacific Northwest Laboratories, Richland, WA, 1975, p. 171.

TABLE 3. Summary of Radiochemical Analyses of Goose Samples, 1971-1975

(Concentrations in ρCi/g of Muscle Tissue, Wet Weight)

Year	No. of Samples	^{40}K Max.	^{40}K Min.	^{40}K Avg.(a)	^{60}Co Max.	^{60}Co Min.	^{60}Co Avg.	^{65}Zn Max.	^{65}Zn Min.	^{65}Zn Avg.
1971	7	3.2	1.7	2.5	*	*	*	1.3	*	0.4-0.5
1972	30	4.7	1.8	2.8	0.1	*	0.003-0.1	0.4	*	0.04-0.2
1973	23	6.5	*	2.9-3.0	0.1	*	0.004-0.1	*	*	*
1974	14	3.4	2.2	2.7	0.2	*	0.01-0.1	*	*	*
1975	16	9.5	2.0	3.1	*	*	*	*	*	*

Year	No. of Samples	^{90}Sr(b) Max.	^{90}Sr(b) Min.	^{90}Sr(b) Avg.	^{137}Cs Max.	^{137}Cs Min.	^{137}Cs Avg.
1971	7			N.A.	0.6	*	0.1-0.2
1972	30	0.02	*	0.002-0.006	1.0	*	0.1-0.2
1973	23			N.A.	0.2	*	0.03-0.1
1974	14			N.A.	0.2	*	0.02-0.1
1975	16			N.A.	0.2	*	0.03-0.1

*Less than detectable. The detection level for gamma spectrometric measurement of ^{40}K, ^{60}Co, ^{65}Zn and ^{137}Cs depends on the various types and quantities of radionuclides present. Approximate detection levels are: ^{40}K ∿2-, ^{60}Co ∿0.1-, ^{65}Zn ∿0.2-, ^{90}Sr ∿0.005-, and ^{137}Cs ∿0.1- ρCi/g.

N.A. Not Analyzed

(a) Range of arithmetic average shown was derived by assuming first that all "less than detectable" values are equal to zero, and then that all "less than detectable" values are equal to the detection levels.

(b) ^{90}Sr analyses only done in 1972 and then on 14 of the 30 birds collected.

January 1971). Also, the lack of ^{65}Zn data for geese samples from definite background areas further limits the interpretation of the data.

Strontium-90 data were collected only during 1972 and then on only 14 of the 30 geese samples collected, as shown in Table 3. Only 2 of the 14 analyses done showed a positive count and these were near the detection limit of the analysis. The observed ^{90}Sr activity is attributed to worldwide fallout since there is no indication that Hanford operations have contributed to the observed levels.

A similar situation is found in the ^{137}Cs data. Sixteen of the 90 geese analyzed were above the detection level of 0.1 ρCi/g. Given the variability observed in fallout levels, the data are too few to determine any contribution attributable to Hanford operations.

Figure 2 presents log-normal probability plots of the ^{40}K, ^{65}Zn, and ^{137}Cs data. The ^{40}K concentrations are well represented by a log-normal distribution and a median value of 2.7 ρCi/g in geese muscle tissue would be expected. The number of positive analyses for ^{65}Zn and ^{137}Cs are insufficient to distinguish any Hanford contribution from regional fallout levels. Also, the lack of analogous data from definite background locations further limits the identity of any Hanford contribution to the observed concentrations. However, the data show that regardless of the origin of the radionuclides, the concentrations would contribute a relatively minor dose impact. Assuming a hunter ingested 5 kilograms (11 pounds) of goose meat containing the maximum observed concentrations (^{65}Zn, 1.3 ρCi/g; ^{137}Cs, 1.0 ρCi/g) observed in geese, a 50-year internal dose commitment to the total body of 0.05 mrem from ^{65}Zn and 0.3 mrem from ^{137}Cs would be incurred. This may be compared to the approximate 100 mrem per year received from natural background radiation.

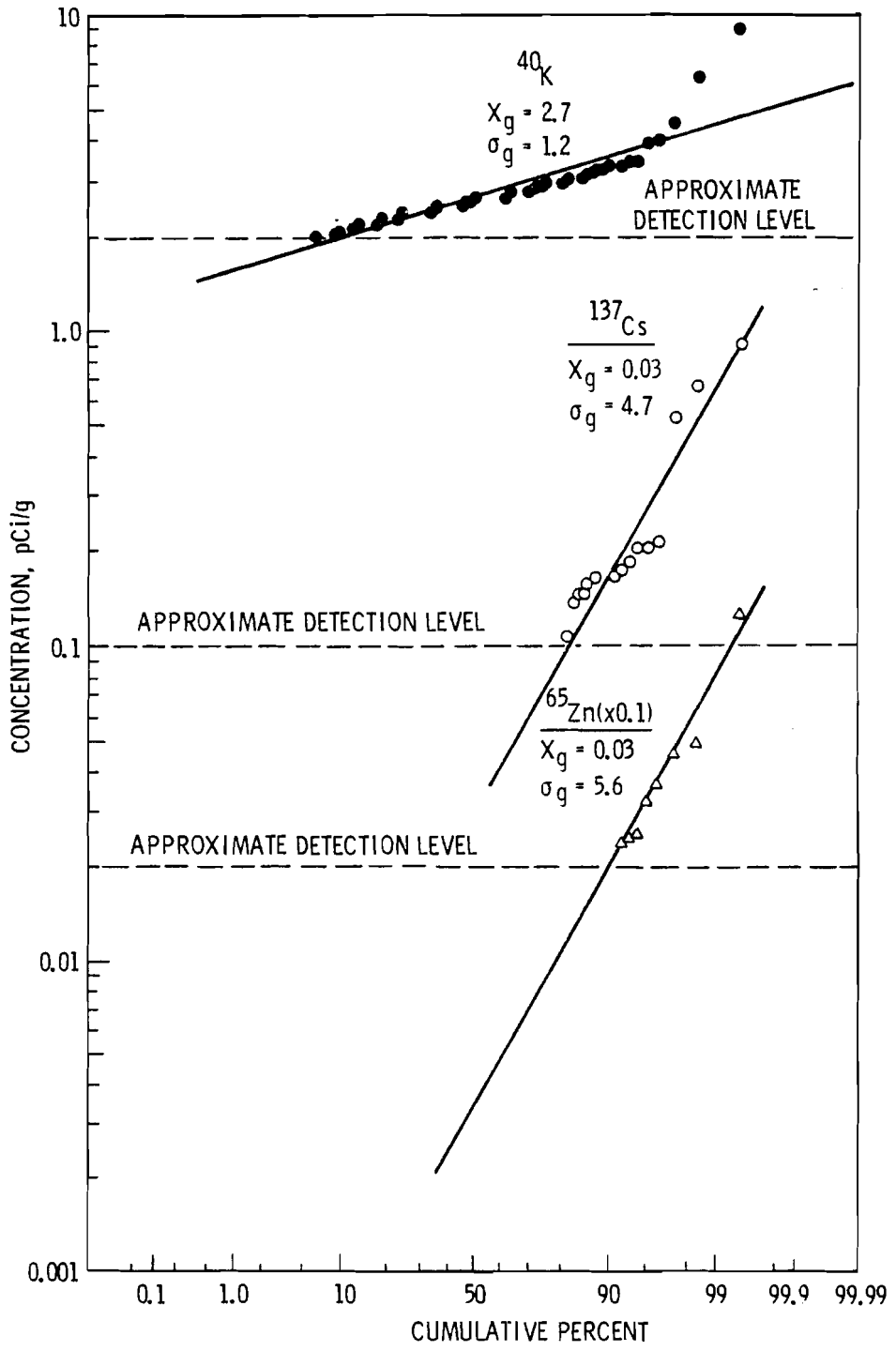

FIGURE 2. ^{40}K, ^{65}Zn and ^{137}Cs Concentrations in Goose Muscle Tissue

DUCKS

Table 4 lists the varieties of duck collected from the Hanford process ponds and along the Columbia River during the period 1971 through 1975. Mallards were predominant among them comprising 76% of the total number. The annual number of ducks sampled (~70) represents a numerically insignificant fraction of the many thousands counted daily along the Hanford reach of the Columbia River during hunting season, 1975.*

Samples of muscle tissue taken from each duck were analyzed by gamma spectroscopy for gamma-emitting radionuclides, such as ^{40}K, ^{60}Co, ^{65}Zn and ^{137}Cs, and by specific radiochemical analysis for ^{90}Sr. In addition, liver tissue from ducks collected at certain process ponds was analyzed for uranium and/or plutonium.

TABLE 4. Duck Varieties Collected from 1971 to 1975

Duck	1971	1972	1973	1974	1975	Total
Mallard	95	57	47	39	35	273
Green Winged Teal	6	26	3	5	2	42
Blue Winged Teal	1	1	1		2	5
Scaup	1			1	1	3
Golden Eye	3	1	5		3	12
Merganser		3	2			5
Ruddy Duck	3					3
Pintail	1			1		2
Widgeon	1				2	3
Redhead	1					1
Gadwall	2			1		3
Shoveler		1		1		2
Old Squaw		1				1
Bufflehead					1	1
						356

*Hedlund, "Waterfowl Census," 1975.

A summary of selected radiochemical analyses for all ducks collected from 1971 through 1975 is presented in Table 5. There is little consistency between the maximum radionuclide concentration observed and the year of observation, with the exception of ^{65}Zn. The maximum ^{65}Zn concentration observed was for a Ruddy Duck collected in 1971 along the Columbia River near the old Hanford townsite, and is probably attributable to releases of ^{65}Zn to the river from the once-through production reactors, the last of which was deactivated during 1971.

TABLE 5. Summary of Radiochemical Analyses of Duck Samples, 1971-1975

(Concentration of ρCi/g of Muscle Tissue, Wet Weight)

Year	No. of Samples	^{40}K Max.	^{40}K Min.	^{40}K Avg.(a)	^{60}Co Max.	^{60}Co Min.	^{60}Co Avg.	^{65}Zn Max.	^{65}Zn Min.	^{65}Zn Avg.
1971	114	8.6	*	2.1-2.2	0.7	*	0.01-0.1	15	*	0.3-0.5
1972	90	9.7	*	2.7-2.7	0.2	*	0.01-0.1	0.8	*	0.1-0.2
1973	58	6.8	*	3.3-3.3	0.9	*	0.02-0.1	1.2	*	0.05-0.2
1974	48	6.2	*	2.3-2.4	0.4	*	0.02-0.1	0.3	*	0.01-0.2
1975	46	6.3	*	3.0-3.0	1.8	*	0.05-0.1	0.7	*	0.02-0.2

Year	No. of Samples	^{90}Sr Max.	^{90}Sr Min.	^{90}Sr Avg.	^{137}Cs Max.	^{137}Cs Min.	^{137}Cs Avg.
1971	114	0.14	*	0.004-0.01	130	*	6-6
1972	90	0.23	*	0.006-0.01	70	*	3-3
1973	58	0.11	*	0.008-0.01	120	*	4-4
1974	48	0.30	*	0.01-0.01	120	*	7-7
1975	46	0.08	*	0.008-0.01	59	*	6-6

* Less than detectable. The detection level for gamma spectrometric measurement of ^{40}K, ^{60}Co, ^{65}Zn and ^{137}Cs depends on the various types and quantities of radionuclides present. Approximate detection levels are: ^{40}K ∿2-, ^{60}Co ∿0.1-, ^{65}Zn ∿0.2-, ^{90}Sr ∿0.005-, and ^{137}Cs ∿0.1- ρCi/g.

(a) Range of arithmetic average shown was derived by assuming first that all "less than detectable" values are equal to zero, and then that all "less than detectable" values are equal to the detection levels.

The duck data have been separated into two groups for intercomparison: 1) those collected from the ponds (total of 95), and 2) those collected from along the Columbia River (total of 216). In this manner, any contribution to the observed activity from the process ponds should be apparent.

Figure 3 is a log-normal plot of the observed ^{40}K and ^{60}Co activity in all ducks analyzed. For ^{40}K, a naturally-occurring radionuclide, the data are well represented by the log-normal plot. A median concentration of 2.7 pCi/g for muscle tissue would be the expected value based on the data shown in Figure 3. The ^{60}Co activity in pond ducks was detected much more frequently than in river ducks based on the relative number of ducks analyzed. Although it is difficult to assess the magnitude of any Hanford contribution in addition to whatever is present from fallout, there definitely is an impact. However, the data do show that the dose impact is relatively insignificant. Assuming a hunter ingested 500 grams of duck meat with the highest observed concentration of ^{60}Co, 1.8 pCi/g, a 50-year internal dose commitment to the total body of about 0.004 mrem would be incurred.

Figure 4 is a log-normal plot of the ^{65}Zn activity in pond and river ducks. The maximum concentrations observed were for ducks collected from along the Columbia River during 1971. This is not surprising considering the quantities of ^{65}Zn released to the Columbia River during operation of the once-through production reactors.

It is expected that the majority of the observed ^{65}Zn activity is due to Hanford operations. Assuming a hunter were to ingest 500 grams of duck meat containing the maximum ^{65}Zn activity observed, 15 pCi/g, a 50-year internal dose commitment to the total body of about 0.05 mrem would be incurred.

Figure 5 is a log-normal plot of the ^{90}Sr data for pond and river ducks. It is apparent that ducks from the ponds have elevated levels of ^{90}Sr activity relative to the ducks collected from along the river. This is further apparent when the number of positive measurements for ^{90}Sr in

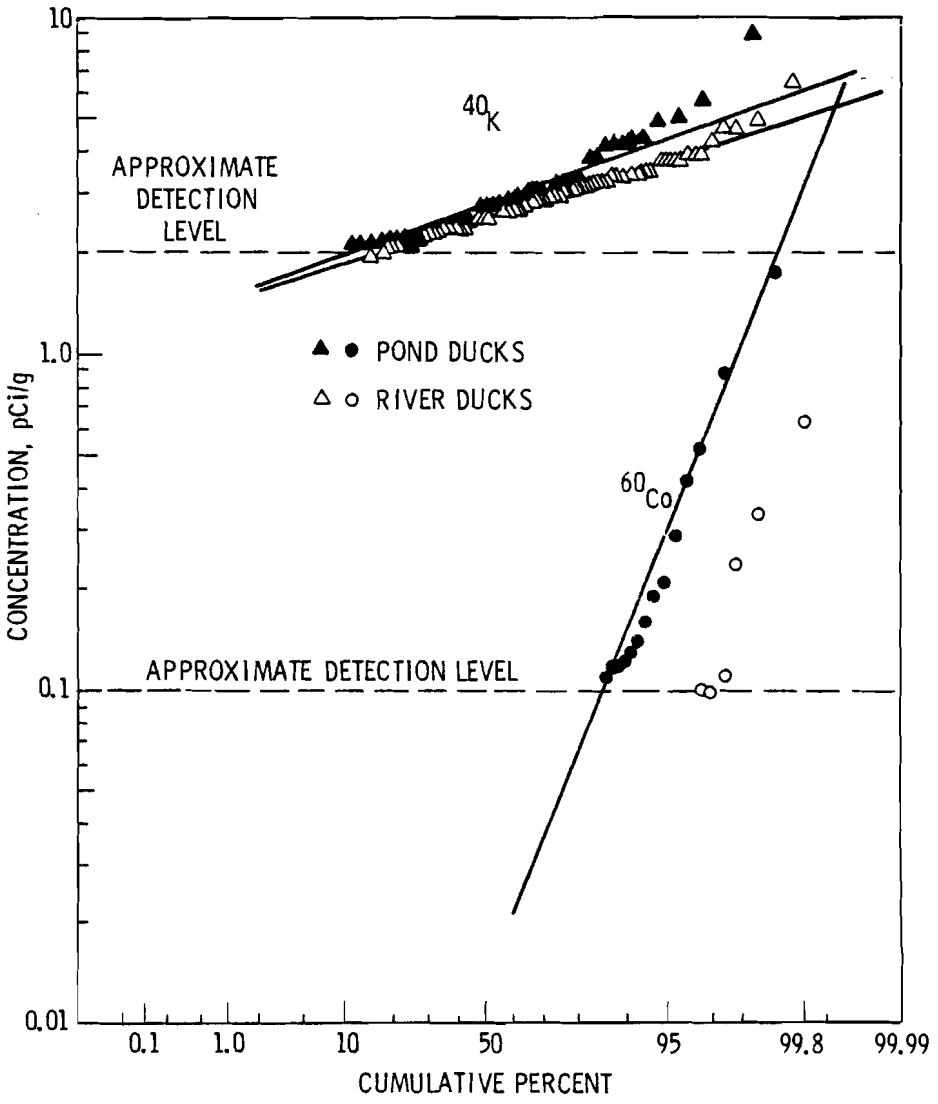

FIGURE 3. ^{40}K and ^{60}Co Concentrations in Muscle Tissue of Ducks Collected from Onsite Ponds and Along the Columbia River

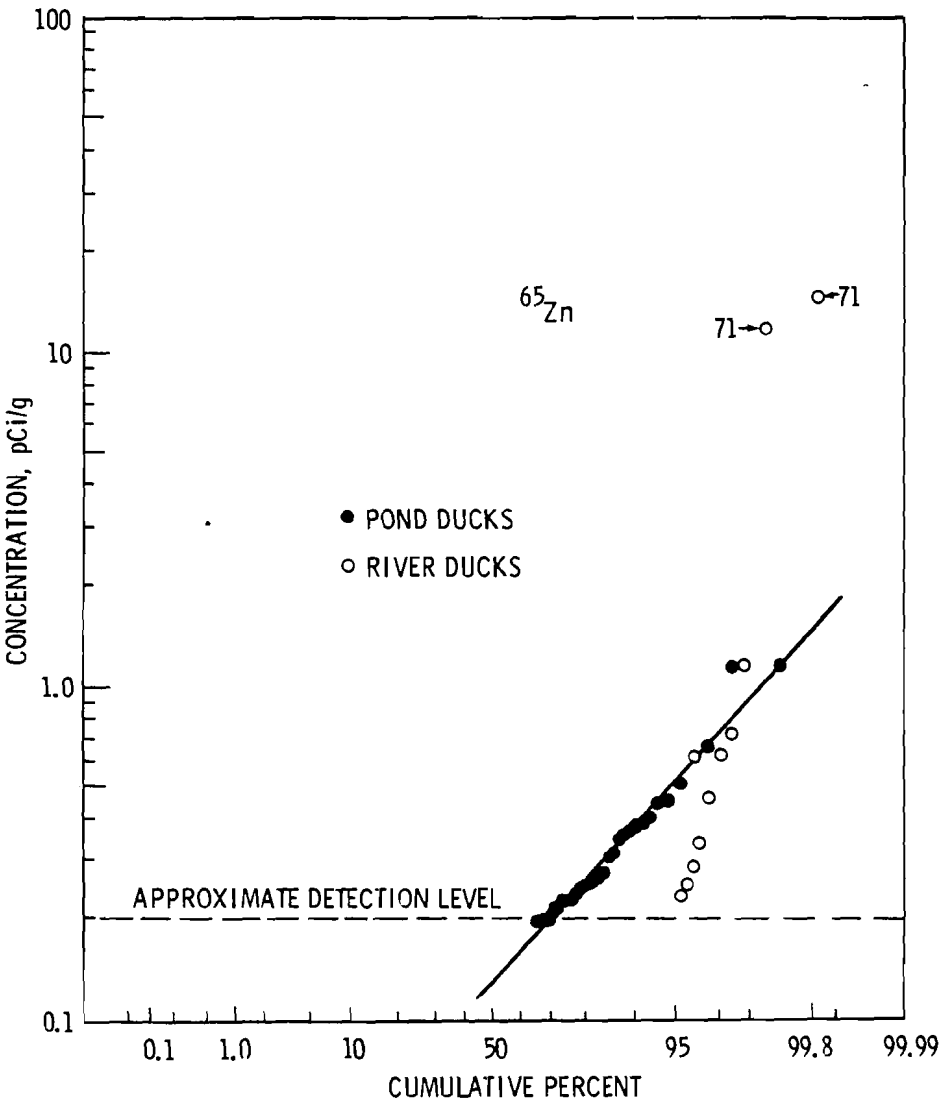

FIGURE 4. ^{65}Zn Concentrations in Muscle Tissue of Ducks Collected from Onsite Ponds and Along the Columbia River

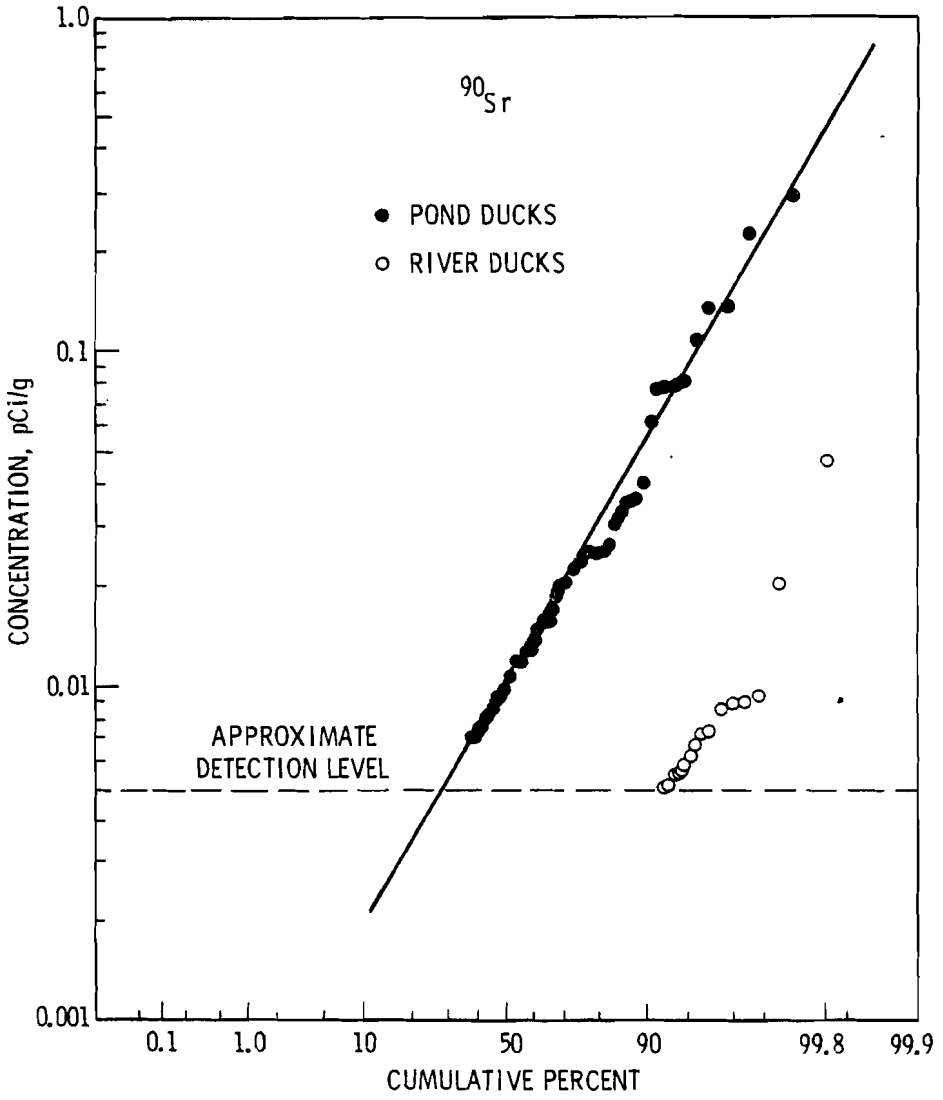

FIGURE 5. ^{90}Sr Concentrations in Muscle Tissue of Ducks Collected from Onsite Ponds and Along the Columbia River

pond ducks (55 out of 95) is compared to the positive measurements in river ducks (17 out of 216). From the data available, it is difficult to determine the expected concentration of ^{90}Sr attributable to fallout. Assuming that a hunter ingested 500 grams of duck meat containing the maximum observed ^{90}Sr concentration, 0.3 ρCi/g, a 50-year internal dose commitment of 0.3 mrem to the total body and 1.1 mrem to the bone would be incurred.

Figure 6 is a log-normal plot of the ^{137}Cs data for pond and river ducks. It is apparent from the graphs that levels in pond ducks nearly three orders of magnitude greater than the levels in river ducks have been observed. Figure 7 is a different plot of the same data derived by grouping all data less than 1 ρCi/g as representing the contribution due to fallout and all data for the pond ducks greater than 1 ρCi/g as representing the contribution due to Hanford operations. Also shown in Figure 7 are the years in which the larger ^{137}Cs concentrations were measured.

The 50-year internal dose commitment to the total body of a hunter who consumes 500 grams of duck meat containing the maximum ^{137}Cs concentration observed, 130 ρCi/g, would be about 4 mrem.

The results of uranium and plutonium analyses of duck liver tissue are shown in Table 6 for each of the years 1971-1975 and presented as a log-normal probability plot in Figures 8 and 9. All of the ducks were collected from onsite process ponds which represented a potential for uptake of uranium and/or plutonium. The contribution to the observed concentrations from naturally-occurring uranium and fallout Pu is not apparent since no ducks from the Columbia River were analyzed. Naturally-occurring U and Pu from fallout are present in Columbia River water at concentrations of about 0.5 ρCi/ℓ and 0.005 ρCi/ℓ, respectively. However, the data do show that the dose potentially received by a hunter who consumes a 60-gram liver from a duck with the highest observed U (0.2 ρCi/g) and Pu (1.0 ρCi/g) concentrations would be very small, less than 0.01 mrem to any organ of the body.

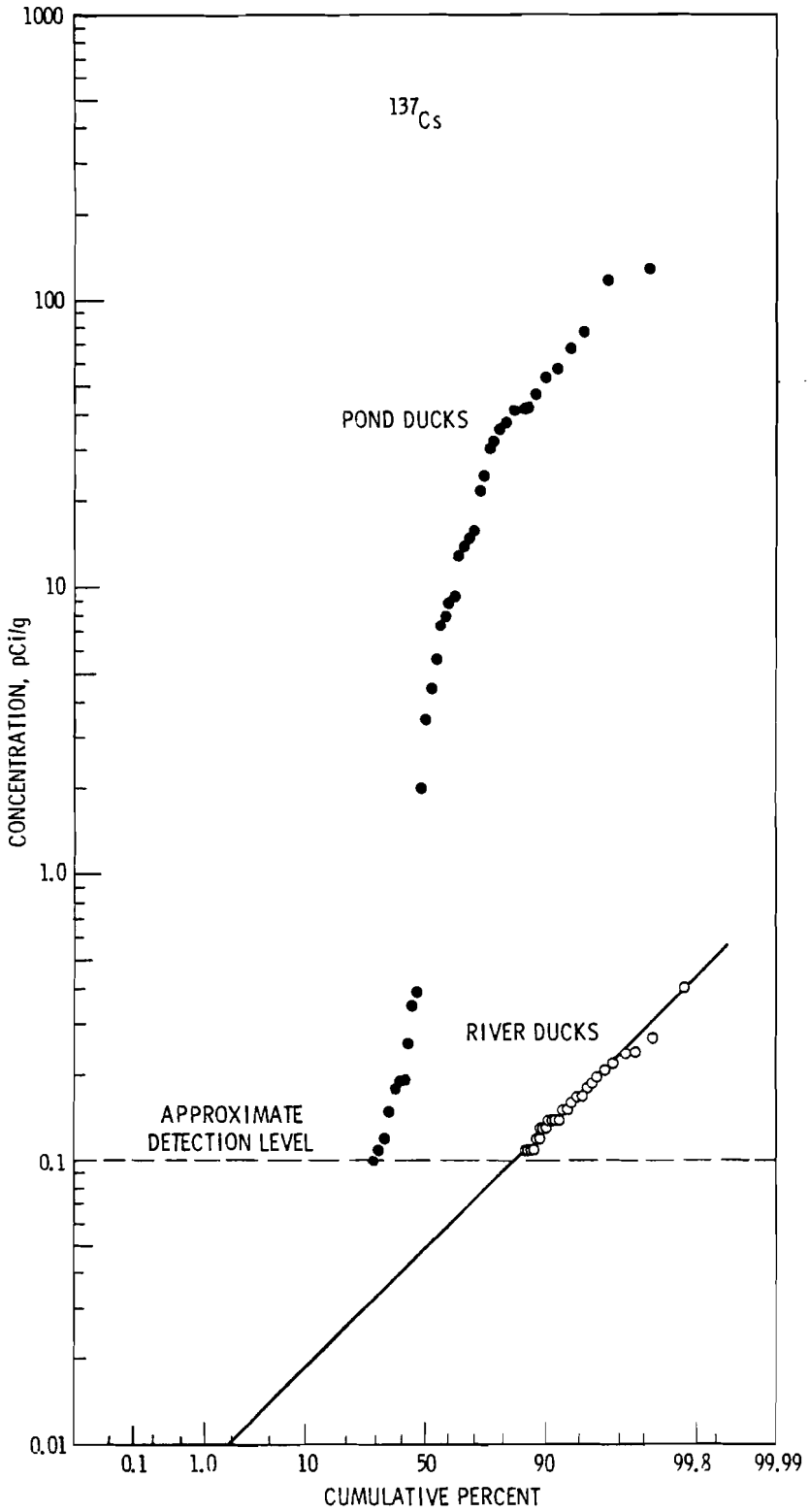

FIGURE 6. ^{137}Cs Concentrations in Muscle Tissue of Ducks Collected from Onsite Ponds and Along the Columbia River

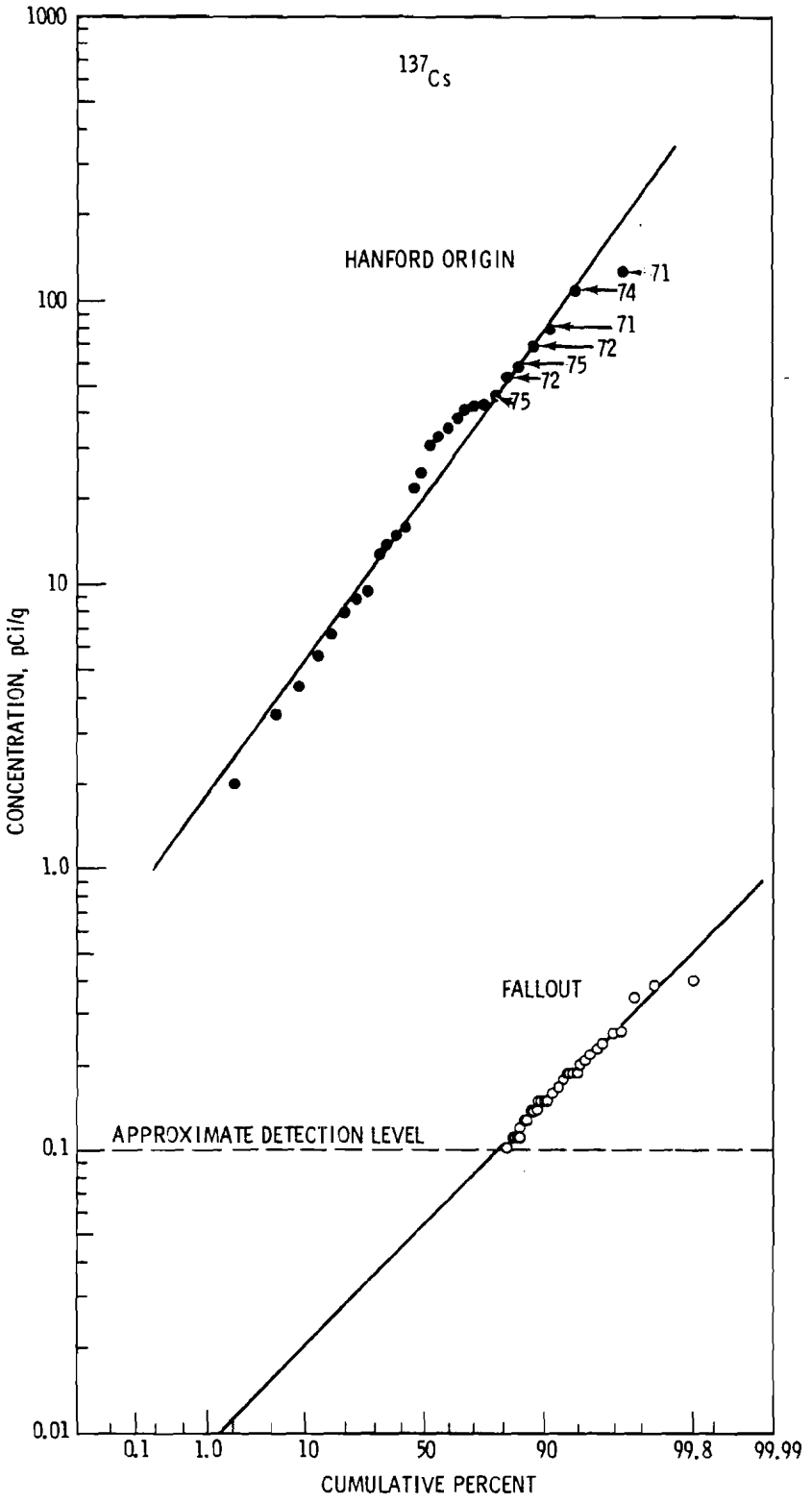

FIGURE 7. ^{137}Cs Data of Figure 6 Separated into Two Components to Show Expected Concentrations Attributable to Fallout and Hanford Operations

TABLE 6. Uranium and Plutonium Analyses of Duck Liver Tissues, 1971-1975

(Concentrations in ρCi/g, Wet Weight)

Year	No. of Samples	U			No. of Samples	Pu		
		Max.	Min.	Avg.		Max.	Min.	Avg.
1971	2	0.005	0.004	0.005	9	1.0	*	0.2
1972	6	0.2	0.002	0.04	9	0.5	*	0.1
1973	3	0.01	0.001	0.005	5	0.01	*	0.004
1974	1			0.7	5	0.1	*	0.03
1975	5	0.07	0.04	0.03	5	0.06	*	0.01

*Less than detectable. Detection limits were approximately 0.001 ρCi/g for U and 0.0002 for Pu

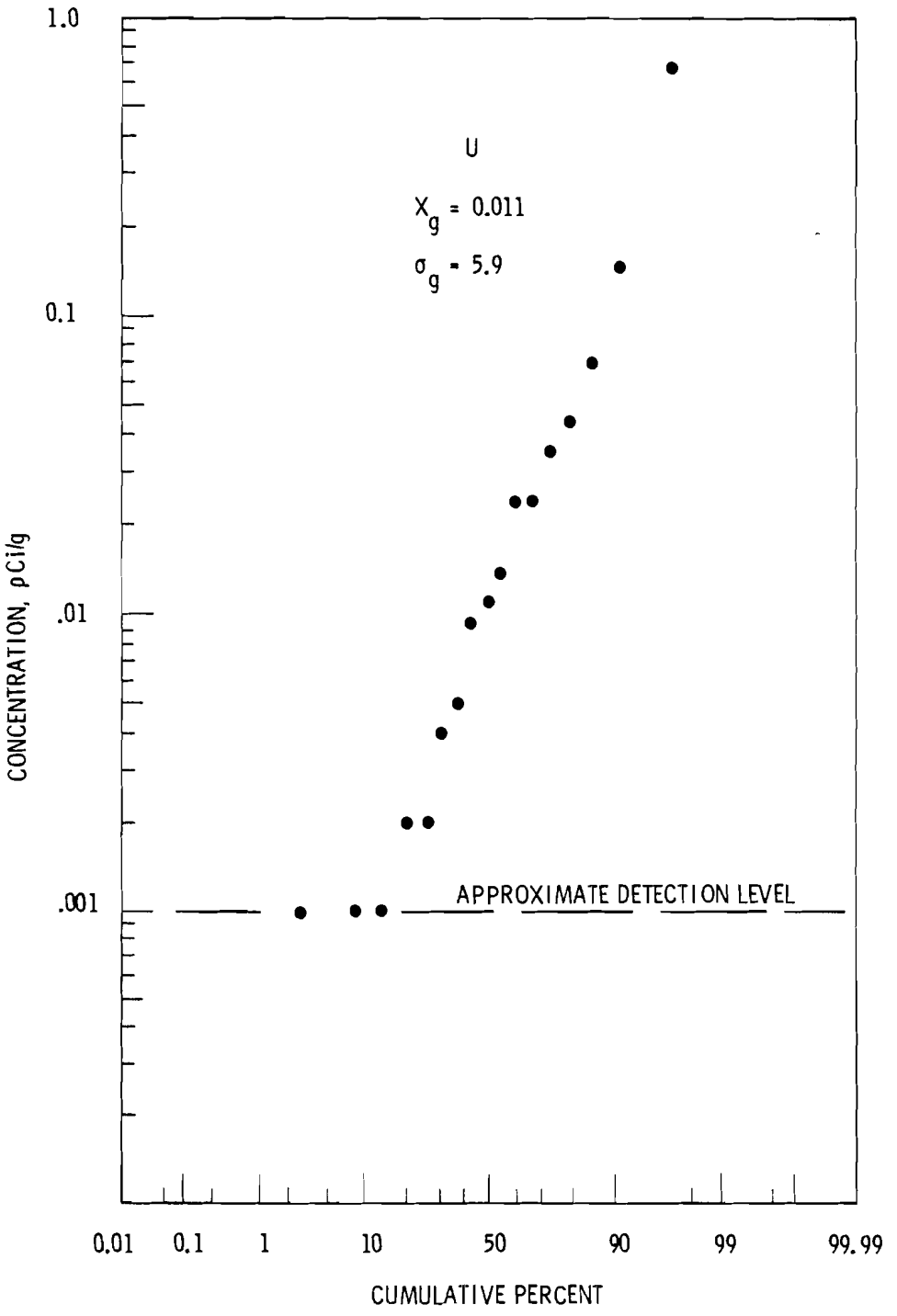

FIGURE 8. U Concentrations in Duck Liver Tissue

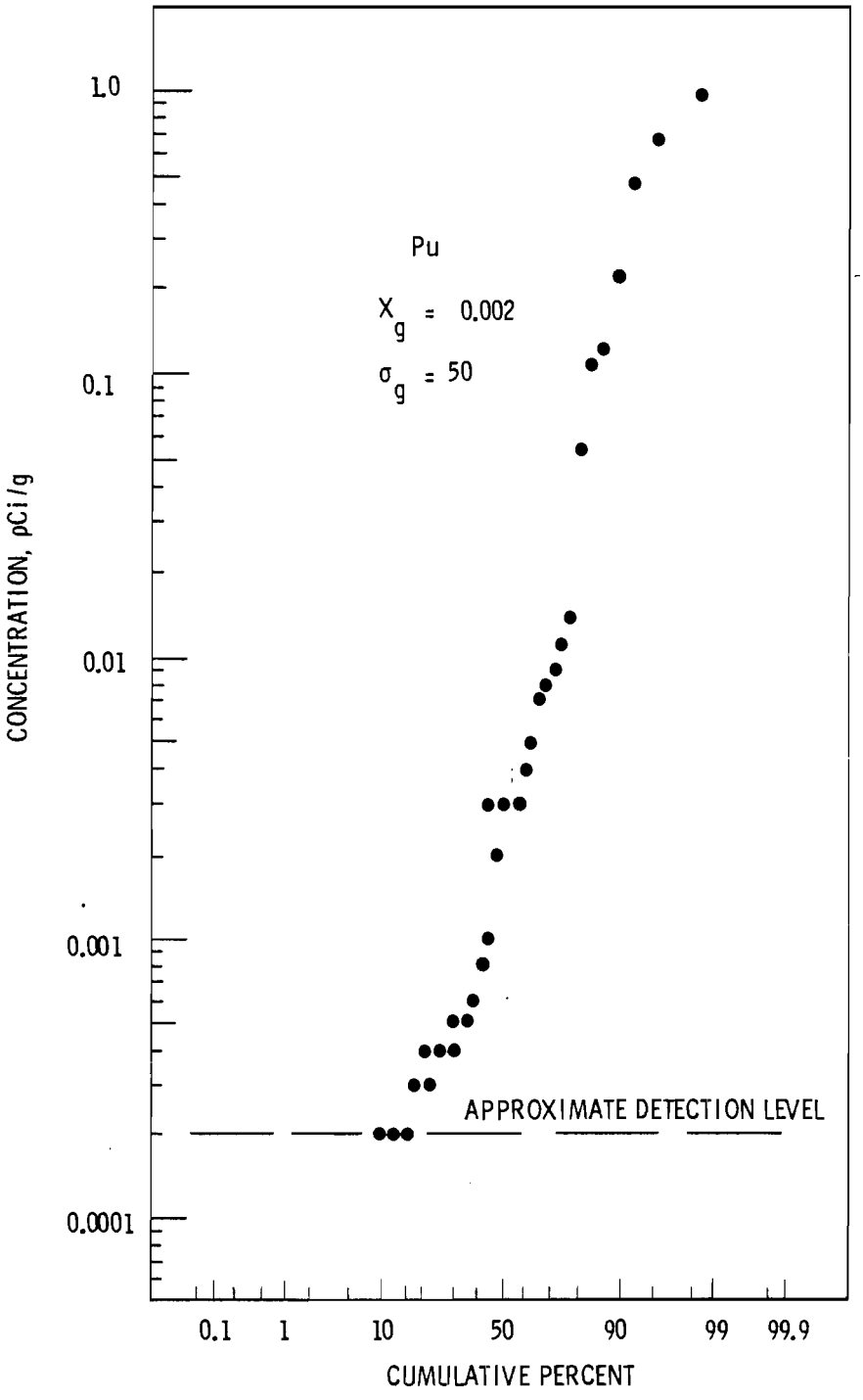

FIGURE 9. Pu Concentrations in Duck Liver Tissue

COOTS

Only 11 coots were collected during the period 1971 through 1975; but because coots are less migratory than some other waterfowl and may therefore take in more activity from Hanford process ponds, the available data were analyzed. Table 7 summarizes the maximum, minimum and average concentrations for all of the available data. All analyses for ^{60}Co except one showed concentrations less than the detection limit of approximately 0.1 pCi/g. This one positive measurement, 0.2 pCi/g, was obtained during 1974. Four of the 11 analyses for ^{65}Zn were statistically positive. From the limited data available, the contribution from fallout to the observed levels is uncertain, but considering the availability of ^{60}Co and ^{65}Zn to

TABLE 7. Summary of Radiochemical Analyses of Coot Samples, 1971-1975

(Concentration in pCi/g of Muscle Tissue, Wet Weight)

Year	No. of Samples	^{40}K Max.	^{40}K Min.	^{40}K Avg.(a)	^{60}Co Max.	^{60}Co Min.	^{60}Co Avg.	^{65}Zn Max.	^{65}Zn Min.	^{65}Zn Avg.
1971	3	6.1	*	2-3	*	*	*	0.6	*	0.2-0.4
1972	3	5.5	*	2-3	*	*	*	*	*	*
1973	0			-			-			-
1974	4	6.2	3.4	4.5	0.2	*	0.1-0.1	*	*	*
1975	1			4.8			*			*

Year	No. of Samples	^{90}Sr Max.	^{90}Sr Min.	^{90}Sr Avg.	^{137}Cs Max.	^{137}Cs Min.	^{137}Cs Avg.	^{239}Pu(b) Max.	^{239}Pu(b) Min.	^{239}Pu(b) Avg.
1971	3	0.1	0.02	0.06	36	0.3	13			N.A.
1972	3	0.1	0.01	0.05	12	3.8	7			0.009
1973	0			-			-			-
1974	4	0.02	*	0.01-0.01	170	4.6	54			0.23
1975	1			N.A.			210			N.A.

*Less than detectable. Detection levels are approximately ^{40}K ~2-, ^{60}Co ~0.1-, ^{65}Zn ~0.2-, ^{90}Sr ~0.005-, ^{137}Cs ~0.1-, and ^{239}Pu ~0.001- pCi/g.

N.A. Not Analyzed.

(a) Average shown is one of 1) arithmetic average if all results were positive, 2) range of arithmetic average by assuming first that less than results are equal to zero and alternatively that less than results equal to detection limit, or 3) less-than detection level.

(b) Results for liver tissue. Only two coots were analyzed, one in 1972 and one in 1974.

coots from Hanford operations, the maximum observed levels are attributed to Hanford. Assuming a hunter were to ingest 500 grams of coot meat (although coot is rarely eaten) containing the maximum observed concentrations of ^{60}Co (0.2 pCi/g) and ^{65}Zn (0.6 pCi/g), the 50-year dose commitment to the total body would be quite low, less than 0.01 mrem to any organ of the body.

Figures 10 and 11 are log-normal probability plots of the ^{40}K, ^{90}Sr and ^{137}Cs data. The observed median concentration of ^{40}K in coots is 4 pCi/g, slightly larger than the approximate 2.7-2.8 pCi/g observed in pheasants, geese, and ducks. However, this may be due to the small number of coots analyzed.

The ^{90}Sr concentrations are similar to the concentrations observed in ducks except that a much larger fraction of the samples analyzed (6 out of 11 showed a positive ^{90}Sr analysis as opposed to ducks collected along the Columbia River (17 out of 216). Assuming the increased frequency of positive measurements of ^{90}Sr is indicative of the impact from Hanford operations, a 50-year dose commitment to a hunter who consumes 500 grams of coot meat with the highest observed concentration of ^{90}Sr, 0.1 pCi/g, would be 0.09 mrem to the total body and 0.4 mrem to the bone.

The ^{137}Cs data in Figure 10 differ from the data for pheasants, geese, and ducks; all of the data are above the detection limit of about 0.1 pCi/g. In previous plots, a large number of data points were less than the detection limit. The data suggest that the coots collected were nesting at the ponds resulting in the uptake of radionuclides from the ponds. Only one coot showed a level of ^{137}Cs, 0.3 pCi/g, which was low enough to be possibly attributed to fallout.

Coot is not a preferred eating bird; however, the calculated first-year dose received by an individual from eating 500 grams of the coot with the greatest observed level of ^{137}Cs, 210 pCi/g, would be 5.8 mrem to the total body and 6.7 mrem to the bone. The 50-year dose commitments to the total body and bone would be 6.4 mrem and 8.0 mrem, respectively.

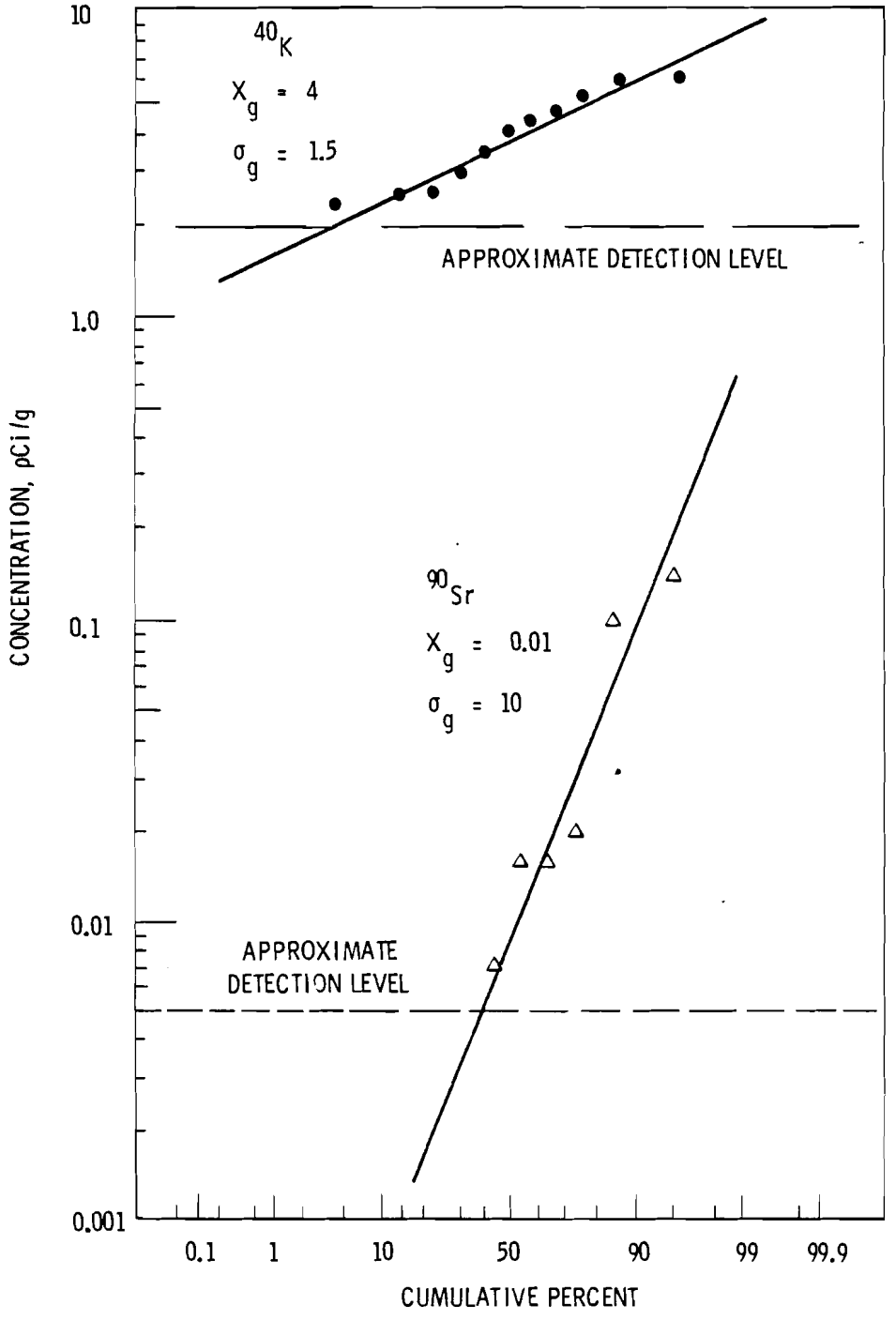

FIGURE 10. ^{40}K and ^{90}Sr Concentrations in Coot Muscle Tissue

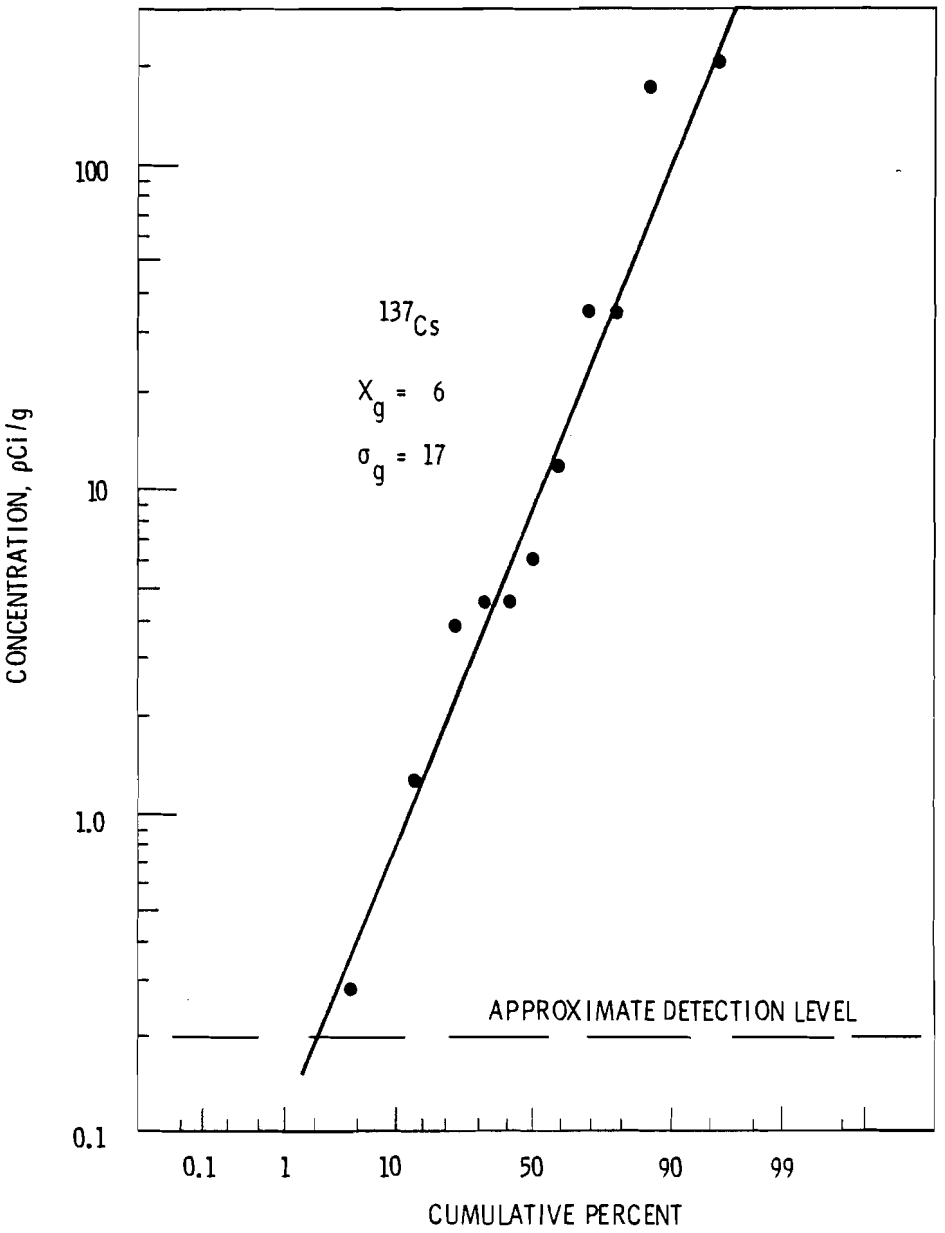

FIGURE 11. ^{137}Cs Concentrations in Coot Muscle Tissue

Only two coots were analyzed for Pu in liver tissue during the period 1971 to 1975, one in 1972 and the other in 1974. Additional coots were not analyzed for Pu because only these two were collected at the specific ponds that present a possibility for Pu uptake. Their respective Pu concentrations in liver tissues were 0.009 pCi/g and 0.2 pCi/g. The potential dose from eating a 60-gram liver containing 0.2 pCi/g of Pu would be very small, less than 0.01 mrem to any organ of the body.

ACKNOWLEDGMENTS

The efforts of several people were necessary to collect, analyze and evaluate the extensive environmental data acquired as part of the ERDA-sponsored Environmental Surveillance Program at Hanford. The laboratories of U. S. Testing Company performed the analyses. Shellie Canada typed the report. Jan Baer arranged for the report's publication.

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