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EVALUATION OF RADIOLOGICAL CONDITIONS IN THE VICINITY OF HANFORD FOR 1963

THE ENVIRONMENTAL STUDIES AND EVALUATION STAFF

FEBRUARY 24, 1964

HANFORD LABORATORIES

HANFORD ATOMIC PRODUCTS OPERATION
RICHLAND, WASHINGTON

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EVALUATION OF RADIOLOGICAL CONDITIONS IN THE VICINITY OF HANFORD FOR 1963

By

The Environmental Studies and Evaluation Staff
R. F. Foster, Manager

Edited by R. H. Wilson
Radiation Protection Operation
Hanford Laboratories

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SUMMARY STATEMENT

An evaluation of results obtained from the Hanford environmental surveillance program for 1963 indicates that most of the environmental radiation exposure for the majority of persons in the neighborhood of the Hanford project was due to natural sources and world-wide fallout rather than to Hanford operations.

Of the low-level wastes released to the environment from the Hanford plants, neutron-induced radionuclides present in reactor cooling water discharged to the Columbia River continued to be the source of greatest potential exposure to the people in the environs. The primary mechanisms of exposure from this source are drinking water derived from the river and consumption of fish and waterfowl which inhabit the river.

The city of Richland started using the Columbia River as a source of sanitary water during 1963. In the 4 months following startup of the new plant in August, this source contributed a total exposure amounting to about 5% of the annual permissible limit for populations. The gastrointestinal tract is the limiting organ for the mixture of nuclides present in drinking water pumped from the Columbia River. In Pasco and Kennewick, which are further downriver, the estimated exposures from drinking water were respectively about 5% and 1% of the GI tract limit (population at large) for the full 12 months of 1963. The only persons who received radiation exposures attributable to Hanford that were greater than those resulting from the drinking water were the people that ate local fish or waterfowl or who regularly consumed produce from nearby farms irrigated with water pumped from the Columbia River below the reactors.

The highly unlikely, but conceivable combination of circumstances that would result in the greatest exposure to an individual from the radionuclides released by the Hanford plants is postulated as; (1) the consumption of some 200 meals of locally caught fish during the year, (2) the consumption of meat, milk, fruit, and vegetables from irrigated farms of the Riverview district, and (3) the drinking of water from the Pasco system.

An individual with such habits could conceivably take in enough radioactive material of Hanford origin (mostly P^{32}) to supply about 45% of the annual permissible amount. In this case the bone is the organ that is most restrictive. This same individual could also take in enough Sr^{90} of world-wide fallout origin to equal about 5% of the permissible amount—more than twice that estimated for 1962. The exposures from nuclides of Hanford origin and from fallout are not additive in relation to limits, however, since the Radiation Protection Guides recommended by the Federal Radiation Council are not applicable to fallout from weapons tests.

The amount of I^{131} in the Hanford environs was substantially less than in the previous 2 years when extensive testing of weapons was in progress. Nevertheless, world-wide fallout continued to be the dominant source of the I^{131} found locally, except for the month of September when abnormally large amounts were released from one of the chemical separations plants. For the calendar year 1963, the I^{131} in milk from local farms could have resulted in radiation exposures to the thyroids of infants of approximately 10% of the Federal Radiation Council Radiation Protection Guide.

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I. INTRODUCTION

The Hanford project* (Figure 1) is located in a semiarid region of southeastern Washington having an average annual rainfall of about 7 inches. Natural vegetation in this section of the state is sparse, primarily suited for grazing although large areas near the project perimeter have gradually been put under irrigation during the past few years. The plant site, shown in Figure 2, comprises an area of about 500 square miles. The Columbia River flows through the project and forms part of the eastern boundary. The meteorology of the region is typical of a desert area with frequent strong inversions occurring at night and breaking during the day to provide unstable and turbulent conditions. Near the plant production sites the prevailing winds are from the northwest with strong drainage and cross winds causing distorted flow patterns.

The populated areas of primary interest near the plant perimeter are Richland, Pasco, and Kennewick. Smaller communities in the vicinity are Benton City, West Richland, Mesa, and Othello. All together about 80,000 people live in the vicinity of the project. Protection of these people from undue radiation exposure attributable to Hanford sources is one of the attendant responsibilities in the operation of the Hanford facilities.

During the course of operation, various radioactive wastes are generated by the several plant facilities. High level wastes are concentrated and retained in storage within the project area. Controlled releases of low-level wastes, for which concentration and retention are not feasible, are made to the ground. The Hanford practices governing radioactive waste disposal are described in the Hearings on Industrial Radioactive Waste Disposal held by the Joint Congressional Committee on Atomic Energy in 1959.(1)

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* Operated for the Atomic Energy Commission by the General Electric Company under Contract Number AT(45-1)-1350.

FIGURE 1

Geographical Relationship
of Hanford Works to Pacific Northwest

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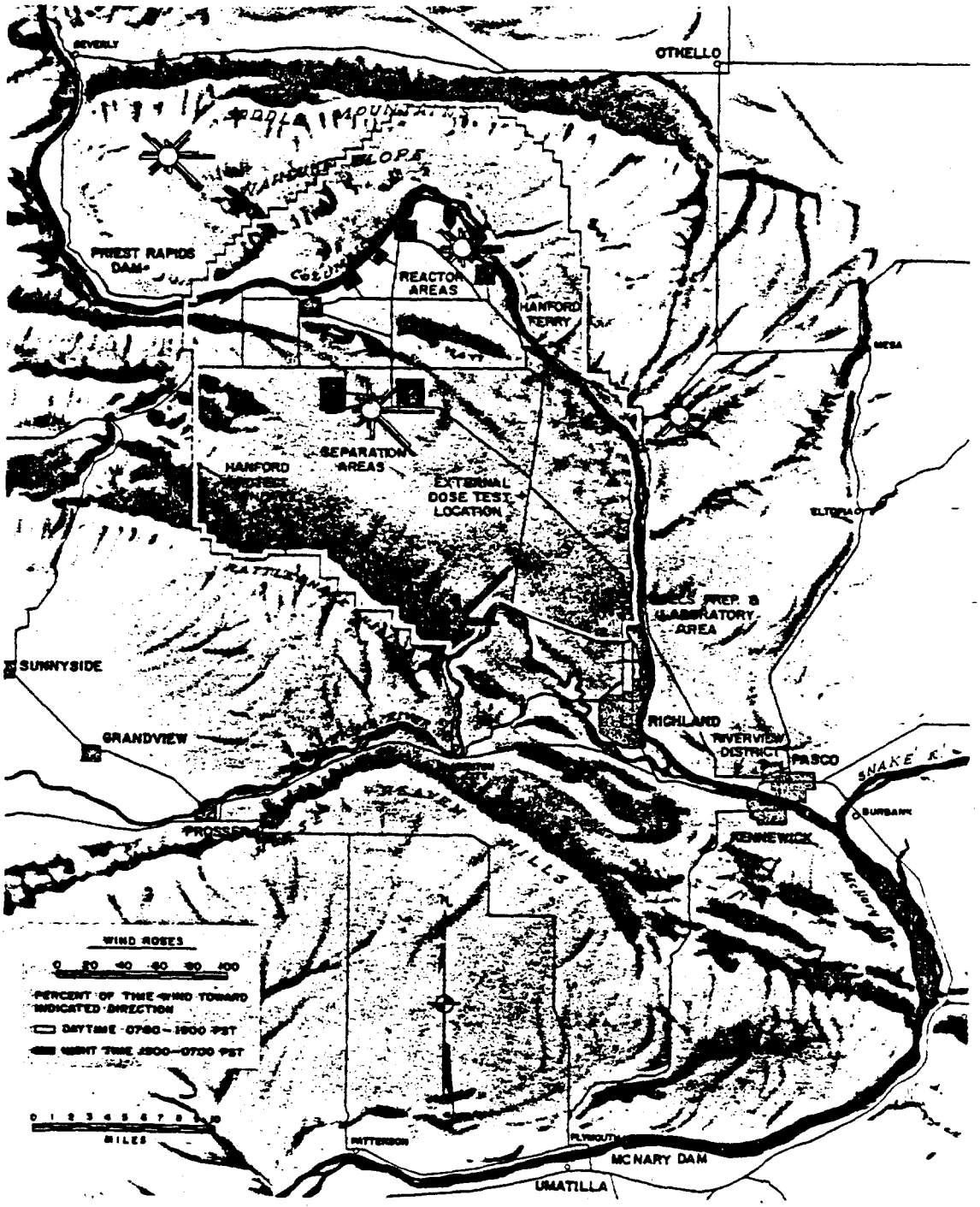

FIGURE 2

Features of Hanford Project and Vicinity

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AEC-GE RICHLAND, WASH.

The AEC Manual Chapters[2] and the recommendations of the National Committee on Radiation Protection and Measurement (NCRP),[3] the International Commission on Radiological Protection (ICRP),[4] the Federal Radiation Council (FRC),[5] and the results of Hanford research programs form the basis of radiation protection practices at Hanford. The recommendations of these organizations in the form of permissible rates of intake of specific nuclides and guides for radiation exposure constitute criteria against which radiation exposures estimated from measurements of the Hanford environmental surveillance program are compared. The results of this comparison indicate the effectiveness of Hanford waste control and radiation protection practices and point out any conditions requiring attention.

This report estimates the annual exposure received by the individuals who are expected to receive the greatest amount of radiation from environmental sources, and the exposure received by people who are more typical residents of this region. These exposures are compared with the recommendations of the NCRP and FRC. The NCRP recommendations, in the form of maximum permissible exposures for individuals that are not employed in radiation work are 1500 mrems per year to the GI tract, 500 mrems per year to the total body, and 3000 mrems to the thyroid. The limits for bone-seekers are calculated with reference to biological effects observed from deposition of radium and are most readily applied in the form of maximum permissible rates of intake (MPRI).* Similar evaluations for previous years have also been reported.[1, 6, 7] The Radiation Protection Guides established by the FRC for individuals are 1500 mrems per year to the thyroid, 1500 mrems per year to the bone, and 500 mrems to the whole body. The Radiation Protection Guides for the "average of a suitable sample of an exposed population group" are one-third of those for individuals.

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* The MPRI is taken as the maximum permissible concentration in water for a given radionuclide, as recommended by the NCRP for persons in the neighborhood of controlled areas, multiplied by the rate of water intake as defined for the standard man. This amounts to one-tenth of the MPC's for continuous exposure of occupational workers multiplied by 2200 cc per day, or by 800 liters per year in the case of annual estimates.

II. ENVIRONMENTAL CONDITIONS

A discussion and interpretation of the results of the various Hanford environmental sampling programs are presented in the following text and figures. The raw data for many of the programs and brief descriptions of analytical methods used in determining the amounts of radionuclides in various samples are presented in the appendices.

A. Radionuclides in the Columbia River

Hanford's eight production reactors are cooled with Columbia River water. This water goes through filtration processes and then passes once through the reactors as a coolant before being returned to the river. Stable elements present in the cooling water are transformed into radionuclides during passage through the reactors, and radioactive materials formed on the surfaces of the fuel elements and channels are washed away by the cooling water.

The relative abundance of the radionuclides found in the cooling water, as adjusted to 4 hours past irradiation, is shown in Table I.

TABLE I

RELATIVE ABUNDANCE OF REACTOR EFFLUENT RADIONUCLIDES

Reference Time - 4 Hours Postirradiation

Major, 90%	Minor, 8%	Trace, 2%		
Na^{24}	P^{32}	H^{3}	Ag^{111}	Pm^{147}
Si^{31}	Zn^{65}	C^{14}	Cd^{115}	Nd^{149}
Cr^{51}	Zn^{69m}	S^{35}	I^{131}	Pm^{149}
Mn^{56}	Ga^{72}	Ca^{45}	I^{132}	Pm^{151}
Cu^{64}	Y^{90}	Sc^{46}	Cs^{137}	Eu^{152}
As^{76}	Sr^{91}	Sc^{47}	Ba^{140}	Sm^{153}
Np^{239}	Sr^{92}	Mn^{54}	La^{140}	Eu^{156}
	Y^{92}	Fe^{59}	Ce^{141}	Sm^{156}
	Y^{93}	Co^{60}	La^{141}	Eu^{157}
	Nb^{97}	Sr^{85}	Pr^{142}	Tb^{160}
	I^{133}	Sr^{90}	Ce^{143}	W^{187}
	I^{135}	Y^{91}	Pr^{143}	Po^{210}
	U^{239}	Zr^{95}	$Ce\text{-}Pr^{144}$	Ac^{227}
		Mo^{99}	Pr^{145}	U^{238}
		Ru^{103}	Nd^{147}	Pu^{239}

(Trace nuclide composition based on analyses by the Radiological Chemistry Operation made in 1958.)

Many of the radionuclides formed in reactor cooling water are short-lived and decay rapidly after formation. In addition to radioactive decay, some portion of the radionuclides is removed from the water by sedimentation and uptake by aquatic organisms. The radionuclides in the river also include some contribution of "fallout" from weapons tests.

Samples of river water were obtained every 2 weeks from Vernita Ferry, Hanford Ferry, 300 Area, the inlet to the Pasco municipal water plant, and Vancouver. Some samples of river water were also collected at Richland, particularly during the latter part of the year when the new water plant was in operation. River water samples were analyzed for several radionuclides and the results of the analyses are presented in Appendix A, Tables 1, 2, 3, and 4.

The relative abundance of the significant radionuclides at Hanford Ferry, Pasco, and Vancouver is illustrated in Figure 3. The areas of the circles are proportional to the total activity measured at the three locations. The average concentrations of radionuclides measured routinely at the four river sampling stations are shown in Table II.

TABLE II

ANNUAL AVERAGE CONCENTRATIONS
OF SEVERAL RADIONUCLIDES IN COLUMBIA RIVER WATER - 1963

Units of pc/l

Radionuclide	Hanford Ferry	Richland	Pasco	Vancouver
Total Beta	52,000	23,000	11,000	500
RE+Y	1,800	640	440	-
Na^{24}	7,700	3,400	1,600	-
P^{32}	340	260	190	30
Cr^{51}	12,000	8,800	6,700	2,600
Mn^{56}	9,800	-	-	-
Cu^{64}	17,000	5,900	2,300	-
Zn^{65}	470	380	220	60
As^{76}	2,400	1,200	750	-
Sr^{90}	1	1	1	1
I^{131}	12	8	8	4
Np^{239}	3,300	2,100	1,600	-

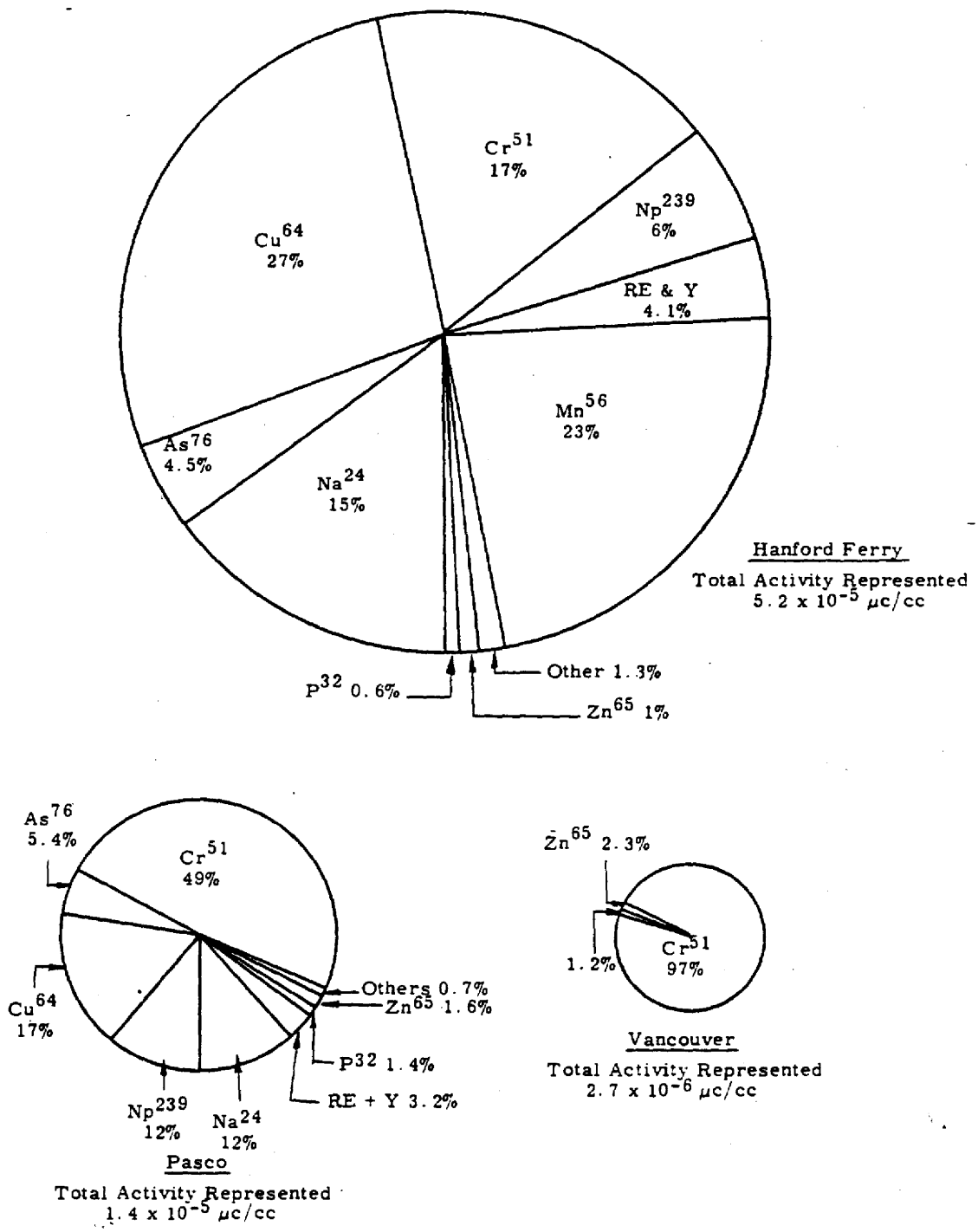

FIGURE 3

Relative Abundance of Radionuclides in Columbia River Water at Several Locations. Annual Averages 1963

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The Hanford Ferry monitoring station is about 7 miles downstream from the closest production reactor and about 6 miles upstream from the point where the project boundary crosses the Columbia River. Studies of effluent distribution at the Hanford Ferry indicate nonuniformity which causes sample results to show higher concentrations of most radionuclides than the average of the cross section at this location. Measurements on a traverse across the river at Richland indicated a fairly uniform distribution of the longer-liver radioisotopes throughout the river at this point. At Pasco, the distribution of radioisotopes in the river is slightly nonuniform because of the entry of the Yakima River some 10 miles upstream.

Vancouver, about 260 miles from the reactors, is the farthest downstream location where river water is routinely sampled for Hanford's surveillance program. Further downstream the intrusion of sea water into the Columbia River complicates quantitative measurement of the radionuclides.

Seasonal variation in the flow rate of the Columbia River markedly affects the quantity of water available for dilution of the reactor effluent. Also affected is the time required for a specific volume of water to move from one location to another. The flow rate of the Columbia River at Pasco and Vancouver for 1959 through 1963 is shown in Figure 4. The variation in concentration of several radionuclides in the river water at Pasco for the same period is shown in Figure 5. The rate of transport of these same radionuclides past Pasco is shown in Figure 6, and in Table 8 of Appendix A. The rate of transport of certain radionuclides passing Vancouver may be used as an index of the quantities entering the Pacific Ocean from the Columbia River. The annual average rate of transport of selected radionuclides is given in Table III and detailed measurements are tabulated in Appendix A, Table 9.

TABLE III

ANNUAL AVERAGE RATE OF TRANSPORT
OF SELECTED RADIONUCLIDES PAST VANCOUVER

curies/day

Radionuclides	1963	1962	1961
P^{32}	12	13	29
Cr^{51}	860	650	840
Zn^{65}	28	29	44

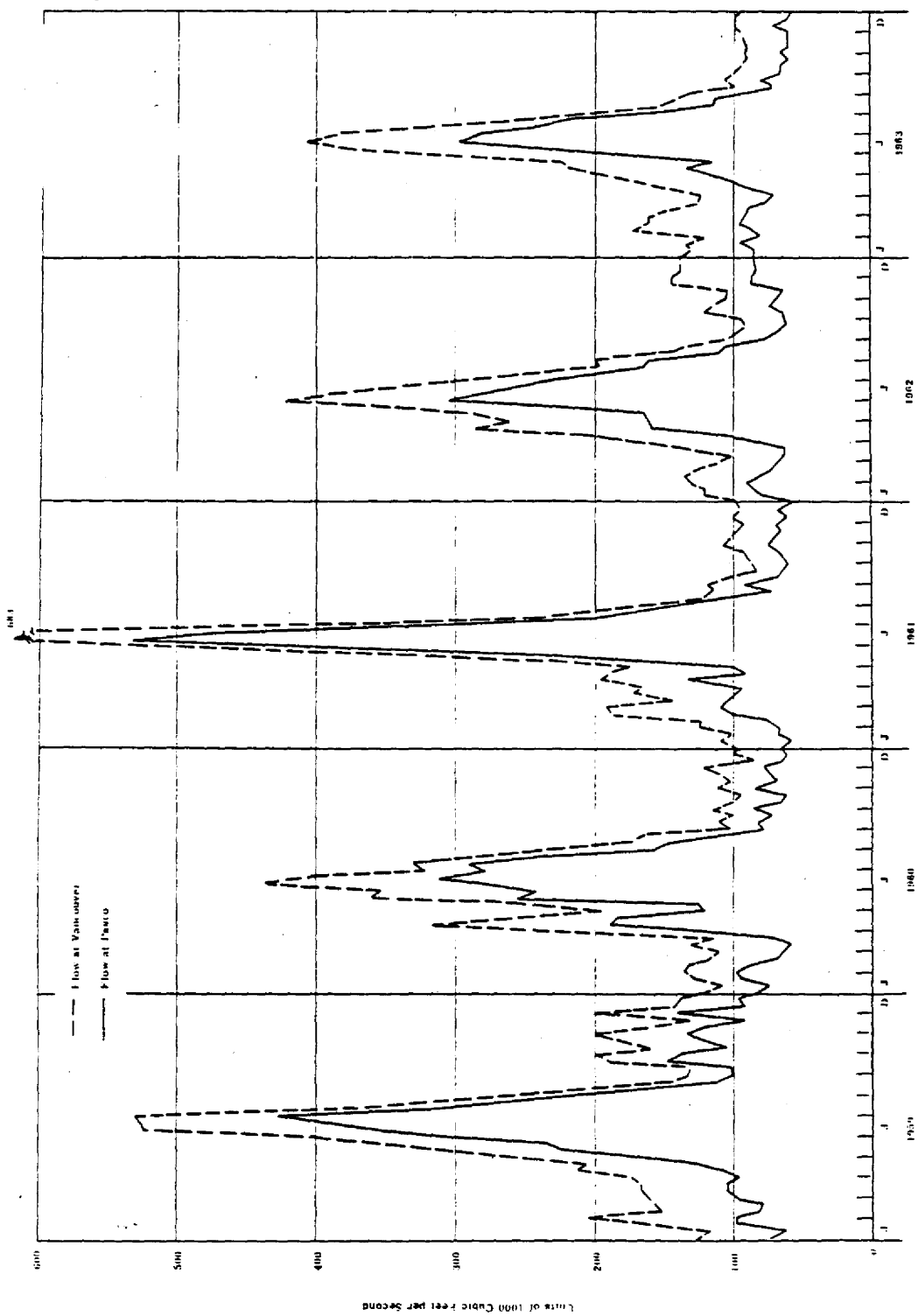

FIGURE 4

Columbia River Flow at Pasco and Vancouver

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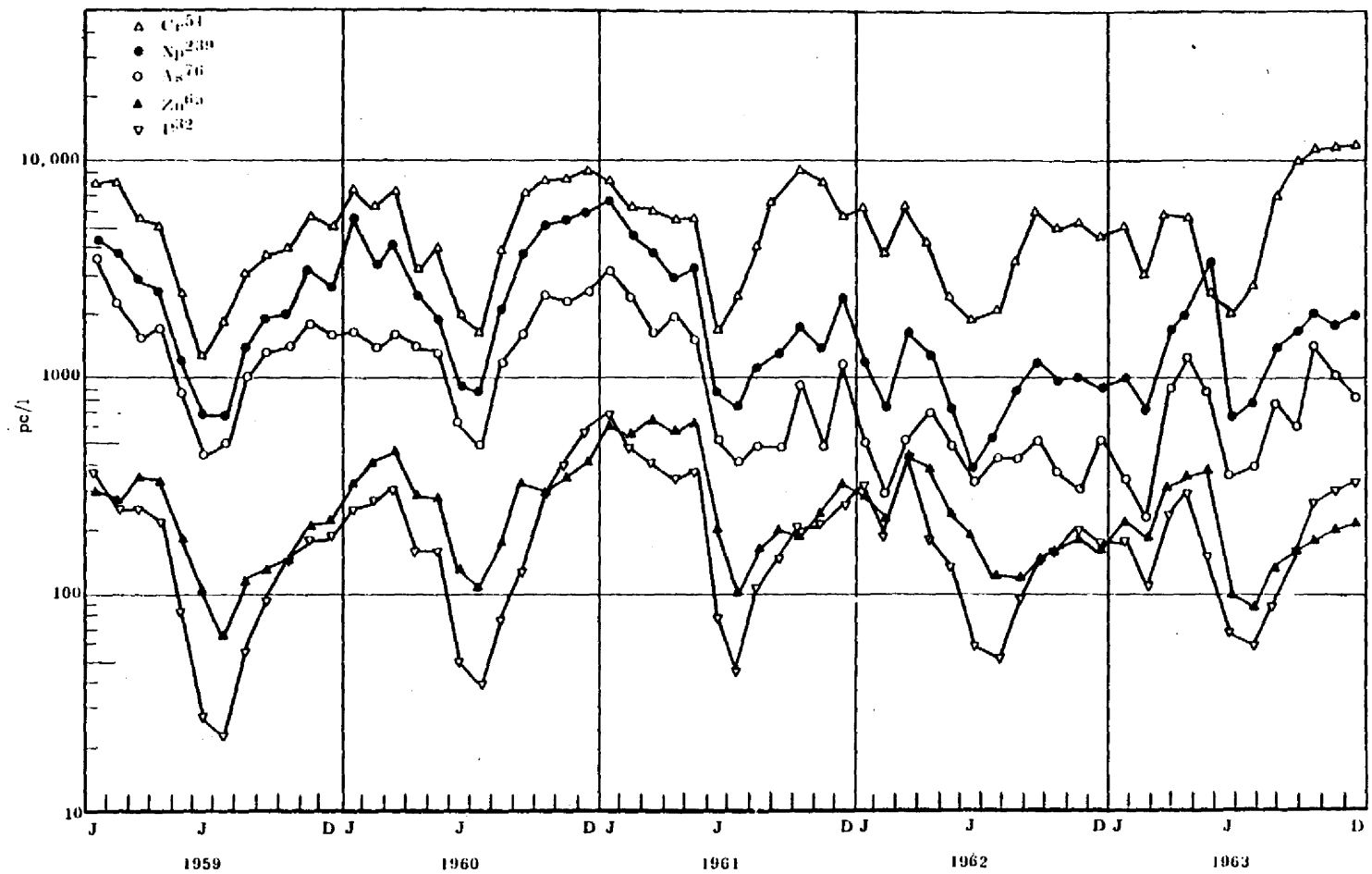

FIGURE 5

Concentration of Radionuclides in Columbia River Water at Pasco, Washington

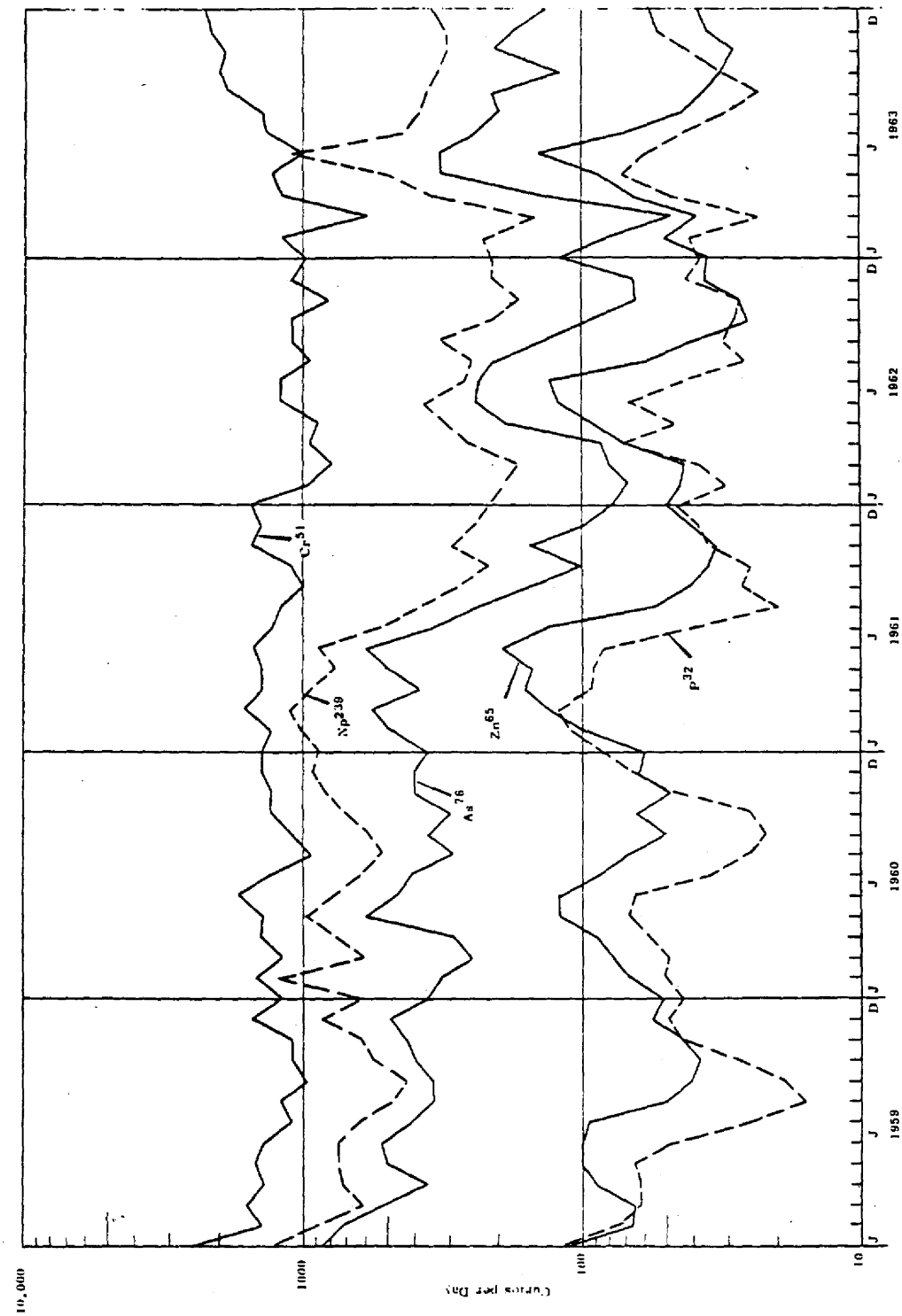

FIGURE 6

Rate of Transport of Radionuclides at Pasco, Washington

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The inventory of each of these nuclides which exists in the ocean can be calculated by assuming an equilibrium between the rate of addition through the river and the rate of decay in the ocean. A constant rate of entry into the ocean equivalent to that indicated by the 1963 Vancouver measurements, implies inventories of about 250 curies of P^{32}, 30,000 curies of Cr^{51}, and 9,000 curies of Zn^{65}.

Radiation exposure that results from the drinking of water pumped from the river and sent through treatment plants is discussed in the next section of this report. There is no known instance of untreated river water being consumed routinely by humans. For comparative purposes, however, the relationship between the concentrations of radionuclides in the untreated Columbia River water and published values for maximum permissible concentrations in water is shown in Table IV. In this case the comparison is with the MPC's listed in Column 2, Table II of Annex I of AEC Manual Chapter Appendix 0524.[2] For the most part these MPC's are equivalent to one-tenth of the most limiting values recommended by the NCRP[3] for occupational workers. The marked reduction in percent of MPC_w that occurs with distance downstream from the reactors results principally from radioactive decay of the shorter-lived nuclides.

TABLE IV

RELATIONSHIP BETWEEN THE CONCENTRATIONS OF RADIONUCLIDES IN UNTREATED COLUMBIA RIVER WATER AND MAXIMUM PERMISSIBLE CONCENTRATIONS

Sampling Location	% of MPC*
Hanford	34
Richland	17
Pasco	12
Vancouver	2

* This is a summation of the percents of MPC's contributed by the several individual radionuclides measured routinely in the river water. The MPC's used and the method of summation are taken from AEC Manual Chapter 0524.[2]

B. Radionuclides in Drinking Water

In the latter part of 1963, Richland started up a new water treatment plant that draws water from the Columbia River. Previously Richland obtained its water from wells, and Kennewick and Pasco (downstream from Richland) were the nearest cities to the Hanford reactors that used Columbia River water. Sanitary water was collected at the Richland and Pasco water treatment plants every 2 weeks and analyzed for the important radionuclides. Similar analyses were made on Kennewick water once each month. The results of the radioanalysis of water from these plants are presented in Appendix A, Tables 5, 6, and 7 are summarized in Table V.

TABLE V

ANNUAL AVERAGE CONCENTRATION OF SEVERAL RADIONUCLIDES MEASURED IN SANITARY WATER - 1963

Units of pc/l

Radionuclide	Richland*	Pasco	Kennewick
Total Beta	23,000	4,000	600
RE+Y	90	50	10
Na^{24}	3,000	600	90
P^{32}	130	40	<10
Cr^{51}	14,000	5,400	2,500
Cu^{64}	3,000	400	90
Zn^{65}	80	90	<20
As^{76}	800	200	<60
Sr^{90}	2	1	<0.5
I^{131}	10	5	<3
Np^{239}	2,500	800	30

* Averages for Richland are based only on the last quarter of 1963 when the new water treatment plant was in full operation. These averages may change significantly when a full year's operation is used.

The concentrations of short-lived radionuclides in the water at the time it is consumed is less than shown in the table because there is a significant flow time between the water plant and most consumers. The flow time may vary from hours to days depending upon the location of the customer on the distribution system.

Table VI shows the removal of several radionuclides by the water treatment at Pasco and Richland. These data include the radioactive decay of the short-lived radionuclides during travel through the water treatment plant.

TABLE VI

DEPLETION OF RADIONUCLIDES FROM COLUMBIA RIVER WATER BY TREATMENT AT THE RICHLAND AND PASCO WATER PLANTS - 1963

Radionuclide	% Depletion	
	Pasco	Richland
RE+Y	90	80
Cu^{64}	80	40
P^{32}	80	50
As^{76}	80	40
Na^{24}	60	15
Zn^{65}	60	80
Np^{239}	50	-
Cr^{51}	20	-

The calculated annual average dose to the GI tract, total body and the percentage MPRI for bone from sustained consumption of sanitary water at the three cities is presented in Table VII.

TABLE VII

CALCULATED ANNUAL DOSE FOR SELECTED ORGANS FROM ROUTINE INGESTION OF SANITARY WATER* - 1963

	Total Body mrem	GI Tract mrem	Bone % MPRI	Thyroid (Small Child, 1 l/day) mrem
Richland**	1	25	0.8	22
Pasco	1.5	20	0.9	40
Kennewick	<1	<5	<0.5	<20

* Here and elsewhere in this report where a dose from an ingested nuclide is expressed in mrem units, the determination is made from parameters used by the ICRP tc translate dose rates into Maximum Permissible Concentrations for drinking water. In most cases the estimated annual intakes of individual radionuclides were multiplied by conversion factors derived from the ICRP parameters and published by Vennart, et al.[8]

The "standard man"[4] beverage intake of 1.2 liters per day was used in this calculation. This is a departure from the 2.2 liters per day (total liquid intake for the "standard man" including foods) used for similar calculations in the past, but more reasonably represents the average exposure from drinking water alone.

** The radiation dose shown in this table for Richland residents was all accrued during the last 4 months of 1963 subsequent to the change from wells to Columbia River water.

The thyroid dose shown in Table VII for Pasco residents includes an increment accrued from fission products released by an unusually severe failure of a fuel element in one of the reactors that occurred on May 12, 1963. Fuel element failures are not unusual but the quantities of fission products released to the river from them is ordinarily small. During 1963, only the one on May 12 released enough fission products to warrant special evaluation. For estimating thyroid dose, a small child was considered to have consumed 1 liter of water from the Pasco supply during the time when the maximum concentration of I^{131} was present. The resulting dose to the child's thyroid would have been approximately 8 mrems. This would have increased his dose from about 6% of the FRC Radiation Protection Guide for an exposed population group to about 8%. The dose to the GI tract, bone and total body from this incident was negligible.(9)

The relative contribution of several radionuclides in the Pasco and Richland sanitary water to the calculated annual dose to the GI tract is shown in Figure 7. Short-term variations and long-term trends in the GI tract dose at Pasco are shown in Figure 8.

The dose received by the GI tract of Pasco residents continued at about the same level as experienced in 1962. Treatment of the reactor cooling water for reduction of As^{76}, Np^{239}, and other nuclides was continued during 1963. This modification consisted mainly of increased addition of alum in the clarifying process which reduced the amount of parent materials from which As^{76} and Np^{239} are formed.

C. Radionuclides in Fish and Waterfowl

Fish and waterfowl that feed in the Columbia River downstream from the reactors acquire some radionuclides that enter the river with the reactor effluent water. The concentration of several radionuclides in the flesh of different kinds of fish from several locations on the river are reported in Appendix A, Table 10. Except for suckers, whitefish usually contain the greatest concentration of radioactive materials and P^{32} is the radionuclide of greatest significance. The concentrations of P^{32} in whitefish caught

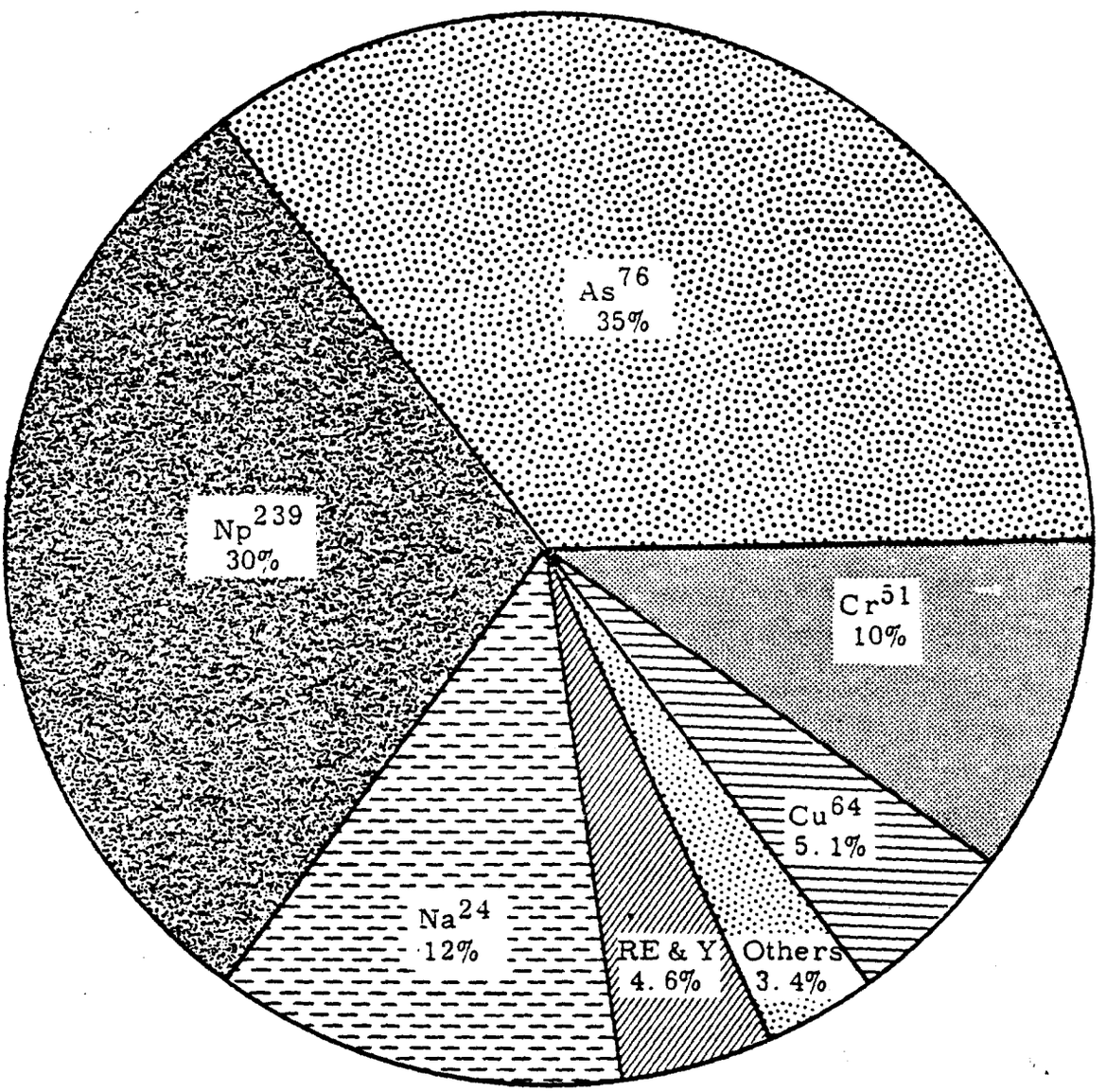

FIGURE 7

Relative Contribution of Radionuclides to GI Tract Dose
Pasco Sanitary Water - 1963

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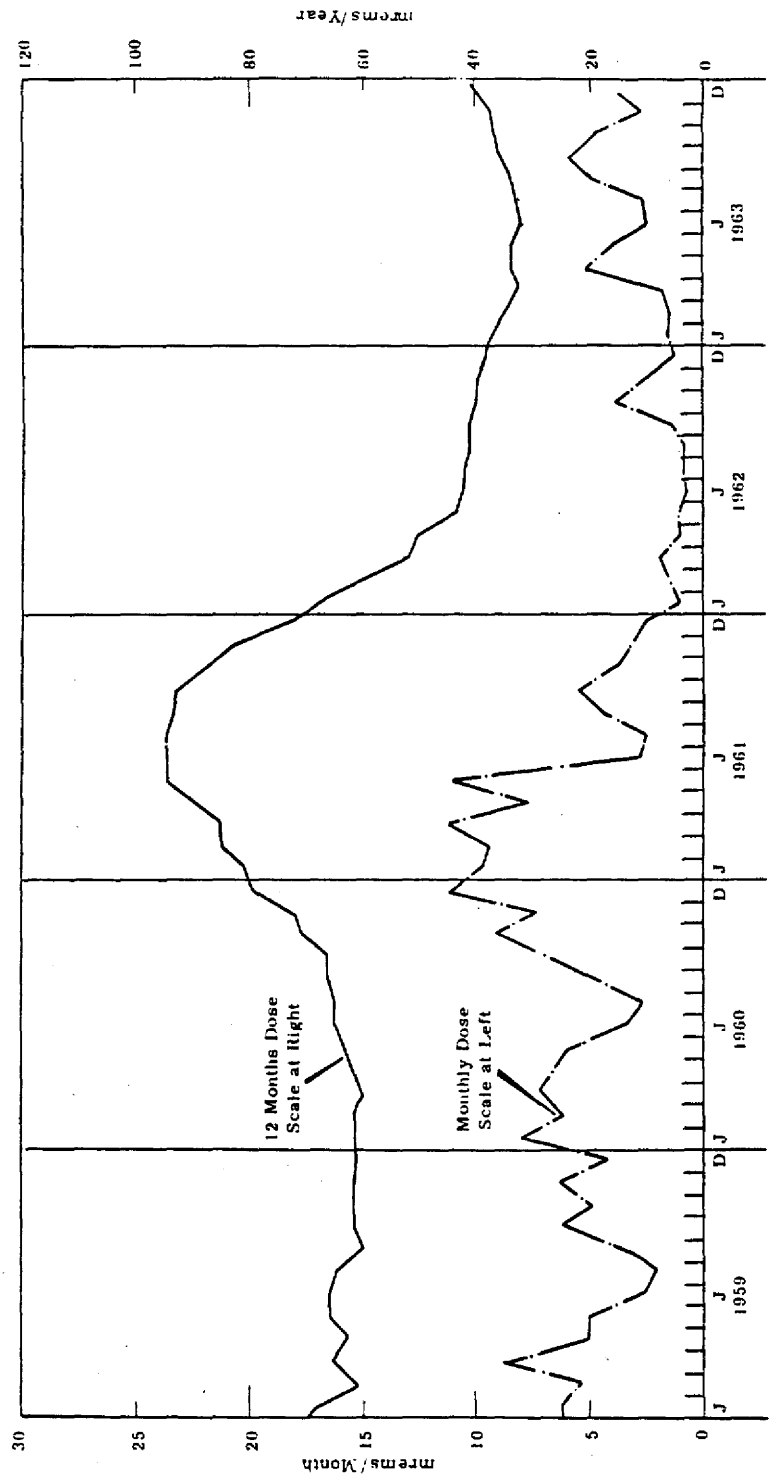

FIGURE 8

Calculated Dose to GI Tract from Pasco Sanitary Water

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between Ringold and Richland are shown in Figure 9. The seasonal variation is affected by the amount of P^{32} released from the reactors, the feeding habits and metabolism of the fish, and flow rate of the river which determines the effective dilution of the reactor effluent. The concentration of P^{32} in whitefish starts to decrease late in the year and, due to cold water and limited feeding, continues to decrease until spring. As the temperature of the river water rises in the spring, the fish eat larger quantities of food organisms that have accumulated P^{32} and this results in an increased deposition of P^{32} in the fish. The trend is reversed in mid-spring by the high flow rates of the Columbia which afford greater dilution of effluent and thus lower concentrations of P^{32} in the food organisms. As the high flows recede in early summer and water temperatures rise further, the P^{32} content in fish again increases and reaches a maximum in late fall. The average concentration of P^{32} in whitefish sampled downstream from the reactors during 1963 was 420 pc/g of flesh, and the sample with the highest concentration contained 2800 pc/g. The annual average Zn^{65} concentration in whitefish was 38 pc/g of flesh and the maximum was 120 pc/g in samples collected at Ringold. If whitefish were eaten at the rate of one meal per week (about 25 lb/year), the intake in 1963 would have been approximately 4.8 μc of P^{32} and 0.43 μc of Zn^{65}. The resulting exposure would have been about 100 mrems to the GI tract, 40 mrems to the total body and 30% of the MPRI for bone.

In order to determine the consumption of locally caught fish more accurately, a number of fishermen were asked to estimate the quantities and kinds of fish they ate each year. This survey was carried out by personnel of the State of Washington, Department of Game. The data obtained thus far show that the individuals who probably ingest the largest amounts of P^{32} are fishermen who claim to eat bass, crappie, perch, and catfish at a frequency of 3 to 5 times a week. This number of fish meals implies an annual consumption of about 90 lb (in contrast with the 25 lb of whitefish used as a reference amount in the preceding paragraph) but the average P^{32} content of the species involved is lower than in the whitefish. An intake of 7 μc of P^{32} during 1963 is estimated for an individual that claimed to eat some 200 meals of fresh fish caught from the Burbank Area.

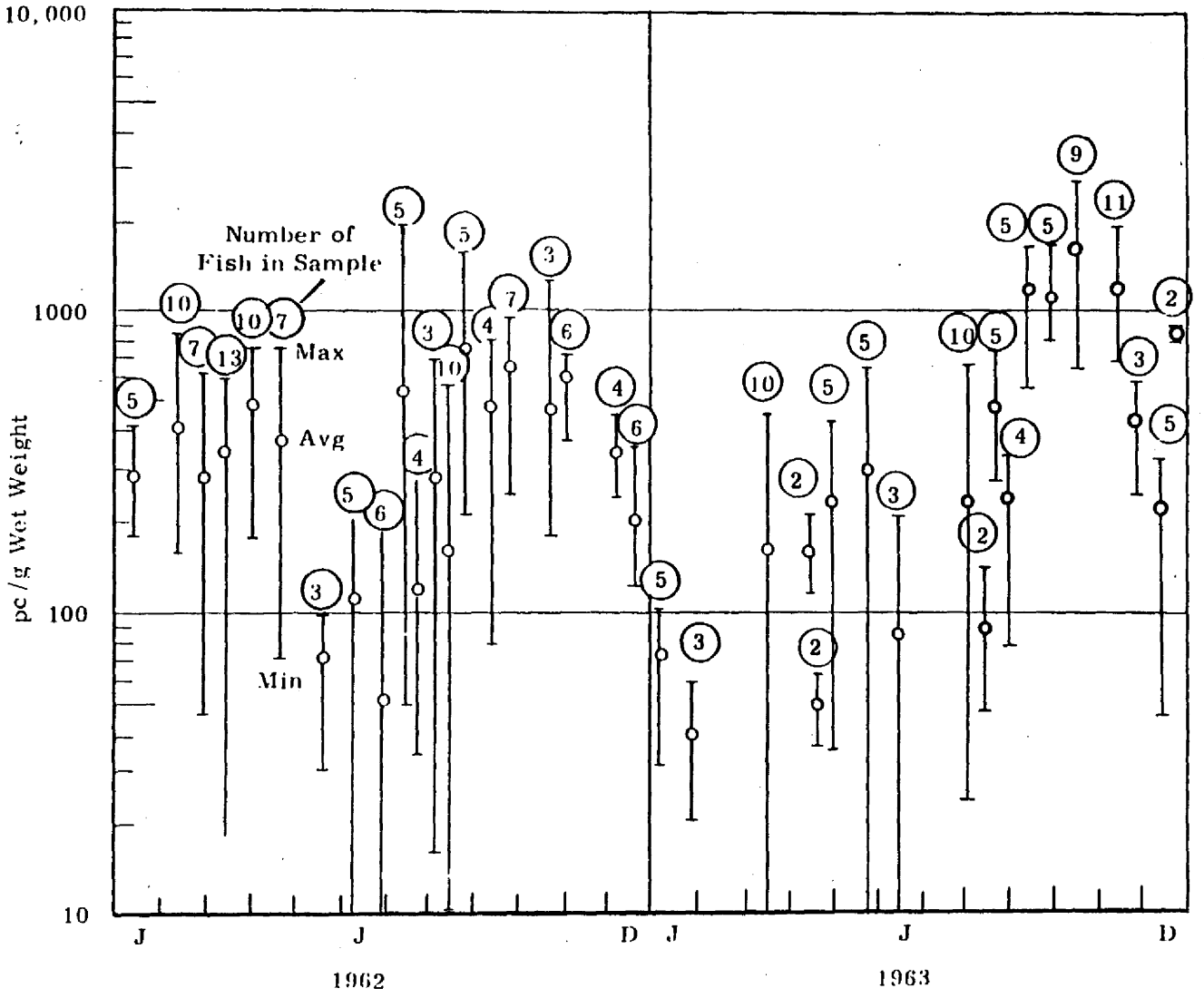

FIGURE 9

P^{32} in Whitefish Caught in Columbia River Between Ringold and Richland

People who eat local fish ingest Zn^{65} along with the P^{32}. The exposure that results from the Zn^{65} is very small but because it is a gamma emitter, its presence in the body can be detected by whole body counting techniques. (Small amounts of P^{32} in the body cannot be measured accurately because P^{32} emits only beta particles.) A few fishermen have been counted in the Hanford Whole Body Counter and the amounts of Zn^{65} detected were much smaller than expected on the basis of their estimated fish consumption. Such results suggest that fishermen tend to over-estimate their fish consumption and, therefore, that calculations of P^{32} intake based on such estimates yield values that are substantially higher than actually occurred.

Migratory waterfowl, such as mallard ducks, Canada geese, etc., that have utilized the Hanford section of the river may also contain P^{32} and Zn^{65}. Hunters from Washington contributed samples from 299 ducks bagged during the 1963 hunting season. Results of radioassay of these samples and of 186 ducks collected from swamps and ponds within the project boundaries, are tabulated in Appendix A, Table 11 and 12. Of all the ducks contributed by hunters, only 22 contained concentrations of P^{32} greater than the detectable level of 50 pc/g of flesh (wet weight) and only one was greater than 500 pc/g (540 pc/g). About one-half of the ducks collected within the project boundary contained detectable amounts of P^{32}, and 37 of these ducks contained greater than 500 pc P^{32}/g. The maximum concentration found was 4800 pc/g of flesh.

D. Radionuclides in Marine Organisms

Zn^{65} and P^{32} are the only radionuclides of reactor effluent origin found in sufficient abundance beyond the mouth of the Columbia River to be of radiological interest. Oysters have been found to contain higher concentrations of Zn^{65} than other common sea food organisms. Concentrations of Zn^{65} and P^{32} measured in oysters grown in the Willapa Bay area are shown in Figure 10, and the analytical results are tabulated in Appendix C, Table 6. The average concentrations in 26 samples (a total of 52 lb) taken periodically throughout the year were 80 pc Zn^{65}/g and 4 pc P^{32}/g.

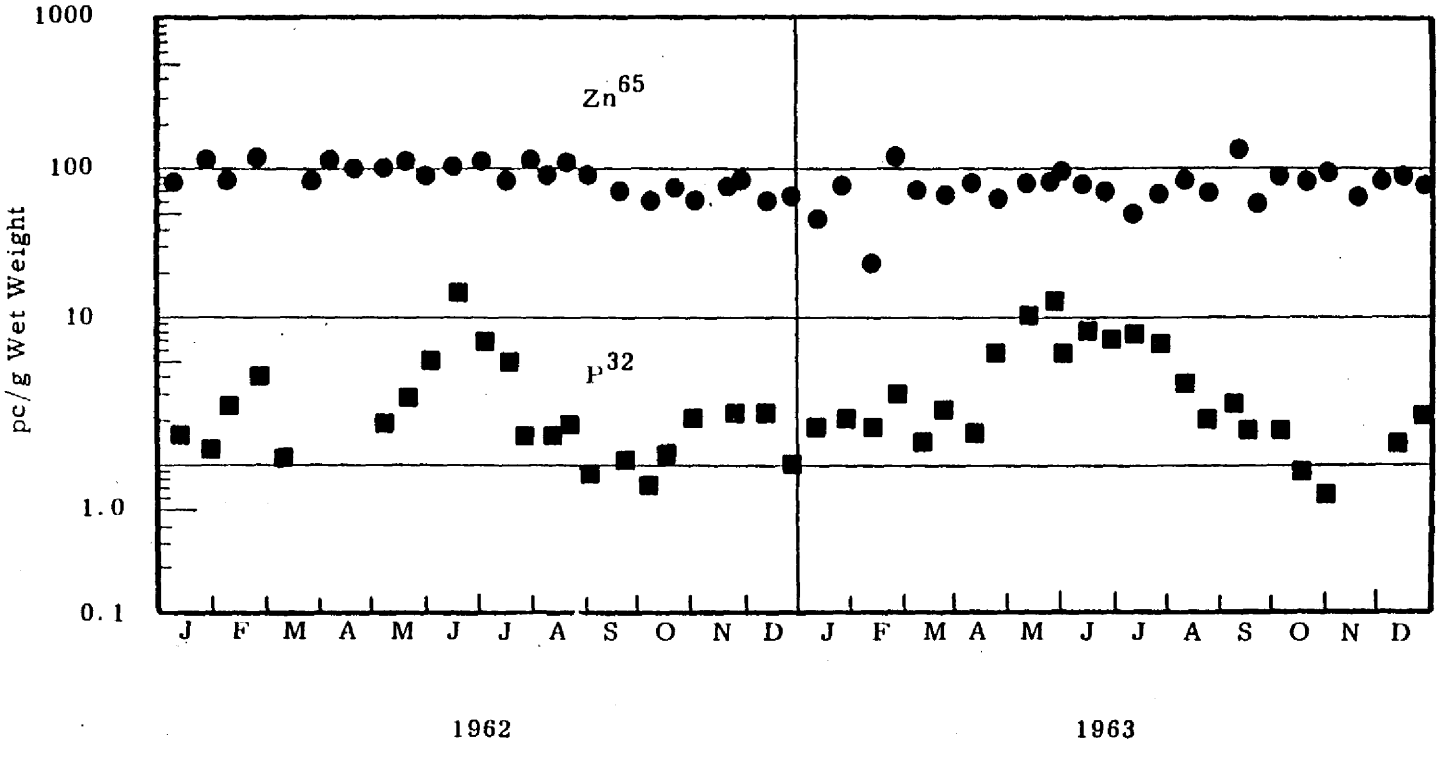

FIGURE 10

Zn^{65} and P^{32} in Willapa Bay Oysters

Consumption of oysters containing these concentrations of Zn^{65} and P^{32} at a sustained rate of one meal per week (1/2 lb) would lead to an annual exposure of about 9 mrems to the GI tract, 6 mrems to the total body, and less than 0.5% of the MPRI for bone.

E. Radionuclides in the Atmosphere

At Hanford, gaseous waste is released to the atmosphere through 200 ft high stacks after removal of some 99% of the radioactive materials present. These radioactive materials are primarily associated with process vessel off-gases from the chemical separations facilities. Under normal operating conditions, the ventilation air from laboratory and reactor buildings contains comparatively minor amounts of radioactive materials.

I^{131} is the radionuclide of principal interest in the separations facilities process off-gases. Measurements for this nuclide are tabulated in Appendix B, Table 2, and average release rates are shown in Figure 11. During 1963 the annual average emission rate of I^{131} from the separations plant stacks was 0.38 curie per day. Monitoring for other specific radioisotopes was discontinued in 1963 because previous measurements have shown insignificant emission rates. Gross beta measurements are now made continuously to detect any change in emission rates of these other radionuclides. The results for the past 2 years are summarized in Table VIII. The fission product recovery facilities operating at Hanford contributed negligible amounts of radionuclides to the environs during 1963. The average emission rate of Sr^{90} from such facilities was less than 0.0018 curie per day.

Measurements of air-borne I^{131} were made routinely at several locations within the Hanford reservation and at several locations adjacent to the plant. Results of these measurements for 1963 are presented in Appendix B, Table 2, and results for the past few years are summarized in Table IX.

TABLE VIII

ANNUAL AVERAGE EMISSION RATES
OF SEVERAL RADIONUCLIDES FROM SEPARATIONS PLANT STACKS

curies/day

Radionuclide	1963	1962	1961
I^{131}	0.38	0.35	0.7
$Zr\text{-}Nb^{95}$	-	0.0024	0.005
Ru^{103}	-	0.0009	0.003
Ru^{106}	-	0.0036	0.005
Ce^{141}	-	0.0002	0.006
Ce^{144}	-	0.015	0.01
Filterable Gross Beta	0.013	-	-

TABLE IX

AVERAGE I^{131} CONCENTRATIONS IN ATMOSPHERE

Units of pc/m^3

Location	Distance from Separation Stacks miles	1963	1962	1961	1960
Benton City	20	0.03	0.08	0.02	0.05
North Richland*	20	-	0.10	0.04	0.04
Richland	23	0.02	0.04	0.02	0.03
Pasco	32	0.02	0.08	0.04	0.02

* The North Richland sampling location was discontinued in October 1963. A new sampling location was installed at the Prosser Barricade which lies in the same direction from the separations areas but is about 6 miles closer.

The four locations listed in Table IX lie within a 45 degree sector southeast to south of the separations centers.

The annual average I^{131} concentrations in air during 1963 returned to the levels observed in 1961 prior to resumption of nuclear testing by the USSR. The long-term average release closely approximated the restrictive local

operation guides (Figure 11) until early September when an unplanned release of I^{131} occurred from a chemical separations facility. Early recognition of the abnormal condition and immediate action successfully retained a major portion of the I^{131} within the plant. The concentration of I^{131} measured in air about the plant perimeter increased temporarily, but this did not significantly affect the longer range annual exposure from inspired air. Measurement of I^{131} in air at locations about the plant perimeter indicated the average concentration during 1963 was less than 0.05 pc/m^3. If such a concentration were sustained in inspired air, the resulting annual dose to the thyroid of the "standard man" would be less than 1 mrem.

F. Radionuclides in Milk and Agricultural Produce

The radioactivity in locally grown agricultural produce can be influenced by deposition of air-borne radionuclides, or by irrigation with water containing reactor effluent radionuclides. Chemical separations facilities are generally considered to be the principal local source of air-borne radionuclides. Under certain condition, ventilation stacks of the reactors or laboratory facilities could possibly become of some small interest. The closest farming area to the separations facilities is about 13 miles away, and under most meteorological conditions this distance affords adequate dilution before the radioactive effluents reach the farming areas.

Most of the irrigated farm land near the Hanford plant uses water from the Yakima River, or from the Columbia River above the project, However, the Ringold farms and the Riverview district west of Pasco, which are about 15 and 30 miles downstream from the reactors, respectively, take water from the Columbia River for irrigation. Some of the reactor effluent radionuclides can be traced through the irrigation water to milk and other farm products. The Ringold farms, approximately 13 miles east of the production areas, involve about 20 people working some 500 acres of land with fruit as their principal product. The Riverview farm area has about 30 families that raise fruit, vegetables, beef, and dairy herds. This area is located about 30 miles southeast of chemical separations plants. Another agricultural area near the project is Benton City, located on the Yakima River about 20 miles directly south of the separations facilities.

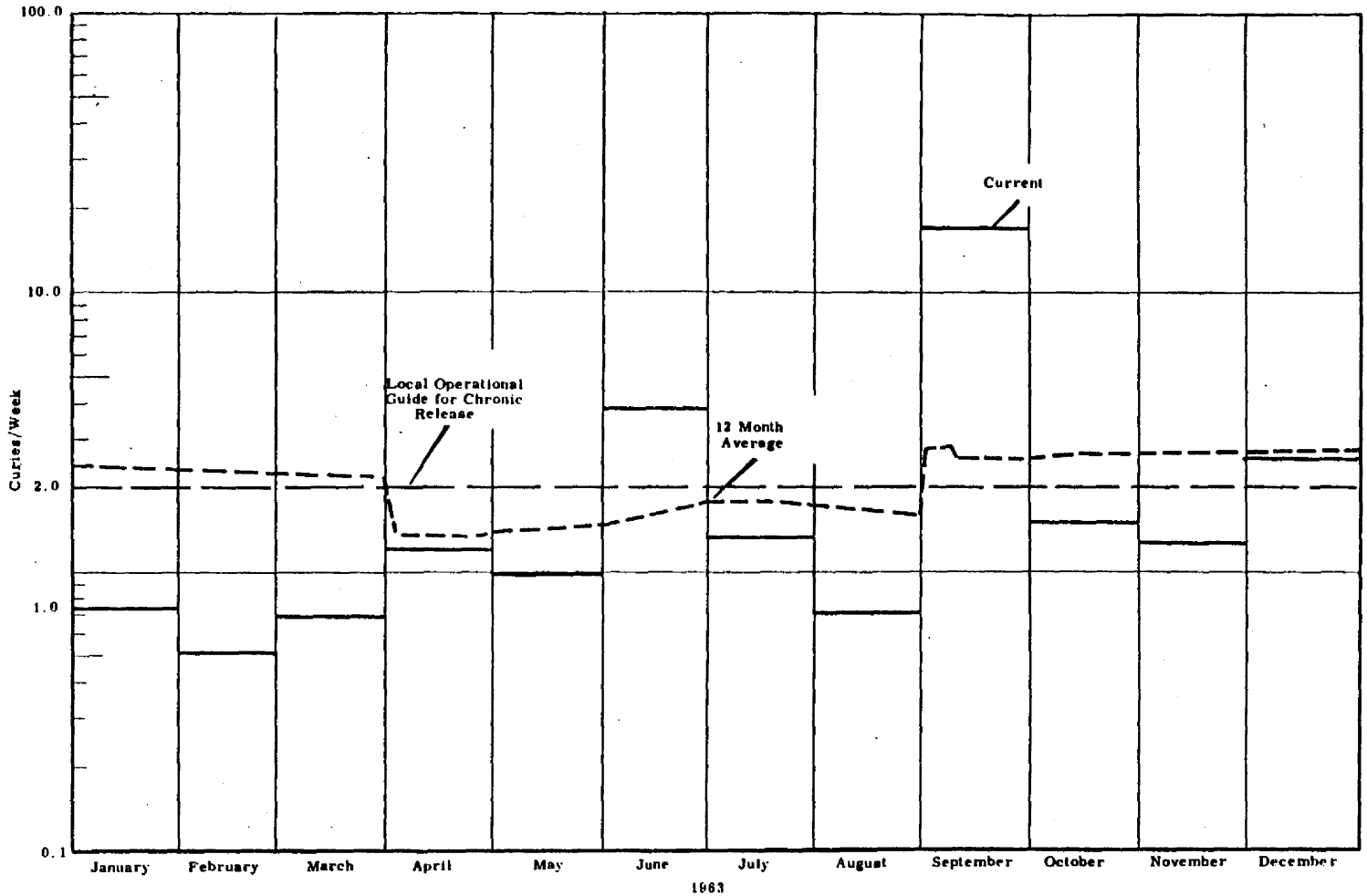

FIGURE 11

Release of I^{131} to the Atmosphere

Surveillance of the milk available to people living near the Hanford plants included samples from local farms and dairies and samples of commercial supplies sold in local stores. The concentrations of radionuclides found in the milk sold by stores was similar to that reported by the U. S. Public Health Service and the Washington State Department of Health.(10) Milk from farms irrigated with water pumped from the Columbia River downstream from the reactors contained P^{32} and Zn^{65} as well as the fission products of fallout origin.

The Sr^{90} concentration in milk known to be of local origin ranged from less than 2 to 21 pc/l as shown in Figure 12. Such values are similar to concentrations found in commercial milk produced in areas that could not be affected by the Hanford plants. The average concentration of Sr^{90} in milk produced in the Hanford environs during 1963 was about 13 pc/l which is among the lowest concentrations in the nation. A temporary increase in Sr^{90} was noted during the spring as a result of the seasonal influx of world-wide fallout. Concentrations of Sr^{89} and Cs^{137} in milk analyzed at Hanford were generally below the detection level of 4 pc Sr^{89}/l and 30 pc Cs^{137}/l. World-wide fallout is the principal source of these radionuclides in milk.

Measurements for I^{131} were made on all milk samples collected in 1963. The results of these measurements are illustrated in Figure 13. During the early part of the year, I^{131} concentrations were well below 10 pc/l and were following a generally decreasing trend. The seasonal influx of world-wide fallout, which began in May and reached a peak in June, resulted in a maximum concentration of 84 pc/l on June 19, 1963. Activity levels then decreased rapidly to levels of 10 pc/l or less.

In early September, I^{131} concentrations in milk again increased as a result of the inadvertent release of I^{131} from a separations plant previously described. The milk sampling program was increased in September and October and the maximum concentration actually measured was 140 pc I^{131}/l in a sample collected in the West Richland-Benton City area. It was estimated that the highest thyroid dose resulting from the I^{131} release was probably received by a small child residing at the farm where the maximum milk

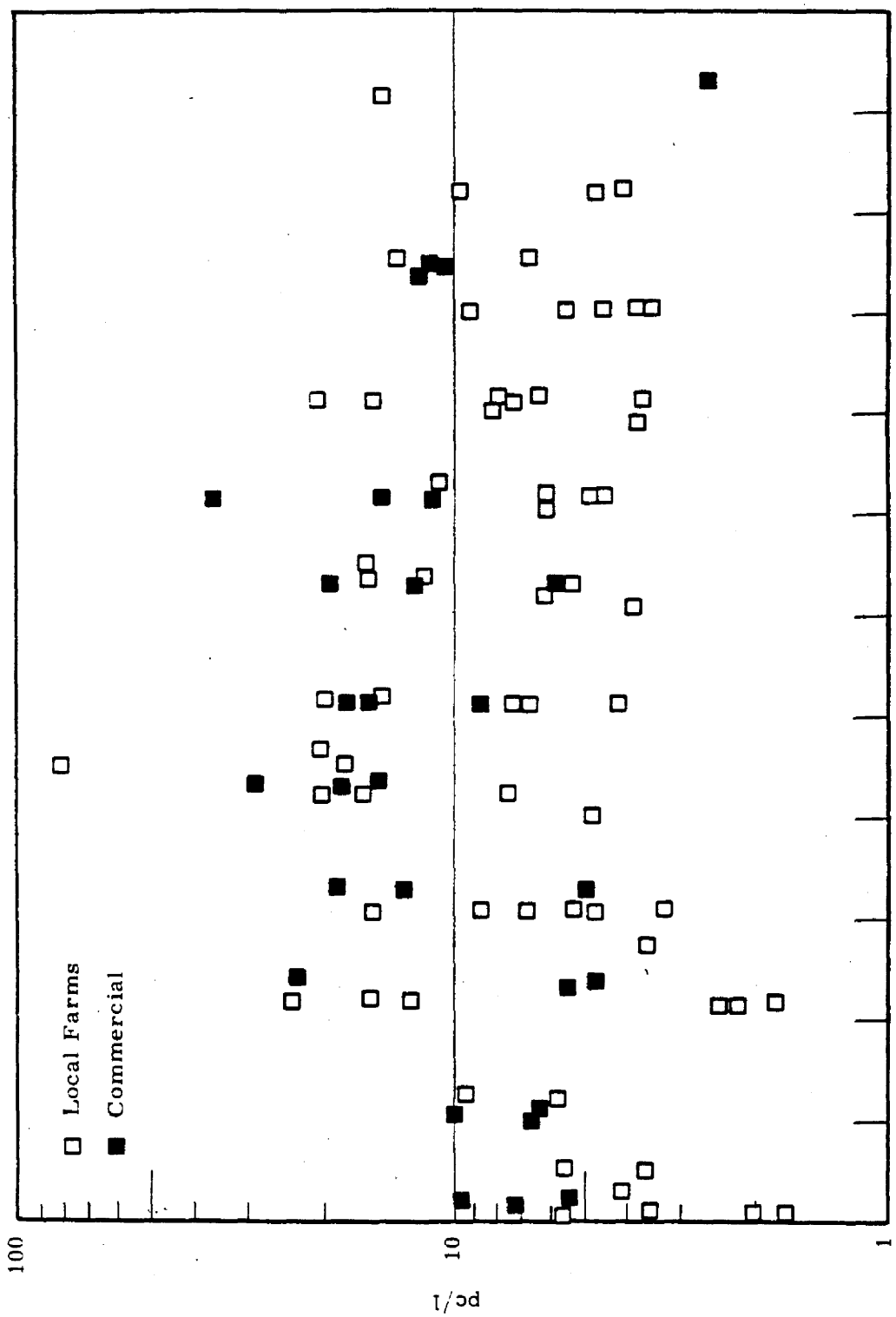

FIGURE 12

Sr^{90} in Locally Produced Milk

AEC-GE RICHLAND, WASH.

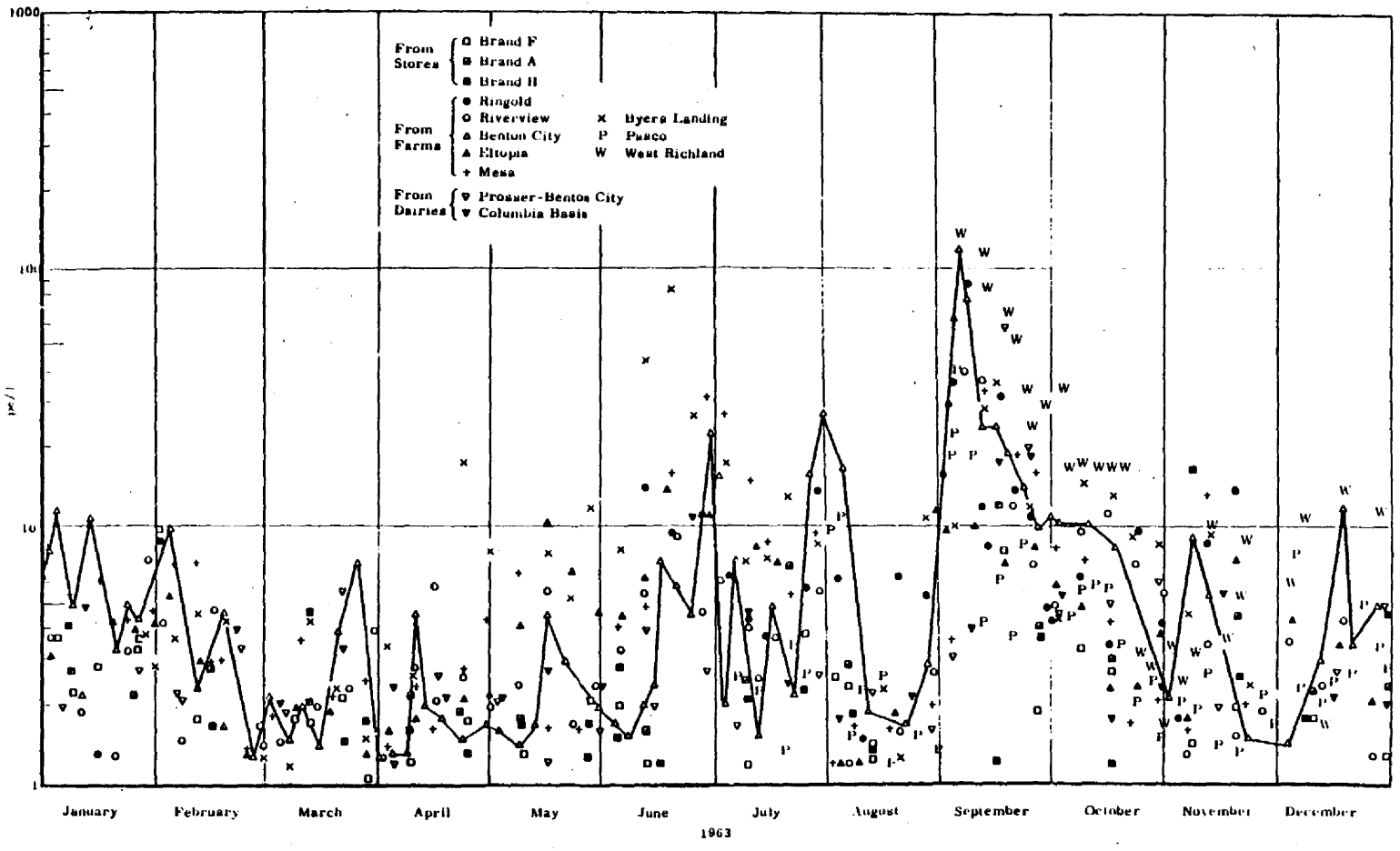

FIGURE 13

I^{131} in Locally Produced Milk

results were obtained. By assuming a 4 gram thyroid for a 4 year old child and consumption of 1 liter of milk per day produced at the farm, it was estimated that the maximum thyroid dose during the 3 month period following the incident did not exceed 30 mrems. A whole body counter measurement of this child's thyroid in October 1963 confirmed the estimated thyroid burden of I^{131}. The value of 30 mrems can be compared with the FRC Radiation Protection Guide for individuals of 1500 mrems per year.

Columbia River water removed below the reactors for irrigation is a source of P^{32} and Zn^{65} in milk at dairy farms in the Riverview and Ringold areas (Figures 14 and 15). The average concentrations of Zn^{65} in milk from the Riverview-Ringold area during 1963 was about 600 pc/l, and the concentration of P^{32} was about 800 pc/l. Zn^{65} or P^{32} are usually not detected in milk that is distributed through commercial outlets in the Tri-City area because such milk is not usually obtained from areas irrigated with water obtained from the Columbia River below the reactors.

At a consumption rate of 1 liter of milk per day the "fallout" radionuclides would contribute an average annual dose of less than 1 mrem to the GI tract, about 8 mrems to the total body, and about 7% of the FRC rate of intake guide for bone.* Those residents who drink milk obtained locally from the Ringold and Riverview areas would receive some additional exposure from P^{32} and Zn^{65} amounting to about 8 mrems to the GI tract, 3 mrems to the total body, and about 2% of the MPRI for bone. Data concerning concentrations of radionuclides in milk are continued in Appendix C, Table 1.

Analyses of miscellaneous fresh produce purchased during the 1963 growing season from local farms and markets substantiated prior experience that only small quantities of radionuclides are present in locally grown produce under normal plant operating conditions. Results of measurements on farm produce are tabulated in Appendix C, Tables 3, 4, and 5.

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* The Federal Radiation Council does not consider fallout from the testing of weapons to be from "normal peacetime operations" and thus subject to Radiation Protection Guides applicable to industry.

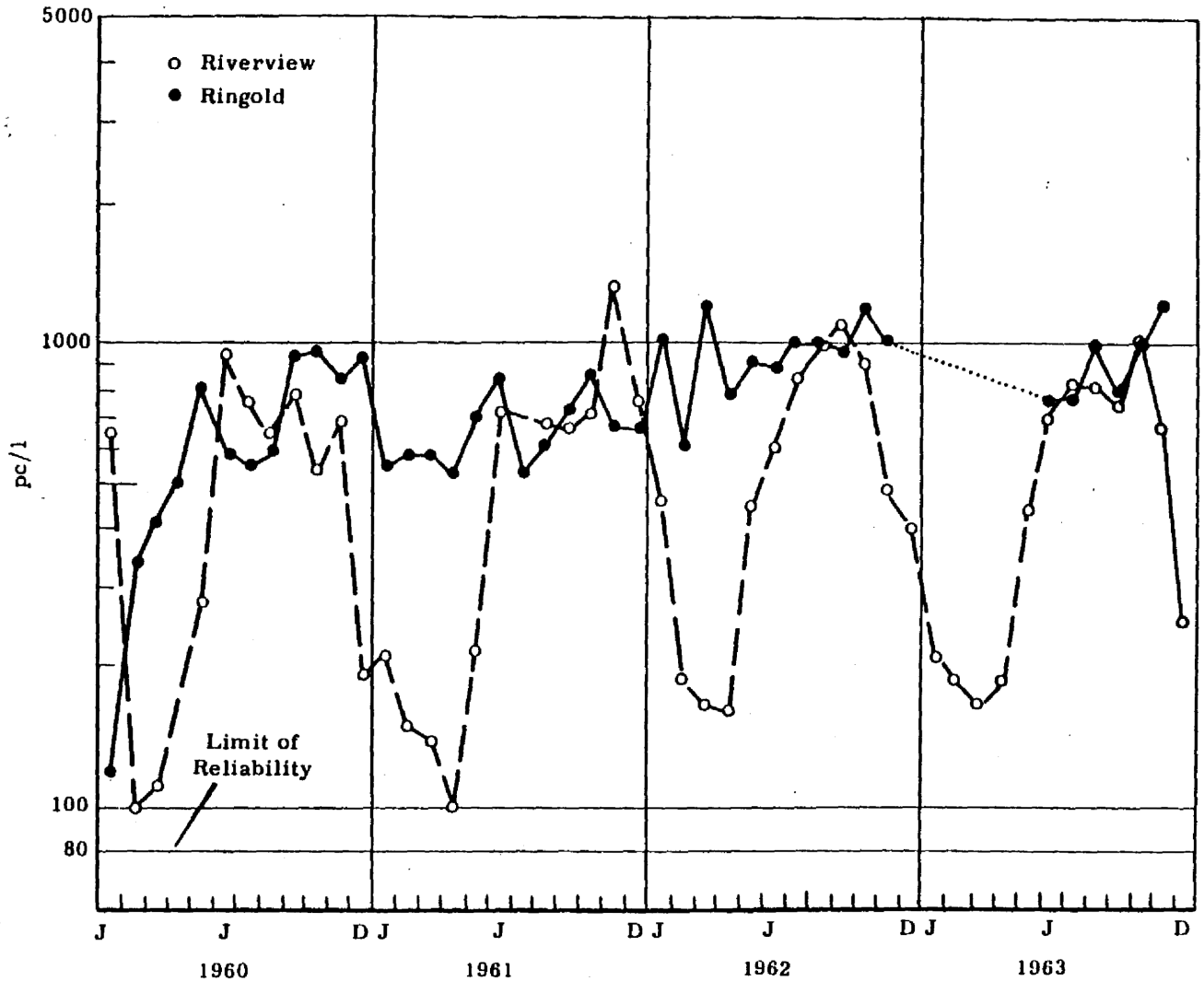

FIGURE 14

Zn^{65} in Locally Produced Milk

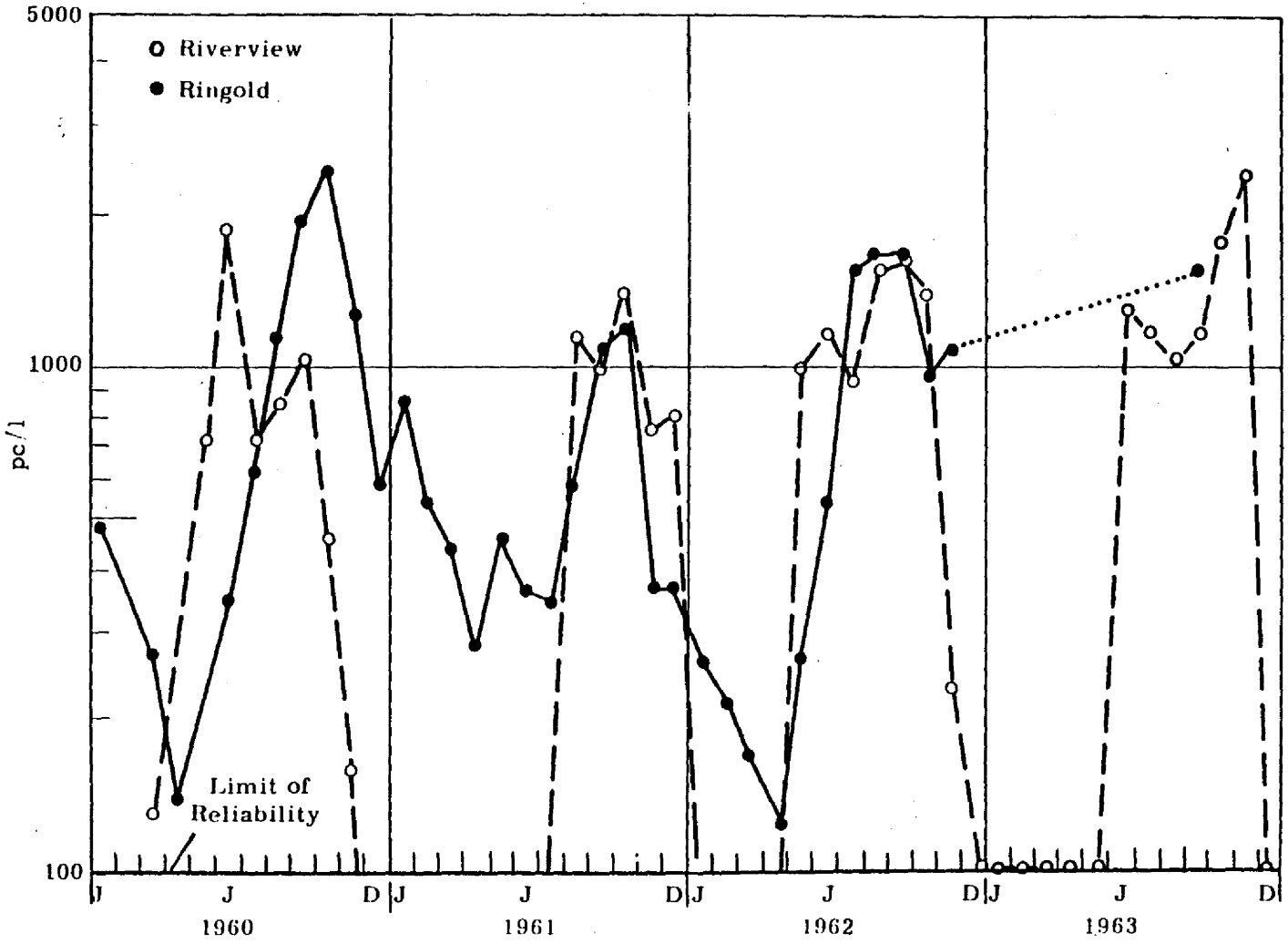

FIGURE 15

P^{32} in Locally Produced Milk

The average concentration of I^{131} measured on samples of leafy vegetables collected from local farms and vegetable markets during the period of May through September was less than or approximately equivalent to the detection level of 0.05 pc/g. Considering a consumption rate of 100 g of leafy vegetables per day throughout the 5 month growing season, the average annual intake from local vegetables would be about 750 pc I^{131}. Such an intake implies an annual exposure of about 1 mrem to the thyroid of a "standard man".

G. Concentrations of I^{131} in Cattle Thyroids

The collection of thyroids from cattle slaughtered at Pasco was initiated in 1960 and then broadened in 1962 to include collection of thyroids of cattle slaughtered at Moses Lake, Toppenish, Walla Walla, and Wenatchee. Since the concentration of I^{131} in bovine thyroids is about 2 orders of magnitude higher than that in the pasture grass or in milk, it is advantageous to use thyroid measurements to follow probable trends in concentrations of I^{131} in milk and farm produce when the levels in milk and vegetables are too low for practical measurement. The sensitivity of cattle thyroids is evident from the significant increase in I^{131} concentrations observed for a short period in September following the unplanned release of I^{131} from one of the chemical separations facilities (Figure 16). The maximum concentration, however, was only 62 pc/g which was considerably less than levels observed in late 1962 and early 1963 as a result of I^{131} from fallout.

Data obtained from the cattle thyroid program for 1963 are presented in Appendix B, Table 4.

H. Radioactive Particulates in the Atmosphere

Air sampling stations are maintained at several locations within the Hanford reservation and at several sites throughout the Pacific Northwest. Sample filters are changed weekly by cooperating agencies at Seattle, Spokane, Walla Walla, and Yakima in Washington; Meacham and Klamath Falls in Oregon; Boise and Lewiston in Idaho; and Great Falls, Montana. These filters are sent to Hanford where they are analyzed for total beta activity. Individual

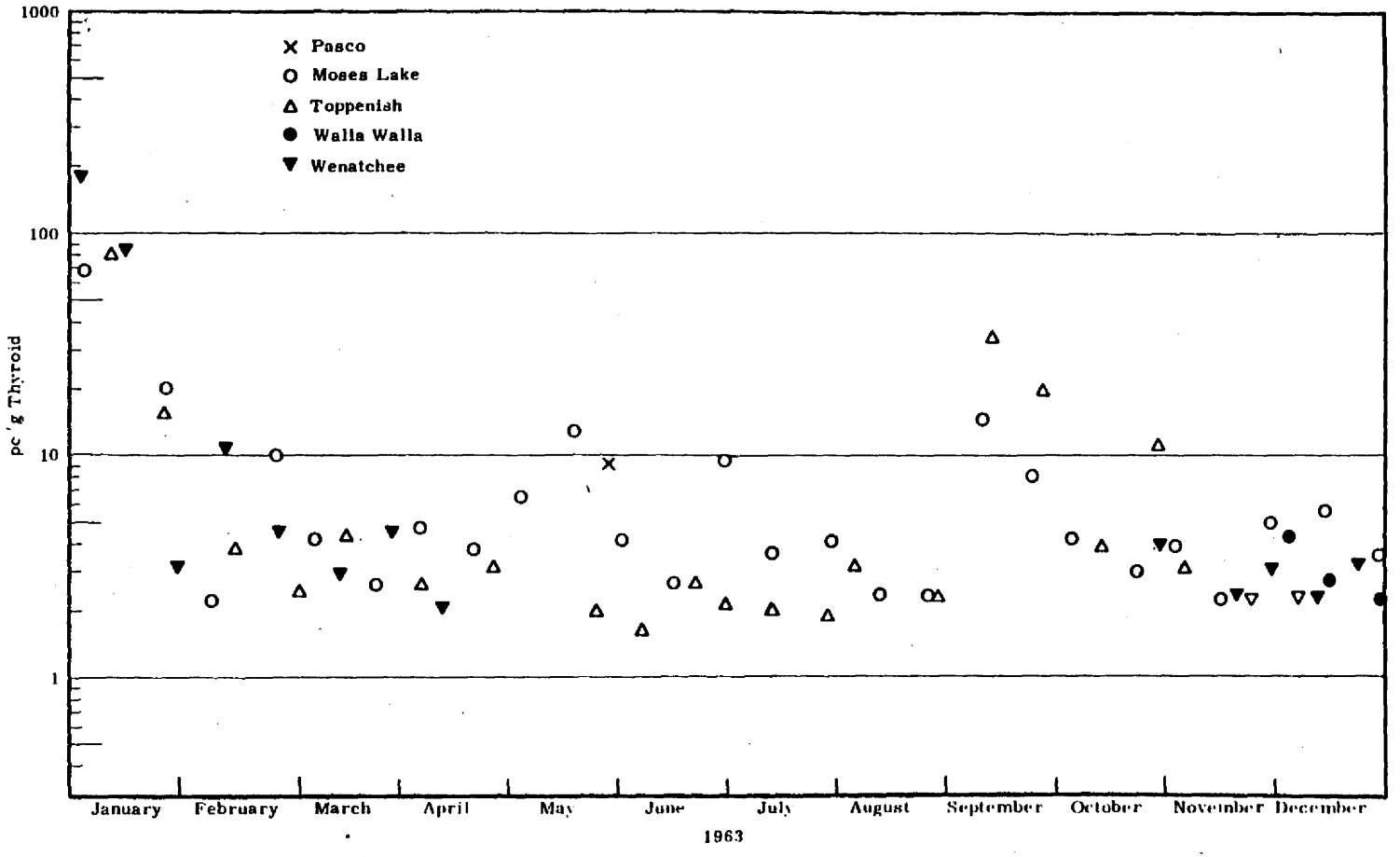

FIGURE 16
Average Concentrations of I^{131} in Beef Cattle Thyroids

measurement results are tabulated in Appendix B, Table 1. The concentrations of beta emitters in air, filtered at several of the sampling locations, during the past 3 years are shown in Figure 17. The geographical locations of these sampling stations are also shown.

During the early part of 1963, the activity observed on air filters remained at nearly the level measured following USSR nuclear testing in the fall of 1962. Two peak activity periods occurred, one in February and one in May indicating an influx of world-wide fallout. Analysis of the May activity, the highest since the fall of 1961, indicated the material was approximately 1 year old. In August a very rapid decline in concentrations occurred and by October the level was about 1 pc β/m^3.

Results of air filter samples are not used in estimating exposure but serve to illustrate the trends in atmospheric contamination. Sudden changes in concentrations are used to signal the need for shifted emphasis in other portions of the environmental monitoring program related to atmospheric contamination.

I. External Radiation

Measurements with ionization chambers stationed above the ground and submerged in the Columbia River were used to estimate the combined exposure from external sources in the vicinity of the Hanford project. Measurements over the ground indicated that the annual exposure for 1963 was about 170 mr, essentially the same as measured during 1962. Virtually all of this radiation originates from natural background and world-wide fallout from nuclear testing and any additional contribution from Hanford sources is not readily discernible. Background measurements were relatively low during the first part of the year, and then increased during the latter half of the year. Measurements of external radiation in 1961, 1962, and 1963 are shown in Figure 18 and are tabulated in Appendix D, Table 1.

Immersion dose measurements were obtained with pocket-type ionization chambers submerged 2 to 5 feet below the surface of the Columbia River. Exposure rates in the river are higher than those measured over land

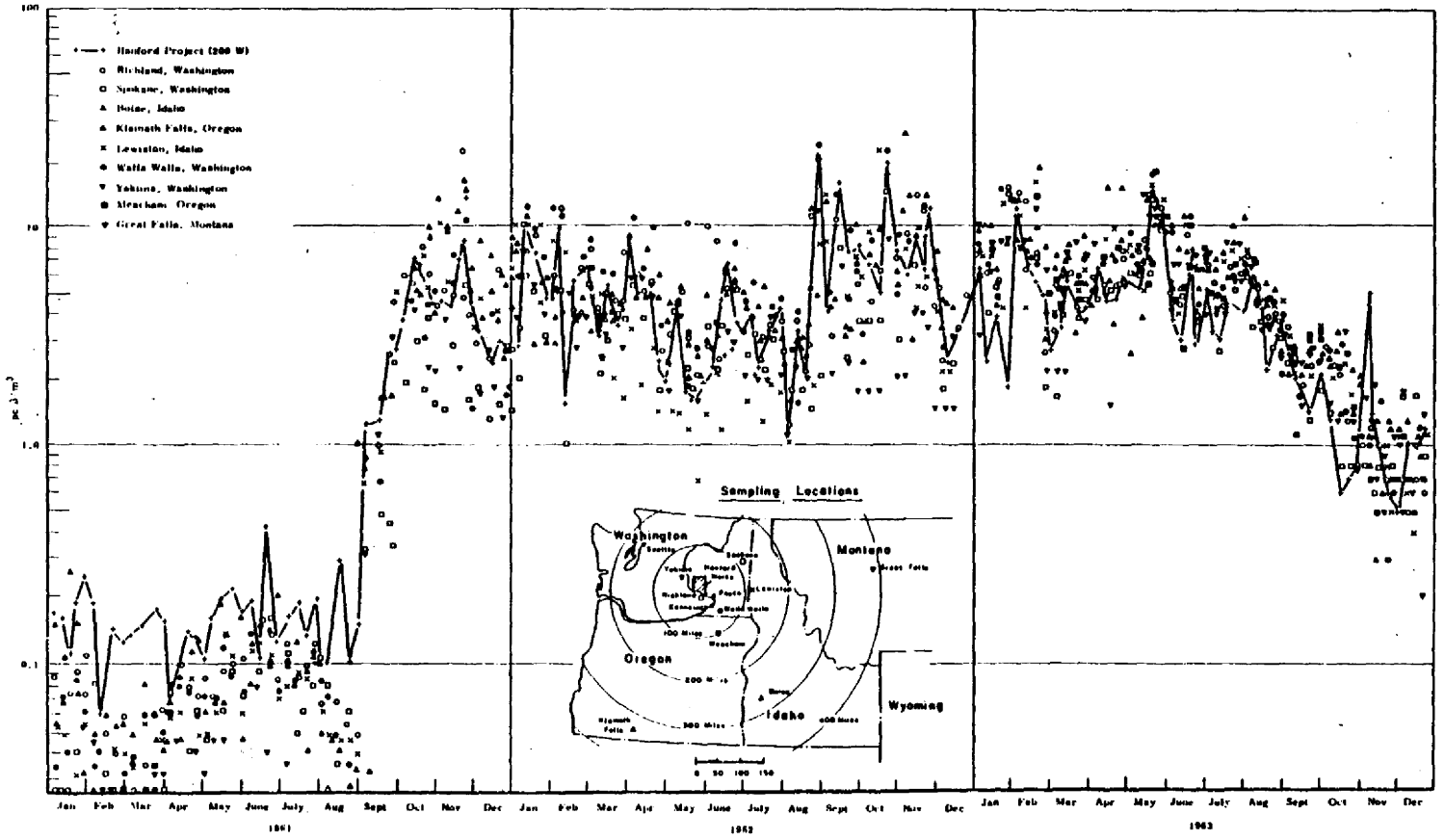

FIGURE 17

Activity on Filters from Several Northwestern United States Sampling Stations

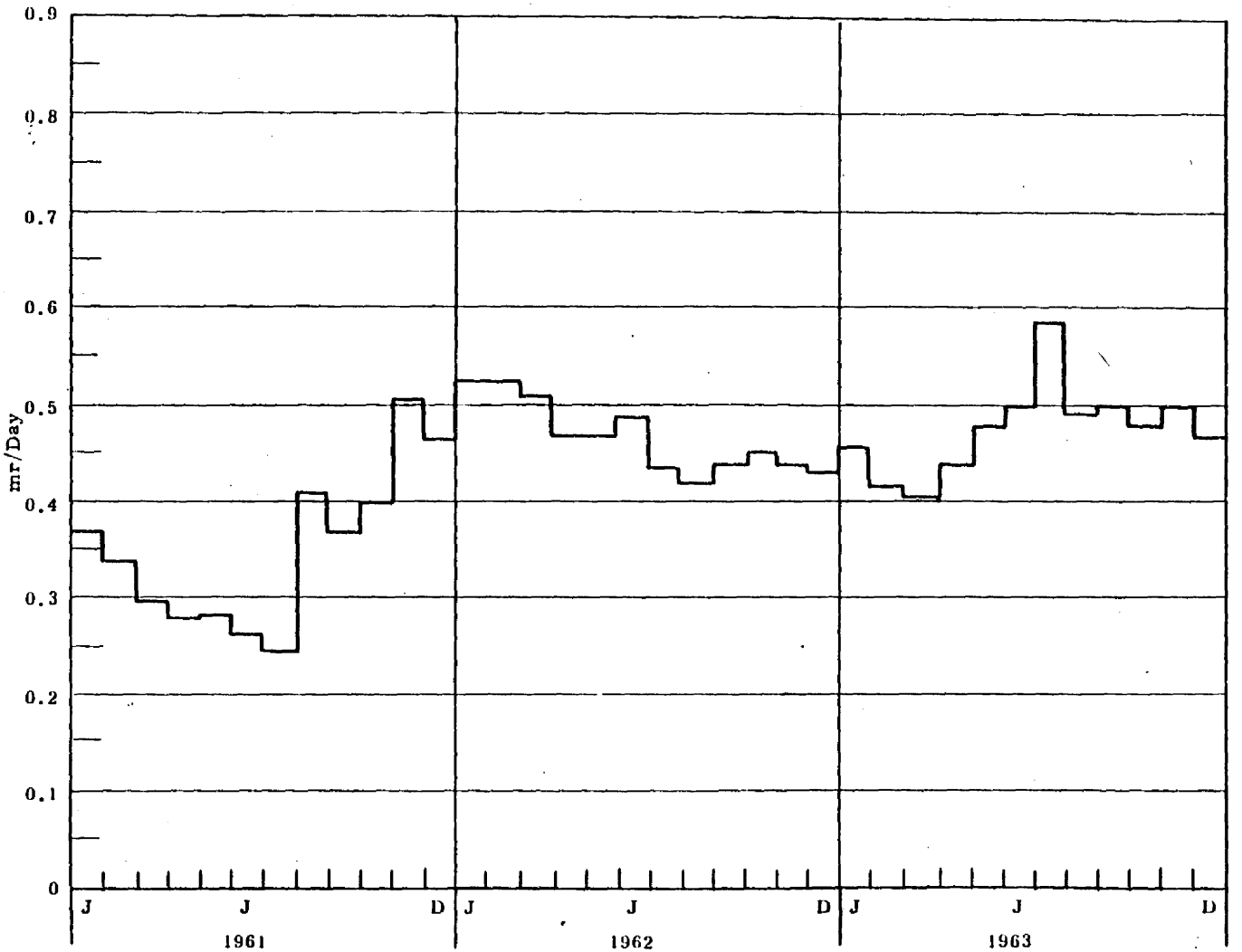

FIGURE 18

External Dose Rate as Measured at Hanford External Dose Test Location

because of the presence of gamma emitters, especially Na^{24}, from reactor effluent. Near Richland and Pasco the average dose rates measured in the river during the months of April through October were about 2 and 1.5 mr per day, respectively. Further upstream near the laboratories area the dose rate was 3 mr per day. A person swimming or boating in the river for 240 hours during the year would receive about 20 mr total body exposure in the vicinity of Richland and about 15 mr near Pasco. Measurements of immersion dose are shown in Appendix D, Table 2.

At the river shoreline radiation measurements indicated the dose rate was about 0.25 mr/hour from radionuclides deposited with debris and in the mud and sand by the fluctuating water level. An ardent fisherman spending 6 hours per week, 8 months of the year, along the river bank in the vicinity of Richland would receive an annual whole body exposure of about 50 mr.

J. Radioactive Wastes Released to Ground

Liquid wastes from the Chemical Separations areas are routed to various facilities dependent upon their burden of radionuclides. High level wastes, normally containing concentrations greater than 100 $\mu c/cc$, are stored in concrete tanks lined with steel. Intermediate level wastes, ordinarily containing concentrations in the range of 5×10^{-5} $\mu c/cc$ to 100 $\mu c/cc$, are sent to underground "cribs" from which they percolate into the soil. Low level wastes, usually containing less than 5×10^{-5} $\mu c/cc$, are sent to depressions in the ground where surface ponds or "swamps" have been formed as a result of the continuous addition of relatively large volumes. The areas selected for liquid waste disposal have soil with good ion exchange capacity and depths of 150 to 350 feet to ground water.

One important objective in the management of wastes placed in the ground is the prevention of radiologically important radionuclides from reaching the ground water in quantities that could ultimately cause significant human exposure should they migrate to the Columbia River. For this reason wells have been drilled in and around crib and tank storage areas to detect any leaks in the tanks

and for measuring radionuclides that have reached the ground water. Virtually all of the radionuclides present in the ground water have been introduced with liquids sent to the cribs.

The quantity of radioactive materials sent to ground during 1963 (excluding tritium and the materials sent to the storage tanks) was about 36,000 curies. This did not significantly change the historical total which is estimated to be 2.6×10^6 curies. Because of radioactive decay, the current total in the ground is estimated as 2.6×10^5 curies. In order of abundance, the bulk of this material is Ru^{106}, Cs^{137}, and Sr^{90}. Figure 19 shows the probable extent and concentration of radioactive materials (excluding tritium) in the ground water.(11)

The detectable beta contamination (not including tritium) in the ground water beneath the 200-W Area was less extensive in 1963 than in previous years. This resulted because of a reduction in the amount of contaminants discharged to ground, radioactive decay, and further dilution in the ground water.

A substantial amount of tritium has been sent to the ground with the intermediate level liquid wastes from the separations plants. Figure 20 shows the probable extent and concentration of tritium in the ground water in December, 1963.(11) In all probability some tritium and Ru^{106} originating at the chemical processing areas is now entering the Columbia River. However, the contribution of these nuclides is too small to be detectable in the river water and any exposure from them is negligible.

III. RADIATION EXPOSURE

The total radiation dose that is received from environmental sources differs substantially between individuals because their food and beverages come from various supplies, because the kinds and quantities consumed are subject to individual preference, because some people do more swimming, fishing, and boating than others, and because of other personal habits. These inherent variations between individuals require a somewhat subjective approach to the question of probable total exposure in relation to various limits.

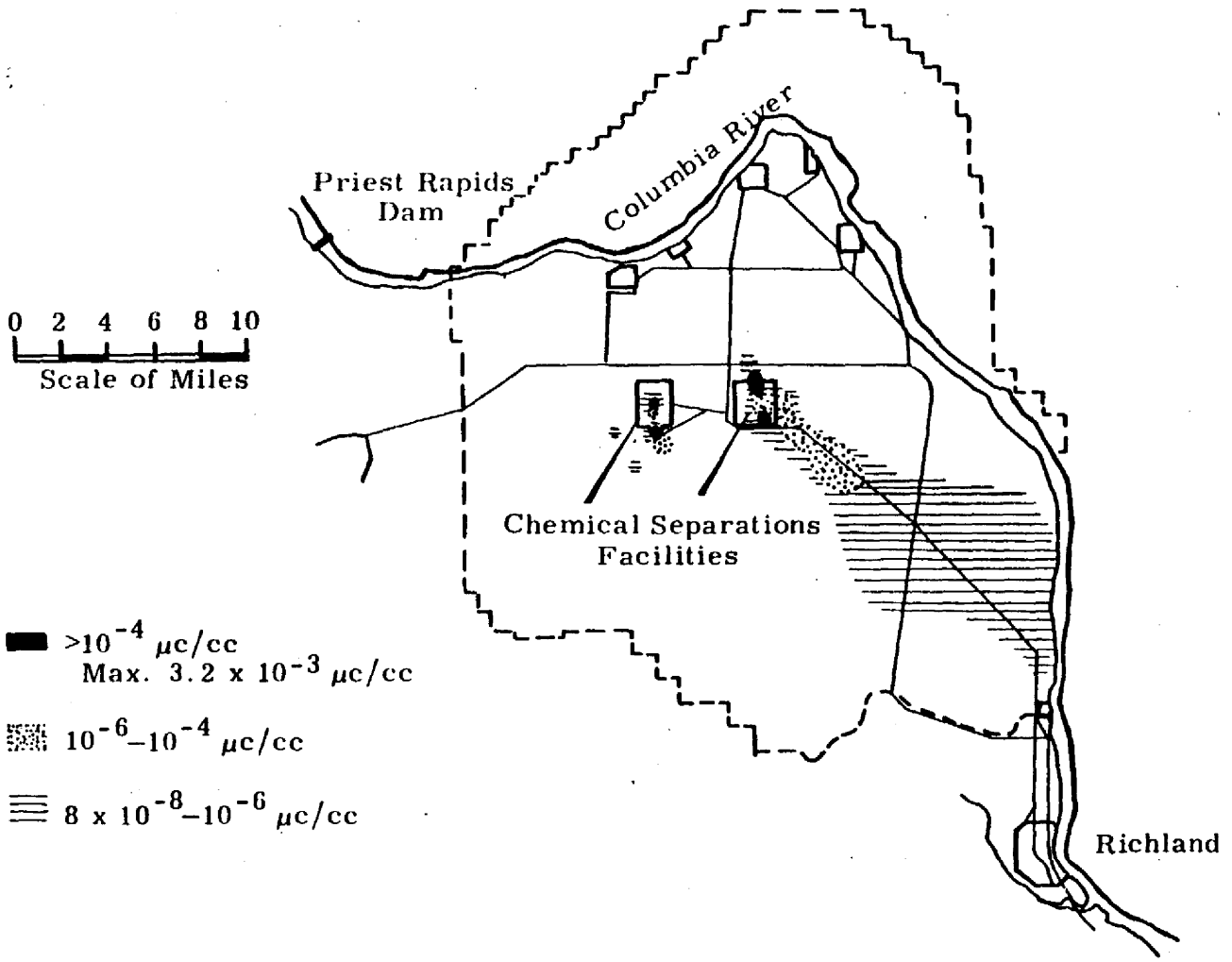

FIGURE 19

Probable Extent of Beta Emitters in Ground Water, 1963

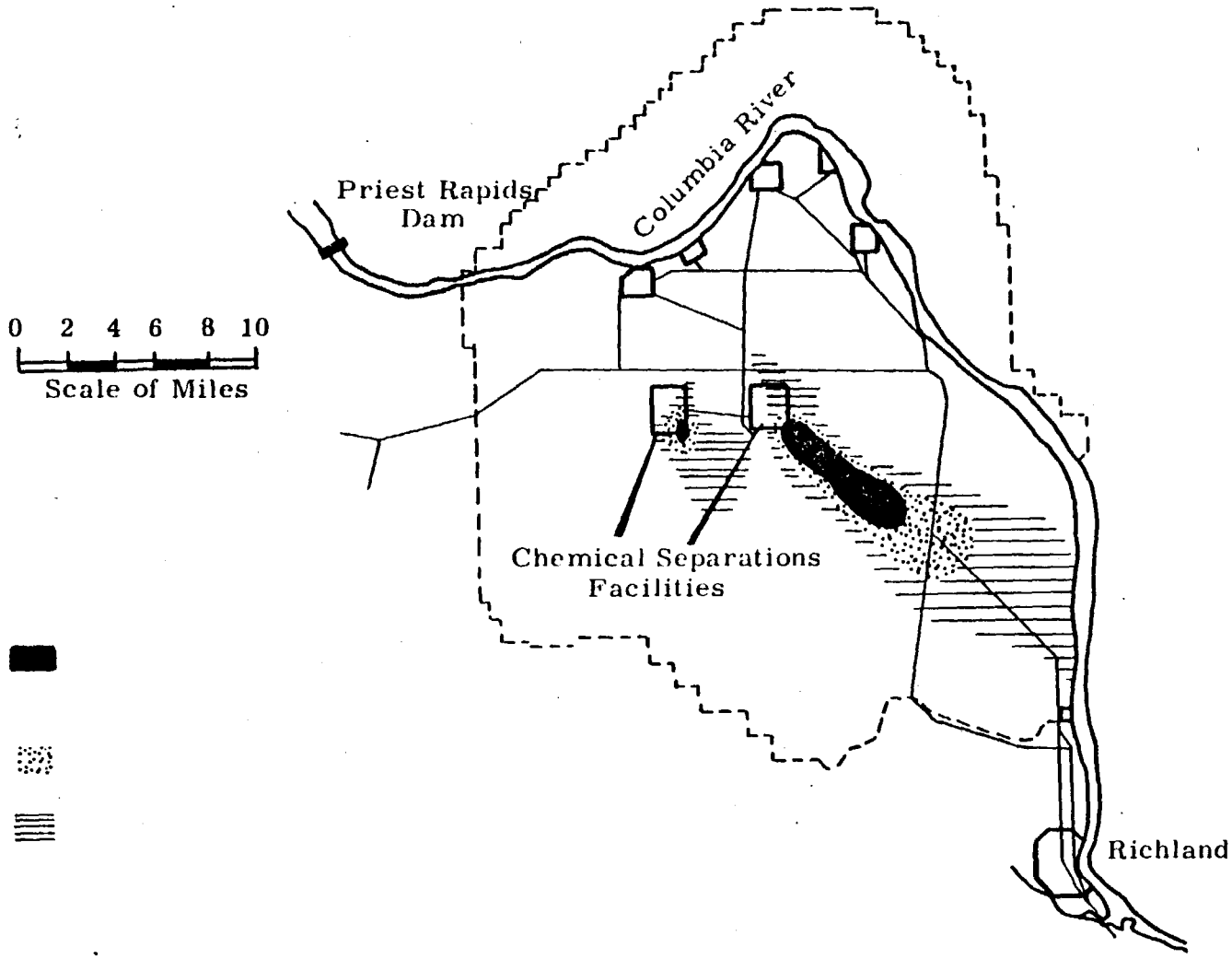

FIGURE 20

Probable Extent of Tritium in Ground Water, 1963

ERRATA

In Figure 20, page 46, of HW-80991 the following call-outs should be added to the three shaded areas:


$> 10^{-4}$ μcurie/cm^3, maximum, 1 μcurie/cm^3


5×10^{-5} to 10^{-4} μcurie/cm^3


1×10^{-5} to 5×10^{-5} μcurie/cm^3

The Federal Radiation Council has provided two sets of guides against which exposures from environmental sources can be judged, viz. one for the individuals that receive the greatest exposure, the other for the average exposure received by an exposed population (taken as one-third that set for individuals). For the Hanford environs, possible exposures from the various sources described in the preceding sections have been combined in two ways to allow comparisons with both the individual and population guides. In one case a hypothetical, but plausible, individual has been assigned dietary and other habits that would result in what would seem to be the greatest rational exposure. As a second case, an exposure has been estimated for the "average" Tri-City resident. Several hundreds (perhaps a few thousands) of people receive more exposure than calculated for the "average" Tri-City resident but very few, (and quite possibly none) receive as much as that calculated for the "maximum" individual. Included in the intermediate group are the families that subsist largely on foodstuffs produced on farms irrigated with water taken from the Columbia River downstream from the plants.

A. The Maximum Individual

Attempts are being made to identify the individuals that actually receive the greatest exposure. Such individuals are undoubtedly persons that frequently eat fish caught locally in the Columbia River and produce grown on farms irrigated with Columbia River water. During the past 2 years, over 600 fishermen have been questioned by employees of the State of Washington Department of Game on their consumption of fish. The greatest consumption reported was about 200 meals per year, consisting dominantly of crappie, perch, bass, catfish, caught near Burbank (Figure 2). On the basis of radiochemical analyses of such fish caught in this area, the intake of P^{32} for this individual during 1963 would have amounted to about 7 μc, (about 45% of the NCRP limit). Whether the individual actually ate that much fish is not confirmed. Some other persons reporting unusually high consumption of local fish have been counted in the Whole Body Counter and contained far less Zn^{65} than predicted on the basis of their estimates of the quantities of fish eaten.

The reported consumption of 200 meals of local fish per year is used as a basis for calculating the maximum intake of radionuclides from this source. This same individual is also assumed to consume each day over 2 qts of water from the Pasco system, and about 1 qt of milk, 1/2 lb of beef, and nearly 1/2 lb of fresh leafy vegetables (in season), all produced on irrigated farms of the Riverview District. The composite exposure from these sources is illustrated in Figures 21, 22, 23, and 24. They amount to about 15% of the appropriate limit for the GI tract, 50% of the limit for the bone, 1% of the limit for the thyroid, and 25% of the limit for the total body. The estimated exposure to the total body includes an increment of 50 mr received from the river bank while catching the fish. It also includes a contribution from ingested Sr^{90} that is unrealistically high (20 mrems) in relation to 1 year's intake, because it assumes an accumulation of Sr^{90} in the body that would only be gained over several decades.

The maximum thyroid dose is postulated to have occurred in a small child, rather than an adult, because of the relatively small mass (2 g versus 20 g for an adult) in which the ingested I^{131} accumulates. On the basis of a daily intake of 1 liter of milk from a farm of the Riverview District, 0.8 liter of water from the Pasco system, and 50 g of fresh leafy vegetables, the intake of I^{131} for the year is estimated at about 6700 pc which would deliver a dose of about 115 mrems–about 7.5% of Radiation Protection Guide for individuals.

B. The Average Tri-City Resident

The vast majority of people who live in Richland, Pasco, and Kennewick obtain their food from local stores (rather than directly from farms) and do not eat fish caught from the Columbia River. The principal sources of radionuclides to these people are world-wide fallout (present to some extent in nearly all foodstuffs throughout the country) and drinking water pumped from the Columbia River.

The contribution from fallout is almost entirely associated with Sr^{90} and I^{131} and is assumed to be the same for all three cities. The Sr^{90} intake is estimated from dietary surveys made elsewhere in the United States and reported by the Federal Radiation Council[5] but adjusted on the basis of the Sr^{90}

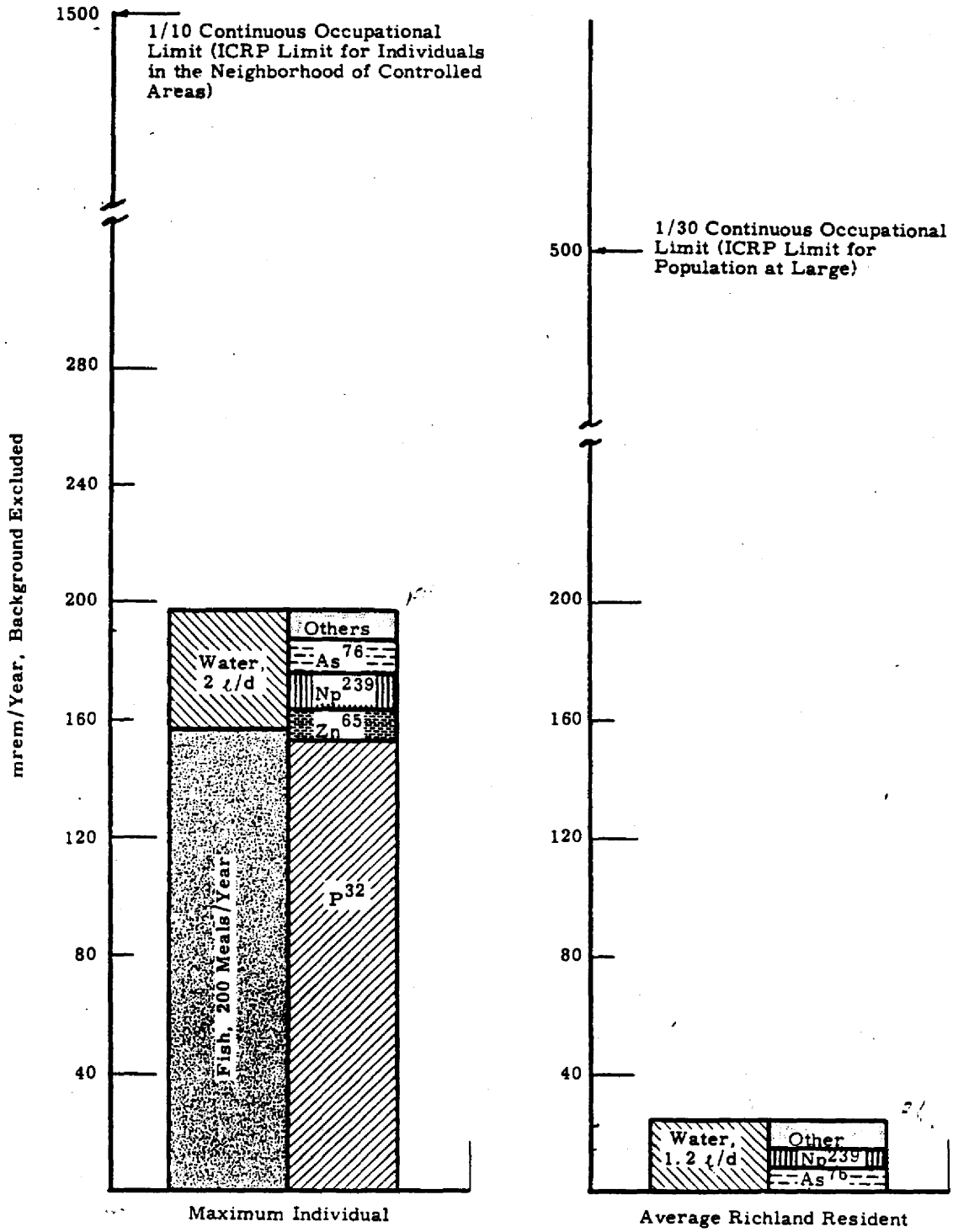

FIGURE 21

Calculated Dose to the GI Tract, 1963

AEC-GE RICHLAND, WASH.

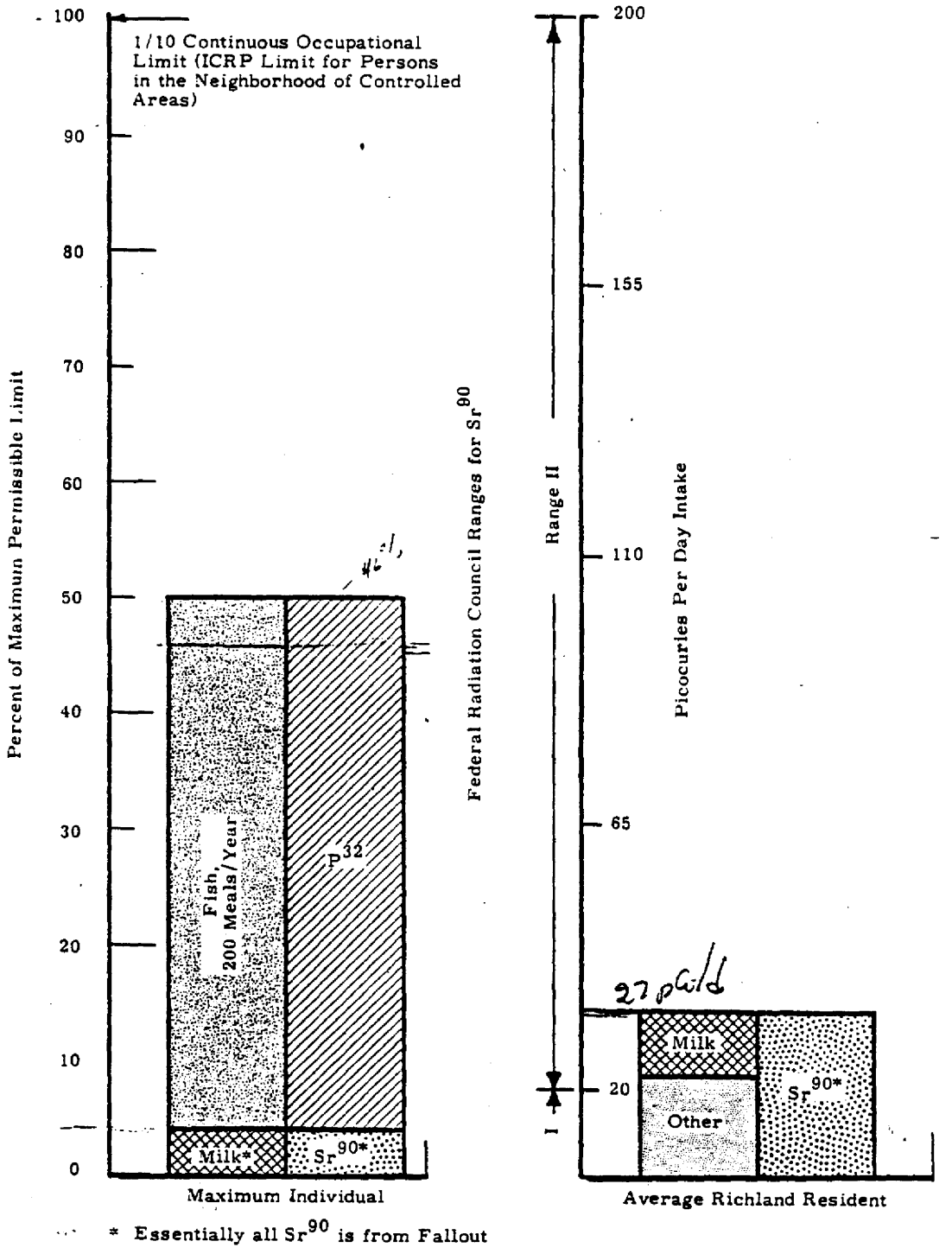

FIGURE 22

Calculated Dose to Bone, 1963

AEC-GE RICHLAND, WASH.

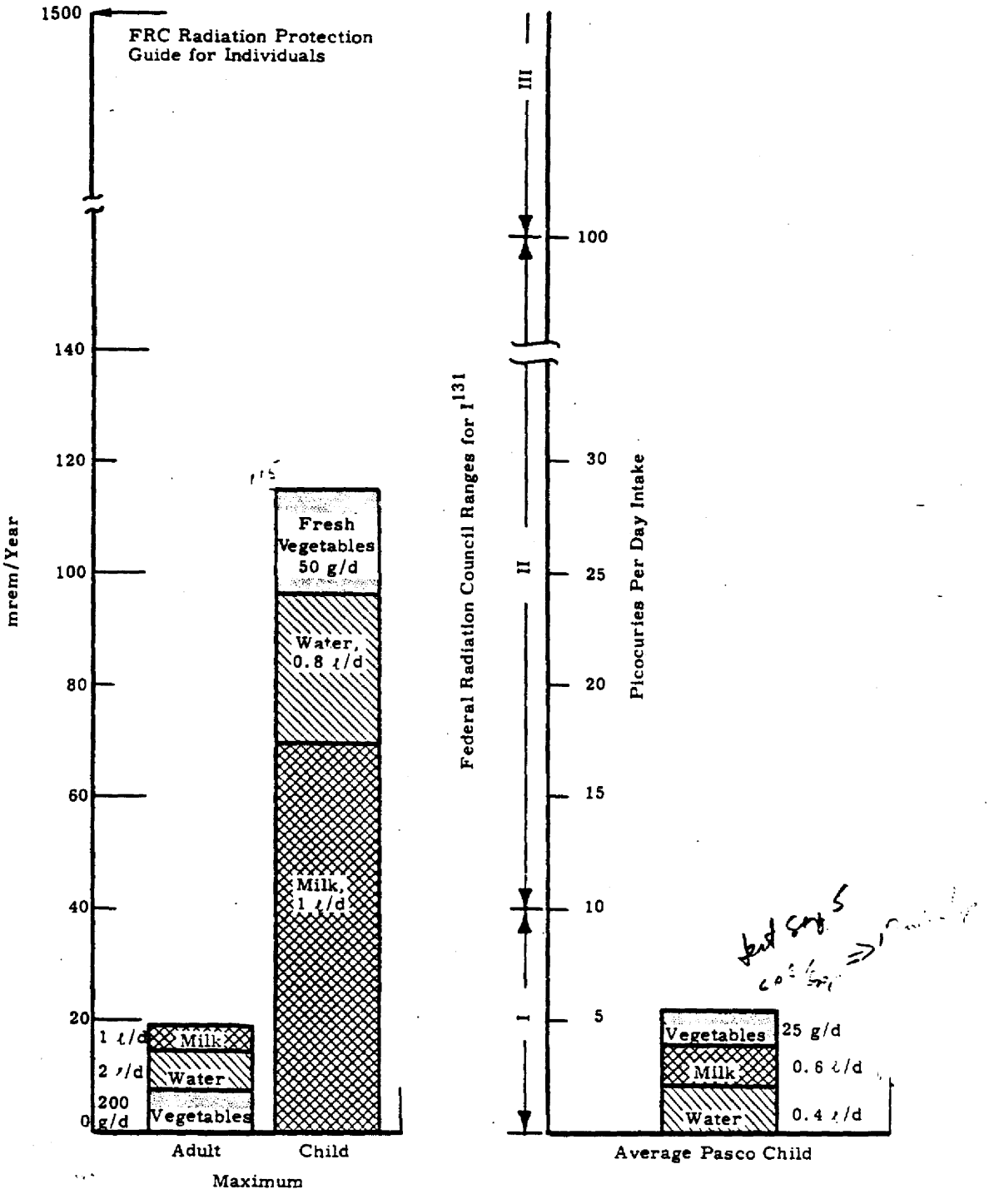

FIGURE 23

Calculated Dose to Thyroid, 1963

AEC-GE RICHLAND, WASH.

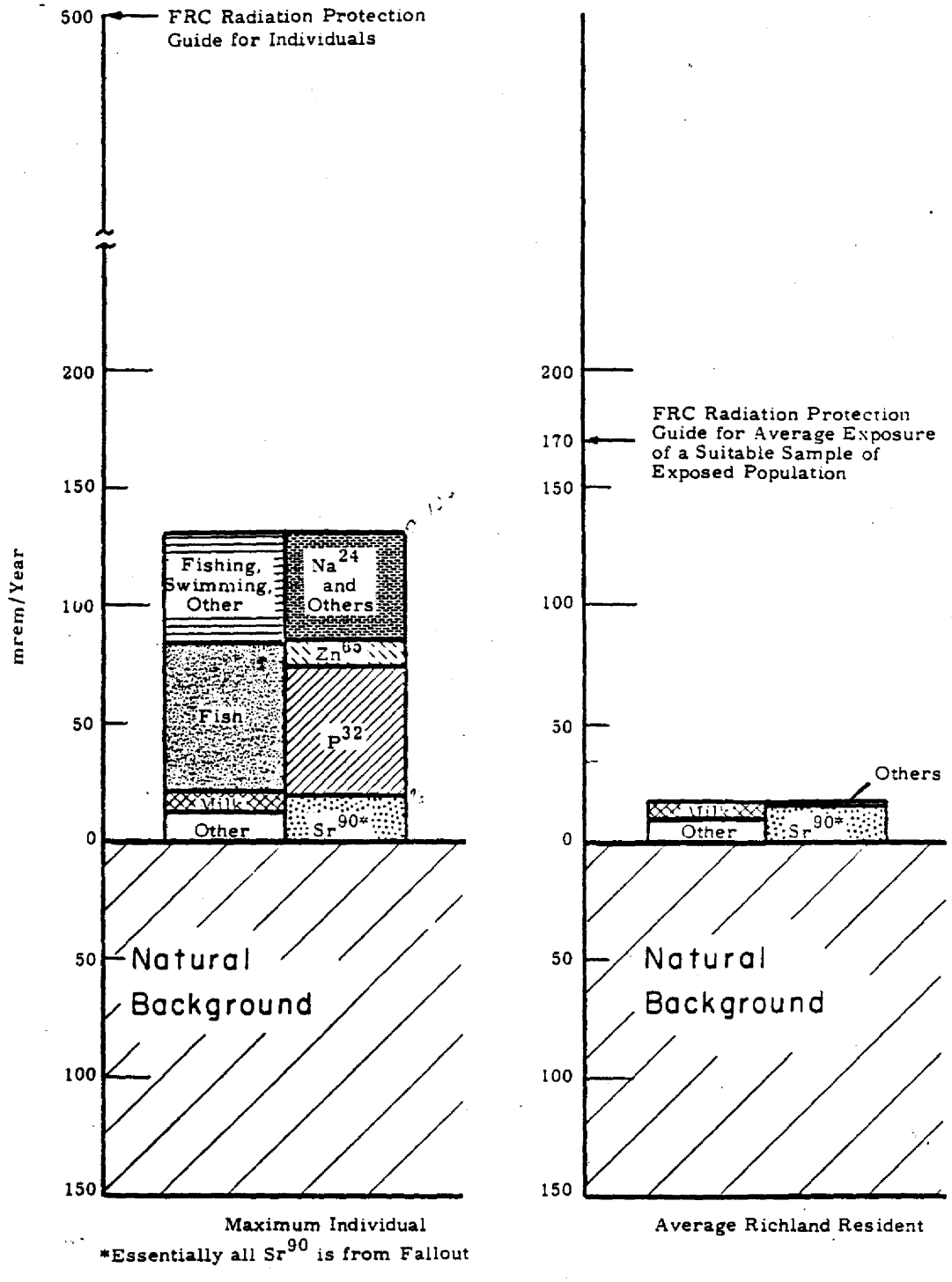

FIGURE 24

Calculated Dose to Total Body, 1963

AEC-GE RICHLAND, WASH.

content of milk sold in local stores during 1963. The result is about 0.01 μc for the year which would be about 15% of the FRC guide for a population exposed to Sr^{90} from a normal peacetime source. Figure 22 shows the relationship to the intake guide based on exposure to the bone.

The contribution from nuclides of Hanford origin in drinking water is substantially different for the three cities as discussed in Section II-B. The dose to the GI tract was greater in Richland than in the cities further downriver because of a greater abundance of the short-lived nuclides. As shown in Figure 21, (and previously in Table VII) the exposure accrued during the last 4 months of 1963 is estimated at about 25 mrems—about 5% of the population limit. The value is expected to be proportionately higher in 1964 when exposure extends over a full 12 month period. The contribution to the GI dose from other sources was relatively insignificant. Conversely, the concentration of bone seekers, such as Sr^{90} and P^{32}, in the water was so low that drinking water did not significantly contribute to the bone dose.

The most appropriate "exposed population" to consider in relation to I^{131} intake and dose to the thyroid would appear to be small children of Pasco who drank water from the municipal system throughout the year (0.4 liters per day) as well as milk from the local stores (1 liter per day). Further, these same children were assumed to eat daily about 25 g of fresh vegetables obtained from local markets. The contributions of I^{131} from these principal sources are shown in Figure 23. The total intake of I^{131} for the year is estimated at about 2000 pc or an average of about 5 pc per day. This is in the middle of the FRC Range I—the most favorable range.

Figure 24 shows the estimated total body exposure from artificial radionuclides of about 15 mrems for the average Richland resident for 1963. Virtually all of this contribution is assigned to Sr^{90} from fallout and the method of calculation yields a value that is unrealistically high as mentioned in the case of the "Maximum Individual". The total dose does, however, include a small contribution (about 1 mrem) from nuclides of Hanford origin (principally Na^{24}, and Zn^{65}) ingested with drinking water and (Zn^{65} only)

beef and sea foods. This total body exposure may be compared with the FRC guide of 170 mrems for the average of suitable sample of an exposed population. Exposure from natural background sources in this region is estimated at about 150 mrems per year (excluded from the FRC guide).

IV. CONCLUSIONS

Comprehensive environmental surveillance of the Hanford environs during 1963 showed that the amounts of radioactive materials present were well within nationally accepted limits at all times and, thus, that the releases of radioactive wastes were adequately controlled.

The most significant source of exposure from the Hanford plants continued to be the P^{32} released to the Columbia River in the reactor effluent and subsequently concentrated by local fish. Individuals who ate such fish as a major part of their diet throughout the year and who also ate large quantities of produce grown on farms irrigated with Columbia River water could conceivably have taken in as much as 50% of the annual permissible amount of bone-seeking radionuclides.

One unusual release of I^{131} occurred from one of the separations plants in September. Extensive surveillance at the time showed that the temporary increase in the I^{131} content of milk and other foods did not substantially alter the annual radiation dose to thyroids of people living in the vicinity of the plant. More Sr^{90} from world-wide fallout was noted in 1963 than in 1962 and consequently the exposure from this source was slightly higher.

V. ACKNOWLEDGEMENTS

The cooperation of many General Electric Company personnel who collected samples, performed the many tedious radioassays, prepared and provided data and reviewed this document is gratefully acknowledged.

The cooperation and contributions of the several City, State and Federal Agencies listed below is gratefully acknowledged.

Kennewick Water Department
Kennewick, Washington

Pasco Water Department
Pasco, Washington

Richland Water Department
Richland, Washington

Washington State Patrol
Yakima, Washington

Washington State Department of Game
Olympia, Washington

U. S. Public Health Service
Portland, Oregon

U. S. Weather Bureau
Meacham, Oregon
Lewiston, Idaho

USAF 408th Fighter Group Air Defense
Klamath Falls, Oregon

Federal Aviation Agency
Walla Walla, Washington
Spokane, Washington
Boise, Idaho
Great Falls, Montana

Civil Aeronautics Administration
Seattle, Washington

Many samples were supplied during the year by the following individuals that provided valuable information about the radiological status in the environs.

Dr. P. M. Aldrich Walla Walla, Washington	(beef thyroids)
Dr. Leon Bodie Moses Lake, Washington	(beef thyroids)
Dr. Christopher Pasco, Washington	(beef thyroids)
Dr. W. H. Harris Toppenish, Washington	(beef thyroids)
Dr. W. E. Welsh Wenatchee, Washington	(beef thyroids)
Mr. Stan Gillies South Bend, Washington	(oysters)

Mr. N. Atterberry Benton City, Washington	(milk)
Mr. Barker Richland, Washington	(milk)
Mr. H. G. Bleazard Eltopia, Washington	(milk)
Mr. F. Buckingham Pasco, Washington	(milk)
Mr. D. Johnson Mesa, Washington	(milk)
Mr. M. Kinne Eltopia, Washington	(milk)
Mr. Tedro Pasco, Washington	(milk)
Twin City Creamery Kennewick, Washington	(milk)

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VIII. APPENDIX A

RIVER AND RELATED SAMPLE RESULTS

APPENDIX A
TABLE 1

CONCENTRATIONS OF RADIONUCLIDES IN
COLUMBIA RIVER WATER AT HANFORD - 1963
Units of pc/l of water

Date	RE+Y	Na^{24}	P^{32}	Cr^{51}	Cu^{64}	Zn^{65}	As^{76}	Sr^{89+90}	Sr^{90}	I^{131}	Np^{239}
1-15	350	3,300	140	3,500	3,400	180	780	3.5	1.0	< 7.5	860
1-29	1500	7,400	290	8,400	12,000	810	1400	7.6	0.79	14	2600
2-12	1800	6,800	280	6,600	11,000	330	1200	8.3	0.74	14	2600
2-26	2500	7,600	330	8,600	13,000	950	2000	12	1.0	8.3	3100
3-12	2600	6,800	400	8,800	12,000	550	2100	7.3	0.53	13	3400
3-26	3900	12,000	650	13,000	18,000	910	5000	10	0.88	12	6400
4-9	6000	13,000	540	9,700	20,000	850	4400	11	0.79	19	4900
4-23	3800	13,000	480	9,200	21,000	700	4300	11	0.54	16	4200
5-7	1600	4,800	260	4,900	8,200	390	980	6.5	0.66	5.0	1600
5-21	1900	11,000	450	9,900	23,000	760	3100	7.4	< 0.61	10	4000
6-4	1500	3,800	170	3,500	9,500	320	1100	7.1	< 0.71	5.4	1500
6-18	1000	3,200	130	3,400	5,900	200	650	3.4	0.74	14	1100
7-23	1500	6,100	160	8,800	15,000	500	1600		0.66	10	2700
8-27	780	5,400	190	14,000	13,000	230	2000		0.81	11	3000
10-22	1200	9,600	510	23,000	26,000	340	3500	11	2.1	16	4200

No entry indicates no analysis made.

APPENDIX A
TABLE 2

CONCENTRATIONS OF RADIONUCLIDES IN COLUMBIA RIVER WATER AT RICHLAND, WASHINGTON - 1963

Units of pc/l of water

Date	RE+Y	Na^{24}	P^{32}	Cr^{51}	Cu^{64}	Zn^{65}	As^{76}	Sr^{90}	I^{131}	Np^{239}
2-11	1100	3400	190	4,300	6600	330	590	< 0.66	7.9	1500
5-6	790	3700	230	4,900	6100	320	1700	0.74	4.3	1900
7-15	380	2400	71	3,700	3900	130	660	0.74	2.7	1000
8-19	400	3100	120	8,500	5700	160	1200	0.93	5.4	1800
9-23	240	2300	160	6,200	2500	190	540	1.7	6.4	1300
10-21	190	4000	490	21,000	5900	430	1800	1.9	14	3700
11-18	330	3700	480	17,000	6200	530	1700	2.0	11	3000
12-16	510	4600	470	21,000	7900	1200	1700	1.9	17	3700

APPENDIX A
TABLE 3

CONCENTRATIONS OF RADIONUCLIDES IN
COLUMBIA RIVER WATER AT PASCO, WASHINGTON - 1963

Units of pc/l of water

Date	RE+Y	Na^{24}	P^{32}	Cr^{51}	Cu^{64}	Zn^{65}	As^{76}	Sr^{89+90}	Sr^{90}	I^{131}	Np^{239}
1-7	340	1900	190	5,200	2000	240	390	11	0.76	5.4	1100
1-21	330	1200	170	4,900	1200	200	290	3.9	< 0.70	4.3	850
2-4	290	750	150	3,700	1100	190	280	9.4	0.72	8.1	880
2-18	180	850	71	2,100	1200	170	180	8.9	0.68	3.5	530
3-4	820	1700	180	4,900	1700	280	610	5.1	< 0.44	5.4	1300
3-18	920	2400	300	6,500	2700	370	1200			17	2100
4-1	850	2200	290	5,500	2400	380	1700	5.9	0.47	9.7	2200
4-15	1200	3100	340	6,400	3500	450	1300			9.5	2300
4-29	760	2200	260	4,700	3100	250	1000	5.5	0.64	6.0	1600
5-13	1800	1300	200	2,600	2000	540	1300	400	4.5	378	6300
5-27	270	1200	91	2,300	2500	200	460	6.2	< 0.90	3.4	780
6-10	340	1300	77	2,000	2200	110	460	7.5	0.53	4.4	720
6-24	260	1300	58	2,100	2300	97	260	5.0	0.46	4.1	600
7-8	300	1700	65	2,900	2600	87	430		< 0.60		730
7-22	200	1300	54	2,800		89	360		0.86	2.4	840
8-12	310	2500	110	8,500	3800	180	970		0.76	4.9	1700
8-26	130	950	67	5,600	1800	91	600		0.83	15	990
9-9	230	1800	180	13,000	2400	160	680		1.6	10	2000
9-23	180	1300	150	6,700	1400	170	540		1.5	8.5	1300
10-7	210	1700	210	9,000	2100	180			1.2	7.0	1700
10-21	160	1900	330	16,000	3000	180	1400		1.8	11	2300
11-4	120	1100	280	11,000	1800	250	1100		2.1	7.4	1400
11-18	210	1600	350	14,000	2600	160	960		1.8	7.1	2100
12-9	180	1500	240	11,000	2000	230	720		2.1	9.8	1600
12-23	330	2000	430	15,000	3300	200	920		3.0	17	2300

No entry indicates no analysis made.

APPENDIX A
TABLE 4

CONCENTRATIONS OF RADIONUCLIDES IN
COLUMBIA RIVER WATER AT VANCOUVER, WASHINGTON - 1963
Units of pc/l of water

Date	RE+Y	P^{32}	Cr^{51}	Zn^{65}	Np^{239}
1-21	14	45	1700	58	ND
2-5	25	62	– 2000	59	ND
2-18	19		1400	72	29
3-4	6.2	28	1300	52	ND
3-18	17		2300	220	14
4-1	16	93	3300	98	87
4-15	21	< 8.8	2200	110	97
4-29	16	70	2300	110	190
5-13	30	56	2100	87	160
6-10	6.7	14	1100	79	
6-24	9.7	23	1000	91	140
7-8	6.9	8.6	1600	84	
7-22		< 5.0	1400	53	170
8-5		19	3100	37	99
8-19		11	3100	< 22	
9-3		< 8.3	3000	< 19	
9-16		14	3600	< 20	
9-30		15	3400	< 17	
10-14		23	3100	19	
10-28		25	4000	< 17	
11-11		37	4400	< 18	
12-2		41	3600	35	
12-16		73	5600		

No entry indicates no analysis made.
ND - Not detected

APPENDIX A

TABLE 5

CONCENTRATIONS OF RADIONUCLIDES IN
SANITARY WATER AT RICHLAND, WASHINGTON - 1963

Units of pc/l of water

Date	RE+Y	Na^{24}	P^{32}	Cr^{51}	Cu^{64}	Zn^{65}	As^{76}	Sr^{90}	I^{131}	Np^{239}
7-1	2.8	< 47	< 8.5	680	28	< 19	< 54	< 0.61	< 4.1	24
7-3	< 4.8	< 28	< 6.0	1,300	28	< 19	< 53		< 4.6	
7-10		< 27	< 8.5	1,200	9.3	< 19	< 69			
8-5	8.5	< 30	< 9.0	380	20	< 19	< 51	< 0.97	< 6.0	38
8-14	< 4.8	< 29	< 8.5	2,700	11	< 19		< 0.57	< 3.9	
9-4	< 4.9	< 32	< 8.4	7.100	22	< 19	< 66	< 1.3	< 4.2	
9-16	< 4.8	57	< 8.5	2,700	30	< 20	830	1.7	11	
10-8	84	2900	74	16,000	2300	38	710	1.3	8.3	2400
10-14	46	2600	77	13,000	3100	60	790	1.9	12	2400
11-6	26	1400	110	8,100	1200	69	570	2.3	7.1	1200
12-3	140	3400	230	16,000	5200	110	840	2.2	9.4	2800
12-17	170	4400	150	18,000	4600	140	940	2.1	16	3000

No entry indicates no analysis made.

APPENDIX A
TABLE 6

CONCENTRATIONS OF RADIONUCLIDES IN
SANITARY WATER AT PASCO, WASHINGTON - 1963

Units of pc/l of water

Date	RE+Y	Na^{24}	P^{32}	Cr^{51}	Cu^{64}	Zn^{65}	As^{76}	Sr^{89+90}	I^{131}	Np^{239}
1-7	22	160	25	4,900	64	95	< 60	0.82	4.0	380
1-14	14	130	18	3,400	40	78	< 54	0.71	< 7.1	380
1-21	15	120	15	3,300	44	89	< 75	< 0.57	< 4.3	310
1-28	23	100	32	3,900	34	86	< 77	0.54	5.1	370
2-4	15	99	22	3,500	36	95	< 70	0.61	5.7	180
2-11	14	99	< 8.9	3,200	26	120	< 62	< 0.56	5.4	230
2-18	16	120	9.9	2,200	70	97	< 60	0.68	4.7	320
2-25	36	450	19	3,200	170	110		0.75	3.5	290
3-4	47	200	36	3,700	110	130	78	0.68	3.6	290
3-11	34	210	32	4,000	68	150	91	0.45	3.5	370
3-18	170	850	99	4,700	550	190	400		6.1	1100
3-25	48	110	42	4,800	69	150	84	0.50	3.7	400
4-1	40	1300	14	6,200	400	220	170	0.47	5.5	1700
4-8	60	790	34	5,600	260	190	160	0.68	8.1	1200
4-15	89	1800	38	5,900	940	250	360		7.0	1700
4-22	44	2200	28	4,000	250	160	190	0.52	5.2	880
4-29	51	1300	28	4,600	740	170	230	0.57	5.0	1100
5-6	55	640	39	3,200	400	99	200	0.42	< 4.3	810
5-13	80	660	33	2,600	410	79	150	0.41	6.1	510
5-20	29	620	17	2,400	390	63	150	< 0.62	4.0	630
5-27	33	690	10	2,100	520	69	110	< 0.79	3.9	530
6-3	18	580	< 8.5	1,500	350	44	47	0.34	< 4.1	410
6-10	32	820	9.3	1,800	560	51	72	0.47	3.7	510
6-17	16	670	< 8.9	1,400	470	37	< 61	0.55	< 3.7	400
6-24	23	800	< 8.4	1,800	410	29	< 50	0.42	3.0	420
7-1	46	1100	16	2,300	710	28	99	0.42	< 4.9	550
7-8	78	960	24	2,800	720	55	170	0.65	2.9	580
7-15	47	1000	18	2,100	700	33	150	< 1.0	2.1	450
7-22	58	820	18	2,400	660	< 19	160	< 0.71	< 2.4	540
7-29	130	1200	39	4,300	1400	47	300	< 0.63	3.5	840

APPENDIX A
TABLE 6 (Continued)

CONCENTRATIONS OF RADIONUCLIDES IN
SANITARY WATER AT PASCO, WASHINGTON - 1963
Units of pc/l of water

Date	RE+Y	Na^{24}	P^{32}	Cr^{51}	Cu^{64}	Zn^{65}	As^{76}	Sr^{90}	I^{131}	Np^{239}
8-5	91	1100	32	4,600	1000	47	520	0.87	6.3	880
8-12	96	1000	46	5,200	840	54	430	0.62	4.1	930
8-19	120	980	56	4,700	920	43	440	0.74	3.2	850
8-26	55	720	38	5,200	730	50	400	1.1	4.3	830
9-9	86	820	87	11,000	670	44	480	1.2	5.2	1400
9-16	56	770	73	7,500	440	61	300	1.3	5.4	1100
9-23	51	1000	69	8,100	550	67	350	1.8	10	1300
9-30	55	1000	76	9,900	610	41	410	1.2	5.8	1400
10-7	38	340	25	7,300	120	78		1.2	4.4	740
10-14	24	400	20	7,500	190	44	120	2.3	6.8	950
10-21	35	320	28	8,800	150	43	150	2.6	5.9	1100
10-28	26	220	31	12,000	95	66	110	1.9	8.7	910
11-4	27	130	42	7,900	49	58	96	1.8	5.8	630
11-11	37	370	40	9,000	190	66	170	1.8	6.1	1000
11-18	23	400	36	12,000	190	51	160	2.2	6.1	1100
12-2	33	650	67	12,000	540	73	210	1.7	9	1500
12-9	36	380	68	6,900	180	88	170	1.8	10	800
12-16	21	230	64	8,200	140	120	160	1.9	6.6	780
12-23	48	250	77	9,500	330	150	140	1.8	5.7	980
12-30	49	310	120	10,000	320	110	220	1.9	9.1	990

No entry indicates no analysis made.

APPENDIX A
TABLE 7

CONCENTRATIONS OF RADIONUCLIDES IN
SANITARY WATER AT KENNEWICK, WASHINGTON - 1963
Units of pc/l of water

Date	RE+Y	Na^{24}	P^{32}	Cr^{51}	Cu^{64}	Zn^{65}	As^{76}	Sr^{90}	I^{131}	Np^{239}
1-28	7.5	60	8.4	1700	34	< 19	< 75		< 4.0	31
2-25	14	94	< 8.6	1300	85	< 20			< 3.8	29
3-25	27	83	13	2700	67	< 19	< 99		< 3.9	4.6
4-22	19	120	9.0	1900	75	< 20	< 76		3.7	69
5-20	14	190	13	1800	190	< 18	< 64		< 4.2	110
6-17	6.9	63	< 8.3	890	98	< 19	< 61		< 3.8	37
7-29	< 4.8	61	< 8.3	1500	59	< 19	< 63	< .62	< 3.8	27
8-19	< 4.9	< 33	< 8.6	210	25	< 22	< 57	< .34	< 1.0	24
9-30	< 4.8	140	10	4300	100	< 17	< 55	< .55	< 2.7	ND
10-28	5.0	74	8.6	4700	69	< 17	< 64		< 3.1	ND
11-11	< 4.8	20	< 8.8	4300	56	< 18	< 47	< .54	< 2.7	ND
12-2	6.8	130	12	5700	220	< 18	< 48	< .65	< 3.1	ND

No entry indicates no analysis made.
ND - Not detected

APPENDIX A
TABLE 8

ESTIMATED RATE OF TRANSPORT OF RADIONUCLIDES
IN COLUMBIA RIVER WATER AT PASCO, WASHINGTON - 1963

Units of curies/day

Date	RE+Y	Na^{24}	P^{32}	Cr^{51}	Cu^{64}	Zn^{65}	As^{76}	Sr^{90}	I^{131}	Np^{239}
1-7	74	410	41	1100	440	52	85	0.17	1.2	240
1-21	79	290	41	1800	290	48	70	< 0.17	1.0	200
2-4	57	150	30	730	220	38	55	0.14	1.6	170
2-18	41	200	16	480	270	39	41	0.16	0.8	120
3-4	200	430	45	1200	430	70	70	< 0.11	1.4	330
3-18	160	400	51	1100	460	62	200		2.9	350
4-1	190	490	65	1200	540	85	380	0.11	2.2	490
4-15	270	690	76	1400	780	100	290		2.1	520
4-29	220	640	75	1400	890	72	290	0.18	1.7	460
5-13	530	380	73	760	580	160	380	/.	4+.	
5-27	150	670	51	1200	1400	110	260	< 0.50	1.9	440
6-10	220	830	49	1300	1400	70	290	0.34	2.8	460
6-24	180	890	40	1500	1600	71	180	0.31	2.8	410
7-8	170	940	36	1600	1400	48	240	< 0.33		400
7-22	85	550	23	1200	1100	38	150	0.37	1.0	360
8-12	88	710	31	2400	1100	51	280	0.22	1.4	480
8-26	31	230	16	1300	430	22	140	0.20	3.6	240
9-9	47	370	37	2700	490	33	140	0.33	2.1	410
9-23	33	240	28	1200	260	31	100	0.28	1.6	240
10-7	34	280	34	1500	340	30		0.20	1.1	280
10-21	24	280	49	2400	450	27	210	0.27	1.6	340
11-4	21	190	49	1900	320	44	190	0.37	1.3	250
11-18	36	280	61	2400	450	28	170	0.31	1.2	370
12-9	35	300	47	2200	390	45	140	0.41	1.9	320
12-23	52	310	68	2400	520	31	150	0.47	2.7	360

No entry indicates no analysis made.

APPENDIX A
TABLE 9

ESTIMATED RATE OF TRANSPORT OF RADIONUCLIDES IN COLUMBIA RIVER WATER AT VANCOUVER, WASHINGTON - 1963

Units of curies/day

Date	P^{32}	Cr^{51}	Zn^{65}	Np^{239}
1-21	14	530	18	ND
2-5	33	1100	31	ND
2-18		540	28	11
3-4	10	480	19	ND
3-18		650	62	3.9
4-1	20	710	21	19
4-15	< 1.9	470	23	21
4-29	33	1100	52	90
5-13	31	1200	48	89
6-10	16	1000	72	
6-24	23	990	90	140
7-8	6.0	1100	59	
7-22	2.8	800	30	97
8-5	7.2	1200	14	37
8-19	3.8	1100	< 7.6	
9-3	< 1.6	570	< 3.6	
9-16	3.5	890	< 4.9	
9-30	3.5	790	< 4.0	
10-14	5.3	710	< 4.3	
10-28	5.3	850	< 3.6	
11-11	8.9	1100	< 4.3	
12-2	9.4	830	8.1	
12-16	17	1300		

No entry indicates no analysis made.
ND - Not detected

APPENDIX A
TABLE 10

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE
OF WHITEFISH TAKEN FROM THE COLUMBIA RIVER - 1963

Units of pc/g

Date	Total Beta	P^{32}	Co^{60}	K^{40}	Zn^{65}	Co^{58}	Cs^{137}
Reporting Limits		2	0.6	1	5	0.7	0.7
Priest Rapids							
1-15		< 4	-	-	-	-	-
1-15		< 3	-	-	-	-	-
1-15		< 5	-	-	-	-	0.7
2-18		-	-	3	5	-	-
2-18		< 5	-	5	-	-	-
2-18		7	2	5	60	2	1
3-18		-	-	6	10	-	-
8-21		3	-	5	-	-	0.7
10-15		< 3	-	2	5	-	-
11-7	7	-	-	4	-	-	-
11-7	6	-	-	4	-	-	-
11-7	570	490	2	4	50	2	0.9
11-7	9	< 3	-	6	-	-	-
11-7	7	< 3	-	4	-	-	-
11-7	230	330	-	5	30	-	0.8
11-7	6	< 4	-	5	-	-	-
11-7	590	500	1	3	50	1	-
11-7	7	< 5	-	4	-	-	-
11-7	14	< 6	-	3	-	-	-
12-3	14	< 10	-	4	-	-	-
12-3	250	200	1	3	50	1	-
12-3	16	< 10	-	3	-	-	-
12-3	37	30	1	4	10	-	-
12-3	120	60	2	4	30	-	-
12-3	30	< 15	-	3	-	-	-
Hanford							
1-9	280	250	2	2	80	3	0.8
1-9	72	63	2	4	60	2	0.9
1-10	86	68	6	2	50	5	1
1-10	35	25	2	5	40	1	0.8
1-10	100	86	2	5	60	2	1
1-10	76	20	1	6	40	2	-
1-10	110	85	6	8	50	5	1

Results less than reporting limit are indicated by a (-).

APPENDIX A
TABLE 10 (Continued)

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE
OF WHITEFISH TAKEN FROM THE COLUMBIA RIVER - 1963

Units of pc/g

Date	Total Beta	P^{32}	Co^{60}	K^{40}	Zn^{65}	Co^{58}	Cs^{137}
Reporting Limits		2	0.6	1	5	0.7	0.7
Hanford (continued)							
1-10	6	-	-	4	-	-	-
2-7	29	21	2	20	30	2	-
2-7	49	19	2	10	30	1	-
2-7	51	34	3	5	30	4	0.9
2-7	22	12	2	5	40	2	0.9
2-20		56	-	30	-	-	1
2-21		< 12	-	-	40	4	-
2-21	31	23	2	3	30	2	-
2-21	30	22	2	3	50	2	0.8
2-21	34	21	2	3	30	2	-
2-28	30	23	2	10	30	1	-
2-28	28	14	3	3	20	2	-
2-28	19	12	3	4	20	2	-
2-28	22	10	3	5	30	3	0.8
2-28	37	32	1	6	40	0.8	-
3-13		22	4	-	30	3	-
3-13	130	130	2	-	60	0.8	-
3-13	110	91	3	8	50	2	-
3-13	37	34	3	2	20	2	-
3-13	32	19	3	3	70	3	-
3-13	65	60	3	5	60	3	0.8
4-29	51	44	2	4	20	0.9	-
4-29	36	27	1	4	20	1	-
4-29	7	47	2	4	20	2	-
4-30	57	54	2	-	20	1	-
4-30	110	100	2	4	40	0.7	-
4-30	130	120	2	-	40	1	-
5-27	130	110	3	2	20	2	-
5-27	42	36	-	2	10	-	-
6-18	50	47	1	4	20	-	-
6-18	68	57	4	6	30	2	1.1
6-18	15	12	-	4	-	-	-
7-1	50	46	2	3	20	0.9	0.8
7-1	23	16	2	3	20	0.8	-

Results less than reporting limit are indicated by a (-).
No entry indicates no analysis made.

APPENDIX A
TABLE 10 (Continued)

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE
OF WHITEFISH TAKEN FROM THE COLUMBIA RIVER - 1963

Units of pc/g

Date	Total Beta	P^{32}	Co^{60}	K^{40}	Zn^{65}	Co^{58}	Cs^{137}
Reporting Limits		2	0.6	1	5	0.7	0.7
Hanford (continued)							
7-2	46	36	2	5	20	2	0.8
7-2	210	200	4	7	40	2	1
8-12	67	57	2	7	6	0.7	-
8-12	280	250	3	9	20	1	
8-12	82	80	1	3	8	0.8	-
8-12	280	240	4	10	20	2	-
9-5	220	160	2	3	20	0.8	-
9-5	430	440	2	5	30	1	-
9-5	730	740	3	4	30	2	-
9-5	470	500	2	2	20	0.9	-
9-5	680	670	-	6	30	0.8	-
10-8	280	220	2	5	40	2	-
10-8	600	500	2	3	30	1	-
10-8	400	370	1	3	40	0.7	-
10-8	500	520	2	4	40	1	-
10-8	790	740	-	3	30	1	-
11-12	380	310	2	2	30	1	-
11-12	500	700	2	3	40	2	-
11-12	380	320	3	-	30	1	-
11-12	430	410	1	3	30	1	-
11-12	240	230	3	8	30	1	-
11-12	470	420	1	7	50	1	0.9
11-12	1700	1600	2	6	80	2	-
12-12	65	46	2	5	20	0.7	-
12-12	380	320	3	6	30	2	-
12-12	260	230	2	7	30	2	-
12-12	390	340	2	7	40	1	-
Ringold							
1-23	16	61	4	-	30	40	-
3-4	120	100	3	30	30	2	1
3-12	21	2	2	8	40	2	1

Results less than reporting limit are indicated by a (-).
No entry indicates no analysis made.

APPENDIX A
TABLE 10 (Continued)

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE
OF WHITEFISH TAKEN FROM THE COLUMBIA RIVER - 1963

Units of pc/g

Date	Total Beta	P^{32}	Co^{60}	K^{40}	Zn^{65}	Co^{58}	Cs^{137}
Reporting Limits		2	0.6	1	5	0.7	0.7
Ringold (continued)							
3-12	230	260	2	10	50	1	-
3-12	89	25	3	7	40	2	0.7
3-12	230	240	2	10	40	1	-
3-12	240	130	2	6	70	2	-
3-12	190	190	2	12	60	1	0.7
3-12	240	240	1	10	60	1	-
3-12	420	450	1	10	20	-	-
3-12		140	4	-	30	1	-
4-4		120	3	4	40	1	-
4-8		220	6	40	40	2	-
4-25	97	88	3	2	40	3	0.8
4-25	45	34	-	2	20	0.7	-
4-25	430	410	3	-	50	2	-
4-25	430	410	-	-	70	0.9	-
4-25	260	250	2	3	40	1	0.7
5-17	5	-	-	5	-	-	-
5-17	6	-	-	4	5	-	-
5-17	680	660	2	4	50	1	1
5-17	240	210	7	-	40	2	0.9
5-17	600	640	1	8	50	0.8	0.9
7-29	460	480	2	10	40	1	-
7-29	83	77	-	1	10	-	-
7-29	400	390	2	1	40	0.7	-
7-29	46	40	1	3	8	-	-
7-29	300	310	-	3	12	-	-
7-29	27	23	-	3	5	-	-
7-29	63	56	2	4	30	1	-
7-29	760	740	3	4	50	0.9	-
7-29	38	31	-	3	-	-	-
7-29	180	190	1	2	20	-	-
8-19	730	740	1	-	30	1	-
8-19	370	390	5	40	20	1	-
8-19	610	580	5	40	40	1	-

Results less than reporting limit are indicated by a (-).
No entry indicates no analysis made.

APPENDIX A
TABLE 10 (Continued)

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE
OF WHITEFISH TAKEN FROM THE COLUMBIA RIVER - 1963

Units of pc/g

Date	Total Beta	P^{32}	Co^{60}	K^{40}	Zn^{65}	Co^{58}	Cs^{137}
Reporting Limits		2	0.6	1	5	0.7	0.7
Ringold (continued)							
8-19	520	500	4	30	40	1	-
8-19	310	270	5	40	30	1	0.8
9-17	1000	930	5	30	40	2	0.7
9-17	1200	980	3	-	60	2	0.8
9-17	1200	1000	4	30	40	1	-
9-17	1600	1600	5	30	70	3	0.8
9-17	1600	1600	3	8	90	2	0.9
9-30	2200	1650	6	-	120	2	0.7
9-30	1100	820	1	8	70	2	-
9-30	1200	1100	2	10	70	3	0.7
9-30	1800	1100	2	10	90	1	0.8
9-30	1100	840	2	5	40	3	1
10-21	690	640	3	2	70	3	1
10-21	1100	1100	3	3	70	2	0.8
10-21	980	1000	3	4	60	2	0.9
10-21	1200	1900	-	2	80	1	1
10-21	2000	1900	2	3	90	3	1
10-21	1900	2000	2	3	80	3	1
10-21	1600	1600	2	6	80	2	0.8
10-21	4100	1800	3	4	100	4	2
10-21	2800	2800	3	5	100	3	2
11-4	720	670	3	-	60	2	1
11-4	690	630	3	3	60	3	0.8
11-4	1100	980	2	3	70	2	1
11-4	1300	1300	2	2	60	2	0.9
11-4	1100	1000	2	-	70	2	1
11-4	1600	1500	-	6	90	2	1
11-4	1300	1300	2	4	80	2	0.9
11-4	1400	1400	2	6	70	2	0.8
11-4	1400	1300	4	-	70	4	1
11-4	1900	1800	4	-	80	3	2
11-4	1600	1600	3	-	60	2	1
12-10	350	230	2	3	40	1	-

Results less than reporting limit are indicated by a (-).

APPENDIX A

TABLE 10 (Continued)

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE
OF WHITEFISH TAKEN FROM THE COLUMBIA RIVER - 1963

Units of pc/g

Date	Total Beta	P^{32}	Co^{60}	K^{40}	Zn^{65}	Co^{58}	Cs^{137}
Reporting Limits		2	0.6	1	5	0.7	0.7
Richland							
1-7	120	100	2	4	60	4	-
1-7	130	86	3	2	50	5	0.7
1-7	38	31	1	-	20	2	-
1-8	70	71	3	5	40	5	-
1-8	69	66	2	3	30	4	0.8
1-16	79	62	2	10	40	3	0.9
1-24	47	41	2	-	40	2	-
1-24	24	20	5	-	40	4	-
3-11	11	4	-	-	20	-	-
4-17	93	64	3	6	40	3	0.8
4-17	50	37	4	4	40	3	-
6-11	55	45	3	3	30	2	0.9
6-11	13	8	-	2	5	0.7	-
6-11	250	210	3	-	40	3	1
8-1	55	47	1	4	10	-	-
8-1	140	130	1	7	10	0.8	0.9
8-23	96	75	1	4	9	-	-
8-23	330	280	-	2	10	1	-
8-23	350	330	1	3	30	1	-
8-23	280	280	1	2	20	1	-
11-22	440	430	1	2	50	-	-
11-22	570	590	2	4	60	1	0.7
11-22	250	250	1	3	30	-	-
12-18	780	840	5	2	90	5	1
12-18	1000	830	5	4	80	5	1
Burbank							
10-30	240	240	-	4	20	-	-
10-30	820	860	4	3	70	4	0.8
10-30	230	220	-	4	30	-	0.8
10-30	460	410	-	4	40	-	-
10-30	580	590	1	5	50	1	-
10-30	340	270	-	6	30	-	-

Results less than reporting limit are indicated by a (-).

APPENDIX A
TABLE 10 (Continued)

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE
OF WHITEFISH TAKEN FROM THE COLUMBIA RIVER - 1963

Units of pc/g

Date	Total Beta	P^{32}	Co^{60}	K^{40}	Zn^{65}	Co^{58}	Cs^{137}
Reporting Limits		2	0.6	1	5	0.7	0.7
Burbank (continued)							
10-30	300	300	-	4	40	-	-
11-14	170	180	1	5	40	-	-
11-14	320	360	-	5	60	-	-
11-14	290	330	-	5	40	-	-
11-14	300	330	-	6	50	-	-
12-4	27	8	1	4	20	-	-
12-4	96	75	-	3	30	-	-
12-4	200	170	-	4	40	-	-
12-4	330	280	-	7	40	-	-
McNary							
6-12		31	-	4	40	-	-

Results less than reporting limit are indicated by a (-).
No entry indicates no analysis made.

APPENDIX A
TABLE 10 (Continued)

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE
OF BASS TAKEN FROM THE COLUMBIA RIVER - 1963

Units of pc/g

Date	Total Beta	P^{32}	Co^{60}	K^{40}	Zn^{65}	Co^{58}	Cs^{137}
Reporting Limits		2	0.6	1	5	0.7	0.7
Hanford							
4-30	8	2	2	-	10	-	-
5-1	11	5	-	3	20	-	0.9
5-16	28	21	-	4	20	-	0.8
5-16	43	38	-	5	20	-	1
5-16	27	19	-	5	20	-	1
5-16	28	21	-	5	20	-	1
5-28	33	24	-	3	10	-	0.7
5-28	74	64	-	4	20	-	0.8
6-18	34	32	-	3	20	-	0.8
6-18	130	130	-	3	30	-	-
7-23	340	340	-	1	20	-	0.8
7-23	430	400	0.7	-	30	-	-
8-13	960	870	0.7	7	20	-	-
9-10	1700	1400	-	6	40	-	1
10-8	760	760	-	3	40	-	0.8
10-8	640	670	-	2	40	-	-
10-8	1100	1100	-	3	50	-	-
10-8	1100	1100	-	2	50	-	-
10-8	1200	1200	-	2	50	-	-
10-8	500	560	-	3	10	-	-
Pingold							
4-4	6	< 3	-	-	10	-	0.9
4-4	7	-	-	-	20	-	-
4-25	9	-	-	3	10	-	0.8
4-25	10	2	-	3	20	-	0.9
4-25	13	4	-	2	20	-	1
4-25	8	< 3	-	2	20	-	0.8
4-25	10	< 3	-	2	10	-	0.8
5-17	19	12	-	4	20	-	1
5-17	36	27	-	3	20	-	1
5-17	27	20	-	4	10	-	1
5-17	55	47	-	6	20	-	0.9

Results less than reporting limit are indicated by a (-).

APPENDIX A
TABLE 10 (Continued)

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE
OF BASS TAKEN FROM THE COLUMBIA RIVER - 1963

Units of pc/g

Date	Total Beta	P^{32}	Co^{60}	K^{40}	Zn^{65}	Co^{58}	Cs^{137}
Reporting Limits		2	0.6	1	5	0.7	0.7
Pingold (continued)							
5-17	35	26	-	6	20	-	0.9
6-3	47	40	-	4	10	-	-
6-3	38	29	-	4	20	-	0.9
6-3	34	27	-	3	20	-	0.8
6-3	47	37	-	6	30	-	1
6-3	140	120	-	6	20	-	-
6-24	15	5	-	1	20	-	0.8
Richland							
7-31	200	190	-	7	30	-	-
10-10	220	210	-	3	30	-	-
10-10	440	460	-	-	30	-	-
Burbank							
6-7	10	3	-	2	6	-	-
8-16	26	19	-	5	-	-	-
McNary							
8-27		97	-	3	10	-	-
9-25	130	120	-	6	10	-	-
9-25	220	200	-	6	20	-	-
9-25	330	310	-	6	30	-	-
9-25	170	160	-	3	20	-	-
9-25	160	150	-	5	10	-	-

Results less than reporting limit are indicated by a (-).
No entry indicates no analysis made.

APPENDIX A
TABLE 10 (Continued)

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE
OF BULLHEADS TAKEN FROM THE COLUMBIA RIVER - 1963

Units of pc/g

Date	Total Beta	P^{32}	Co^{60}	K^{40}	Zn^{65}	Co^{58}	Cs^{137}
Reporting Limits		2	0.6	1	5	0.7	0.7
Hanford							
7-23	300	230	1	4	10	-	-
11-12	120	110	-	4	40	-	-
11-12	180	140	1	5	40	-	0.8
11-12	190	160	1	5	30	-	-
11-12	17	< 6	1	7	5	-	-
Richland							
11-22	< 25	< 29	-	-	-	-	-
11-22	< 35	< 40	-	-	5	-	-
11-22	30	< 25	-	4	-	-	-
11-22	< 18	< 20	-	6	6	-	-
11-22	< 30	< 35	-	5	5	-	-
Burbank							
4-10	< 4	< 9	-	-	8	-	-
5-13	7	< 5	-	-	10	-	-
5-13	7	< 6	-	-	10	-	-
6-19	8	< 5	-	5	10	-	-
6-19	10	5	-	5	20	-	-
6-19	7	< 11	-	6	-	-	-
6-19	11	< 9	-	10	30	-	-
6-19	11	5	-	6	20	-	-
7-11	10	< 9	-	30	10	-	-
7-18	10	4	-	2	9	-	-
7-18	13	< 6	-	10	10	-	-
7-18	19	< 8	-	10	10	-	-
7-18	10	< 3	-	1	8	-	-
8-5	50	35	-	-	20	-	-
8-5	18	10	-	-	10	-	-
8-5	14	10	-	-	9	-	-
8-5	28	19	-	-	10	-	-
8-15	260	210	-	-	20	-	-

Results less than reporting limit are indicated by a (-).

APPENDIX A
TABLE 10 (Continued)

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE
OF BULLHEADS TAKEN FROM THE COLUMBIA RIVER - 1963

Units of pc/g

Date	Total Beta	P^{32}	Co^{60}	K^{40}	Zn^{65}	Co^{58}	Cs^{137}
Reporting Limits		2	0.6	1	5	0.7	0.7
Burbank (continued)							
8-15	91	66	-	7	10	-	-
8-15	150	170	-	-	20	-	-
8-16	180	110	-	7	20	-	-
8-16	480	260	-	-	30	-	-
8-30	150	150	-	-	20	-	-
10-3	180	140	-	-	30	-	-
10-3	140	120	-	6	30	-	-
10-3	130	100	-	-	20	-	-
10-3	200	160	-	-	30	-	-
10-3	270	240	-	3	30	-	-
10-3	350	200	-	5	30	-	-
10-3	150	88	-	-	20	-	-
11-14	76	51	-	-	10	-	-

Results less than reporting limit are indicated by a (-).

APPENDIX A
TABLE 10 (Continued)

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE
OF CATFISH TAKEN FROM THE COLUMBIA RIVER - 1963

Units of pc/g

Date	Total Beta	P^{32}	Co^{60}	K^{40}	Zn^{65}	Co^{58}	Cs^{137}
Reporting Limits		2	0.6	1	5	0.7	0.7
Richland							
10-10	25	20	-	3	-	-	-
Burbank							
3-5	4	-	-	-	20	-	-
3-5	2	-	-	-	20	-	-
4-10	4	-	-	3	7	-	-
4-10	5	< 5	-	5	20	-	-
4-10	6	< 5	-	3	10	-	-
4-10	4	< 3	-	3	10	-	-
4-10	5	< 6	-	5	20	-	-
5-14	5	< 3	-	4	10	-	-
5-14	6	4	-	5	10	-	-
6-7	9	< 3	-	2	10	-	-
6-7	9	< 4	-	2	10	-	-
6-7	7	< 3	-	2	20	-	-
6-7	6	< 3	-	2	20	-	-
6-7	7	< 4	-	-	20	-	-
6-7	8	< 4	-	6	20	2	3
6-7	5	-	-	4	10	0.9	2
6-7	< 5	< 7	-	5	10	-	-
6-7	6	< 7	-	-	10	-	-
6-20	7	< 3	-	3	20	-	-
6-20	4	< 5	-	3	6	-	-
6-20	7	< 4	-	3	20	-	-
6-20	8	< 3	-	-	10	-	-
6-20	6	-	-	3	10	-	-
7-11	11	8	-	4	10	-	-
7-11	7	< 3	-	7	9	-	-
7-11	10	< 4	-	-	10	-	-
7-11	11	7	-	4	10	-	-
7-11	6	-	-	40	10	-	-
7-19	12	7	-	1	10	-	-
7-19	20	16	-	3	9	-	-

Results less than reporting limit are indicated by a (-).

APPENDIX A
TABLE 10 (Continued)

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE
OF CATFISH TAKEN FROM THE COLUMBIA RIVER - 1963

Units of pc/g

Date	Total Beta	P^{32}	Co^{60}	K^{40}	Zn^{65}	Co^{58}	Cs^{137}
Reporting Limits		2	0.6	1	5	0.7	0.7
Burbank (continued)							
7-19	7	2	-	2	7	-	-
7-19	11	5	-	2	10	-	-
7-19	11	6	-	4	9	-	-
8-5	14	8	-	2	8	-	-
8-6	30	22	-	3	10	-	-
8-6	28	19	-	2	9	-	-
8-6	16	10	-	2	10	-	-
8-6	87	74	-	-	10	-	-
8-15	32	20	-	4	10	-	-
8-16	51	39	-	5	20	-	-
8-16	77	75	-	3	20	-	-
8-16	71	47	-	3	20	-	-
8-16	82	36	-	3	10	-	-
8-30	28	23	-	1	10	-	-
9-12	44	39	-	4	20	-	-
9-12	170	170	-	4	30	-	-
9-12	210	210	-	5	20	-	-
9-12	28	13	-	5	10	-	-
9-12	28	20	-	4	9	-	-
9-19	72	70	-	3	8	-	-
9-19	68	50	-	-	5	-	-
9-19	90	65	-	-	20	-	-
9-19	94	86	-	4	20	-	-
9-19	34	14	-	3	10	-	-
10-3	10	3	-	3	10	-	-
10-3	98	68	-	3	20	-	-
10-3	41	31	-	4	10	-	-
10-30	21	38	-	3	10	-	-
10-30	36	28	-	-	10	-	-
10-30	58	55	-	4	20	-	-
10-30	7	5	-	3	8	-	-
McNary							
11-19	90	68	-	-	30	-	-

Results less than reporting limit are indicated by a (-).

APPENDIX A
TABLE 10 (Continued)

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE
OF CRAPPIE TAKEN FROM THE COLUMBIA RIVER - 1963

Units of pc/g

Date	Total Beta	P^{32}	Co^{60}	K^{40}	Zn^{65}	Co^{58}	Cs^{137}
Reporting Limits		2	0.6	1	5	0.7	0.7
Hanford							
7-23	510	560	-	2	30	-	-
Richland							
3-12	5	< 4	-	-	50	-	-
3-12	5	< 5	-	-	-	-	-
3-12	10	< 5	-	-	-	-	-
3-12	8	< 6	-	-	5	-	-
3-12	8	7	-	-	5	-	-
3-12	9	< 6	-	-	-	-	-
3-12	7	< 6	-	-	-	-	-
3-12	< 6	< 6	-	-	-	-	-
3-12	< 6	7	-	-	5	-	-
3-12	10	< 7	-	-	7	-	-
3-12	5	< 6	-	-	-	-	-
3-12	< 5	< 6	-	-	-	-	-
3-12	11	8	-	-	-	-	-
3-12	13	10	-	-	10	-	-
4-16	24	< 18	-	-	9	-	-
4-16	37	30	-	-	-	-	-
4-16	13	< 16	-	-	6	-	-
4-16	16	< 19	-	-	-	-	-
4-16	43	28	-	-	20	-	-
4-16	17	< 27	-	-	10	-	-
5-23	28	28	-	-	5	-	0.7
5-23	17	11	-	9	5	-	-
5-23	< 8	< 8	-	10	-	-	-
5-23	11	< 8	-	8	-	-	-
5-23	7	< 6	-	-	-	-	-
5-23	47	44	-	-	-	-	-
5-23	10	< 10	-	-	-	-	-
5-23	8	< 8	-	12	-	-	-
5-23	44	36	-	9	-	-	-
5-23	< 8	< 9	-	-	-	-	-

Results less than reporting limit are indicated by a (-).

APPENDIX A
TABLE 10 (Continued)

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE
OF CRAPPIE TAKEN FROM THE COLUMBIA RIVER - 1963

Units of pc/g

Date	Total Beta	P^{32}	Co^{60}	K^{40}	Zn^{65}	Co^{58}	Cs^{137}
Reporting Limits	2	0.7	1	5	0.7	0.7	
Richland (continued)							
5-23	6	< 7	-	-	-	-	-
6-14	220	240	-	-	20	-	-
6-14	71	61	-	-	10	-	-
6-14	160	150	-	-	30	-	-
6-14	120	110	-	6	30	-	-
6-14	98	97	-	-	10	-	-
6-14	53	47	-	30	30	-	-
6-14	100	100	-	-	10	-	-
6-14	140	130	-	-	7	-	-
6-14	95	82	-	-	20	-	-
6-14	100	96	-	-	30	-	-
7-31	490	450	-	7	20	0.8	1
7-31	290	290	-	5	20	-	-
7-31	320	320	-	4	20	-	0.9
7-31	550	490	-	6	40	-	-
9-16	1400	1300	-	4	70	-	-
9-16	360	320	2	10	80	1	-
9-16	2600	2300	-	8	90	-	-
10-10	340	330	-	-	40	-	-
10-10	19	17	-	-	6	-	-
11-22	140	87	-	3	40	-	-
Burbank							
4-10	6	< 7	-	7	10	-	-
4-10	7	< 7	-	-	10	-	-
4-10	12	< 8	-	-	30	-	-
5-14	-	-	-	-	20	-	-
5-14	7	< 4	-	-	10	-	-
5-14	16	13	-	-	30	-	-
6-7	10	< 6	-	6	30	-	-
6-7	11	< 7	-	6	30	-	-
7-11	11	4	-	6	10	-	-

Results less than reporting limit are indicated by a (-).

APPENDIX A
TABLE 10 (Continued)

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE
OF CRAPPIE TAKEN FROM THE COLUMBIA RIVER - 1963

Units of pc/g

Date	Total Beta	P^{32}	Co^{60}	K^{40}	Zn^{65}	Co^{58}	Cs^{137}
Reporting Limits		2	0.6	1	5	0.7	0.7
Burbank (continued)							
7-11	28	15	-	7	30	0.8	-
7-11	20	11	-	7	30	-	-
7-11	17	9	-	10	30	-	-
7-19	22	14	-	6	20	-	-
8-6	420	370	-	-	30	-	-
8-16	81	70	-	5	10	-	-
8-30	90	85	-	3	10	-	-
8-30	200	180	-	-	20	-	-
8-30	630	640	-	-	50	-	-
9-12	750	730	-	5	40	-	-
9-12	1300	970	-	5	50	-	-
9-19	400	340	-	3	30	-	-
9-19	180	140	-	-	20	-	-
9-19	190	150	-	4	20	-	-
9-19	150	140	-	2	20	-	-
9-19	670	620	-	3	50	-	-
10-30	94	72	-	3	30	-	-

Results less than reporting limit are indicated by a (-).

APPENDIX A
TABLE 10 (Continued)

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE
OF PERCH TAKEN FROM THE COLUMBIA RIVER - 1963

Units of pc/g

Date	Total Beta	P^{32}	Co^{60}	K^{40}	Zn^{65}	Co^{58}	Cs^{137}
Reporting Limits		2	0.6	1	5	0.7	0.7
Hanford							
6-18	150	140	0.7	7	30	-	-
6-18	190	180	-	4	20	-	-
7-23	1700	1600	-	-	90	-	-
7-23	2000	1800	-	1	80	-	-
7-23	1900	1900	-	-	90	-	-
7-23	1400	1300	-	-	50	-	-
8-13	960	930	1	8	40	-	-
8-13	880	740	1	10	30	-	-
8-13	990	910	-	10	50	1	-
8-13	1400	1200	4	30	50	0.8	-
8-13	410	350	0.8	10	10	-	-
9-10	880	870	1	9	80	-	-
9-10	1500	1400	1	10	70	1	-
11-12	560	480	-	7	40	-	-
11-12	750	630	-	5	70	-	1
11-12	590	530	-	5	70	-	-
11-12	700	650	-	8	90	-	2
Richland							
1-7	5	< 7	-	-	-	4	-
1-7	< 6	< 8	-	-	-	-	-
1-7	10	< 7	-	-	-	-	-
1-7	< 6	< 8	-	-	-	-	-
1-7	< 7	< 9	-	-	-	-	-
1-7	9	< 8	-	-	-	-	-
1-7	12	8	-	-	-	-	-
1-7	8	< 10	-	-	30	-	-
1-7	< 6	< 7	-	-	-	-	-
1-7	< 7	< 9	-	-	-	-	-
1-7	< 5	< 6	-	-	-	-	-
3-11	6	< 4	-	-	40	-	-
3-11	12	< 3	-	3	40	-	1
3-11	< 4	< 4	-	-	-	-	-

Results less than reporting limit are indicated by a (-).

APPENDIX A
TABLE 10 (Continued)

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE
OF PERCH TAKEN FROM THE COLUMBIA RIVER - 1963

Units of pc/g

Date	Total Beta	P^{32}	Co^{60}	K^{40}	Zn^{65}	Co^{58}	Cs^{137}
Reporting Limits		2	0.6	1	5	0.7	0.7
Richland (continued)							
3-11	4	< 4	-	-	-	-	-
3-11	< 5	< 6	-	20	-	-	0.9
3-11	9	< 5	-	-	20	-	-
3-11	9	< 6	-	-	40	-	0.9
3-11	5	< 5	-	-	-	-	-
3-11	6	< 5	-	-	-	-	-
3-11	9	< 6	-	-	50	-	1
3-11	< 5	< 6	-	-	-	-	0.7
3-11	< 7	< 8	-	-	6	1	1
3-11	< 5	< 6	-	-	-	-	-
3-12	9	< 4	-	-	-	-	-
6-11	38	29	-	9	30	-	-
6-11	23	< 11	-	-	-	-	-
6-11	94	86	-	5	30	-	-
9-16	520	510	-	5	60	-	-
9-16	470	420	-	-	70	-	-
9-16	950	870	-	10	120	-	0.8
9-16	1200	1000	-	10	70	-	-
9-16	130	98	-	10	30	-	0.8
11-22	110	60	-	4	30	-	-
11-22	200	140	-	4	30	-	0.9
11-22	370	260	-	7	20	-	-
11-22	120	100	-	7	20	-	-
11-22	200	130	-	4	50	-	-
12-18	140	120	-	4	60	-	1
12-18	140	110	-	4	5	-	1
12-18	110	93	-	5	40	-	-
12-18	140	120	-	3	60	-	1
12-18	170	120	-	4	60	-	1
12-18	110	77	-	-	50	-	0.8
12-18	140	76	-	6	60	-	0.9
12-18	130	91	-	5	40	-	0.9

Results less than reporting limit are indicated by a (-).

APPENDIX A
TABLE 10 (Continued)

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE
OF PERCH TAKEN FROM THE COLUMBIA RIVER - 1963

Units of pc/g

Date	Total Beta	P^{32}	Co^{60}	K^{40}	Zn^{65}	Co^{58}	Cs^{137}
Reporting Limits		2	0.6	1	5	0.7	0.7
Burbank (continued)							
4-10	5	< 4	-	5	8	-	-
4-10	5	< 5	-	-	20	-	-
4-10	7	< 4	-	-	20	-	-
4-10	5	< 4	-	-	30	-	-
4-10	6	< 8	-	-	20	-	-
5-14	6	< 6	-	-	10	-	-
5-14	8	< 6	-	-	20	-	-
5-14	11	< 6	-	-	9	-	-
5-14	9	< 7	-	-	20	-	-
5-14	10	< 13	-	-	10	-	-
6-7	9	< 5	-	6	20	-	-
6-7	9	< 5	-	6	20	-	-
6-7	8	< 3	-	3	10	-	-
6-7	8	< 5	-	6	20	-	-
6-7	10	< 6	-	5	20	-	-
6-19	14	< 6	-	5	30	-	-
6-20	5	< 4	-	4	20	-	-
6-20	10	< 9	-	20	40	-	-
6-20	7	< 7	-	10	40	-	-
6-20	8	< 9	-	-	30	-	-
7-11	8	5	-	3	30	-	-
7-11	10	5	-	5	20	-	-
7-11	8	< 4	-	3	20	-	-
7-11	14	7	-	10	20	-	-
7-11	12	< 6	-	4	20	-	-
7-18	10	< 6	-	10	20	-	-
7-18	18	8	-	6	10	-	-
7-18	11	< 6	-	4	10	-	-
7-18	12	10	-	6	20	-	-
7-18	21	13	-	7	30	-	-
8-5	190	160	-	-	30	-	-
8-5	120	100	-	-	30	-	-
8-6	140	62	-	-	20	-	-
8-6	140	130	-	-	30	-	-

Results less than reporting limit are indicated by a (-).

APPENDIX A
TABLE 10 (Continued)

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE
OF PERCH TAKEN FROM THE COLUMBIA RIVER - 1963

Units of pc/g

Date	Total Beta	P^{32}	Co^{60}	K^{40}	Zn^{65}	Co^{58}	Cs^{137}
Reporting Limits		2	0.6	1	5	0.7	0.7
Burbank (continued)							
8-6	170	150	-	-	30	-	-
8-15	190	140	-	8	20	-	-
8-15	190	150	-	-	20	-	-
8-30	120	91	-	-	20	-	-
8-30	120	110	-	-	10	-	-
8-30	100	81	-	-	20	-	-
8-30	250	190	-	-	20	-	-
8-30	180	150	-	-	20	-	-
9-12	350	330	-	4	30	-	-
9-12	460	440	-	5	40	-	-
9-12	350	330	-	5	40	-	-
9-12	270	280	-	4	20	-	-
9-12	390	350	-	7	40	-	-
9-19	240	220	-	3	30	-	-
9-19	370	330	-	9	30	-	-
9-19	520	500	-	2	50	-	-
9-19	280	280	-	4	40	-	-
9-19	440	430	-	3	50	-	-
10-3	110	97	-	5	20	-	-
10-3	240	150	-	4	30	-	-
10-3	280	210	-	7	40	-	-
10-3	180	150	-	5	30	-	-
10-3	200	150	-	-	30	-	-
10-30	78	45	-	3	20	-	-
10-30	97	83	-	6	30	-	-
10-30	89	65	-	5	30	-	-
10-30	87	69	-	5	30	-	-
10-30	71	20	-	3	30	-	-
11-14	89	32	-	3	30	-	-
11-14	78	83	-	5	30	-	-
11-14	49	30	-	7	30	-	-
11-14	43	40	-	7	40	-	-
11-14	47	39	-	-	30	-	-
12-4	78	43	-	4	30	-	-
12-4	62	39	-	4	30	-	-

Results less than reporting limit are indicated by a (-).

APPENDIX A
TABLE 10 (Continued)

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE
OF PERCH TAKEN FROM THE COLUMBIA RIVER - 1963

Units of pc/g

Date	Total Beta	P^{32}	Co^{60}	K^{40}	Zn^{65}	Co^{58}	Cs^{137}
Reporting Limits		2	0.6	1	5	0.7	0.7
McNary							
2-27		< 6	-	-	50	-	-

Results less than reporting limit are indicated by a (-).
No entry indicates no analysis made.

APPENDIX A
TABLE 10 (Continued)

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE
OF MISCELLANEOUS FISH TAKEN FROM THE COLUMBIA RIVER - 1963

Units of pc/g

Date	Specie	Total Beta	P^{32}	Co^{60}	K^{40}	Zn^{65}	Co^{58}	Cs^{137}
Reporting Limits			2	0.6	1	5	0.7	0.7
Coyote Rapids								
1-18	Steelhead		-	-	4	-	-	-
8-28	Steelhead		-	-	3	-	-	-
8-28	Steelhead		64	1	10	30	-	-
8-28	Steelhead		-	-	4	-	-	-
9-4	Steelhead		-	-	3	-	-	-
9-4	Steelhead		-	-	4	-	-	-
9-4	Steelhead		2	-	3	-	-	-
9-4	Steelhead		2	-	3	-	-	-
9-4	Steelhead		-	-	4	-	-	-
9-18	Steelhead	7	-	-	4	5	-	-
9-18	Salmon	8	-	-	4	-	-	-
9-18	Salmon	8	-	-	4	-	-	-
10-4	Salmon	7	-	-	4	-	-	-
10-4	Sturgeon	6	-	-	3	-	-	-
11-26	Steelhead	25	< 7	-	2	-	-	-
11-26	Steelhead	12	< 4	-	3	-	-	-
12-3	Steelhead	21	< 4	-	3	-	-	-
12-23	Steelhead	12	< 3	-	4	-	-	-
Priest Rapids								
1-15	Sucker		-	-	-	-	-	-
1-15	Sucker		-	-	3	20	-	-
1-15	Sucker		-	-	3	-	-	-
1-15	Squawfish		< 5	-	-	-	-	-
1-15	Squawfish		-	-	-	-	-	-
2-19	Squawfish		< 4	-	6	-	-	-
2-19	Squawfish		-	-	3	-	-	-
3-19	Squawfish		-	-	3	40	-	0.8
3-19	Chiselmouth		-	-	4	50	-	1
3-19	Chiselmouth		-	-	4	30	-	0.8
3-19	Chiselmouth		-	0.6	6	60	-	1
3-19	Chiselmouth		-	-	4	30	-	-
3-19	Sucker		-	-	5	10	-	-

Results less than reporting limit are indicated by a (-).
No entry indicates no analysis made.

APPENDIX A
TABLE 10 (Continued)

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE
OF MISCELLANEOUS FISH TAKEN FROM THE COLUMBIA RIVER - 1963

Units of pc/g

Date	Specie	Total Beta	P^{32}	Co^{60}	K^{40}	Zn^{65}	Co^{58}	Cs^{137}
Reporting Limits			2	0.6	1	5	0.7	0.7
Priest Rapids (continued)								
3-19	Sucker		-	-	4	10	-	-
3-19	Sucker		-	-	4	10	-	-
3-19	Sucker		-	-	6	-	-	-
3-19	Squawfish		-	-	5	-	-	-
3-19	Squawfish		-	-	5	-	-	-
3-19	Squawfish		-	-	3	-	-	-
3-19	Squawfish		-	-	4	-	-	-
3-19	Squawfish		-	-	5	-	-	-
5-10	Steelhead		-	-	5	-	-	-
5-10	Sucker		-	-	5	-	-	-
5-10	Sucker		-	-	5	-	-	-
5-10	Sucker		-	-	3	-	-	-
5-10	Sucker		-	-	3	-	-	-
5-10	Sucker		< 5	-	9	-	0.7	0.9
5-10	Sucker		-	-	4	-	-	-
5-10	Squawfish		-	-	3	-	-	-
5-10	Squawfish		< 4	-	5	9	-	-
5-10	Chiselmouth		< 4	-	6	-	-	-
5-10	Chiselmouth		< 4	-	6	20	-	-
5-10	Chiselmouth		< 3	-	3	10	1	1
7-17	Steelhead		-	-	2	-	-	-
7-17	Sucker		150	-	3	-	-	-
7-17	Squawfish		< 3	-	4	-	-	-
7-17	Squawfish		< 5	-	4	20	-	-
7-17	Squawfish		< 3	-	8	-	-	-
7-17	Squawfish		< 6	-	-	7	-	-
8-21	Carp		-	-	4	-	-	-
8-21	Carp		-	-	5	-	-	-
8-21	Carp		-	-	4	-	-	-
8-21	Sucker		85	-	4	20	-	-
10-15	Sucker	460	430	-	4	30	-	0.8
10-15	Sucker	8	-	-	3	8	-	-
10-15	Sucker	60	46	-	3	20	-	0.8
10-15	Sucker	7	-	-	3	-	-	-

Results less than reporting limit are indicated by a (-).
No entry indicates no analysis made.

APPENDIX A
TABLE 10 (Continued)

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE
OF MISCELLANEOUS FISH TAKEN FROM THE COLUMBIA RIVER - 1963

Units of pc/g

Date	Specie	Total Beta	P^{32}	Co^{60}	K^{40}	Zn^{65}	Co^{58}	Cs^{137}
Reporting Limits			2	0.6	1	5	0.7	0.7
Priest Rapids (continued)								
10-15	Steelhead	5	-	-	3	-	-	-
10-15	Steelhead	5	-	-	2	-	-	-
11-7	Sturgeon	9	< 3	-	4	10	-	-
12-3	Sucker	14	< 5	-	3	-	-	-
12-3	Sucker	4	< 4	-	4	-	-	-
12-3	Sucker	12	< 6	-	4	-	-	-
Hanford								
1-10	Squawfish	67	50	0.8	6	60	-	2
1-10	Squawfish	33	23	-	5	40	-	1
1-10	Squawfish	20	8	-	5	40	-	1
1-10	Squawfish	30	27	-	5	60	-	1
1-10	Squawfish	15	10	-	-	60	-	1
1-10	Chiselmouth	62	45	1	7	100	1	2
1-10	Sucker	91	87	-	2	40	1	0.8
1-10	Sucker	150	120	0.8	2	60	1	2
1-10	Sucker	230	200	1	4	70	2	2
1-10	Sucker	120	99	0.9	2	40	5	1
1-10	Sucker	170	170	0.9	7	70	2	2
1-10	Sturgeon	18	13	-	5	7	-	-
2-7	Chiselmouth	17	7	0.6	8	70	-	1
2-7	Chiselmouth	34	18	-	10	60	-	-
2-7	Chiselmouth	51	35	2	10	90	1	2
2-7	Chiselmouth	46	30	1	8	120	2	2
2-7	Squawfish	10	-	-	8	30	-	2
2-7	Squawfish	3	-	-	6	5	-	2
2-7	Squawfish	10	3	-	6	40	-	1
2-7	Squawfish	18	12	-	10	50	-	0.9
2-7	Squawfish	9	3	-	10	50	-	-
2-7	Sucker	75	76	0.7	6	30	0.7	1
2-7	Sucker	36	27	-	5	30	-	1
2-7	Sucker	86	79	0.7	5	20	-	1
2-7	Sucker	94	17	0.6	6	30	-	0.7

Results less than reporting limit are indicated by a (-).

APPENDIX A
TABLE 10 (Continued)

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE
OF MISCELLANEOUS FISH TAKEN FROM THE COLUMBIA RIVER - 1963

Units of pc/g

Date	Specie	Total Beta	P^{32}	Co^{60}	K^{40}	Zn^{65}	Co^{58}	Cs^{137}
Reporting Limits			2	0.6	1	5	0.7	0.7
Hanford (continued)								
2-7	Sucker	130	130	0.6	8	40	0.8	2
2-7	Sucker	360	340	2	40	60	1	2
2-21	Sucker	26	16	-	3	30	-	1
2-21	Sucker	140	130	0.7	4	60	2	2
2-21	Sucker	80	71					
2-21	Sucker	66	64	-	-	30	1	-
2-21	Sucker	170	170	-	3	40	0.9	0.8
2-21	Sucker	120	110	0.9	3	60	1	2
2-21	Sucker	330	310	-	1	90	1	2
2-21	Chiselmouth	29	20	0.9	2	60	2	1
2-21	Chiselmouth	33	16	1	6	120	2	2
2-21	Chiselmouth	26	13	-	-	100	2	2
2-21	Chiselmouth	15	7	-	1	40	-	-
2-21	Squawfish	12	5	-	3	30	-	-
5-2	Carp	220	210	0.9	-	30	-	0.8
5-2	Carp	76	62	-	-	90	-	-
5-2	Carp	42	33	-	3	40	-	-
5-2	Ling	9	2	-	3	20	-	-
6-18	Sucker	230	220	0.8	5	20	-	0.8
6-18	Sucker	290	280	0.6	3	20	-	0.8
6-18	Sucker	110	100	1	5	40	-	1
6-18	Sucker	400	400	0.7	6	50	-	2
6-18	Sucker	130	140	0.6	5	-	-	-
7-2	Sucker	470	460	0.7	6	10	-	0.7
7-2	Sucker	1100	990	-	10	50	-	1
7-2	Sucker	48	36	-	6	-	-	-
7-2	Sucker	200	180	0.8	7	50	-	1
7-2	Sucker	320	300	1	6	30	-	1
7-2	Chiselmouth	830	790	1	20	30	-	0.8
7-2	Chiselmouth	360	310	0.7	20	60	-	0.8
7-2	Chiselmouth	85	74	-	20	30	-	-
7-23	Sturgeon	27	23	0.6	-	7	-	-
7-23	Sturgeon	65	61	1	-	10	-	-
8-13	Steelhead	92	69	-	4	-	-	-

Results less than reporting limit are indicated by a (-).
No entry indicates no analysis made.

APPENDIX A
TABLE 10 (Continued)

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE
OF MISCELLANEOUS FISH TAKEN FROM THE COLUMBIA RIVER - 1963

Units of pc/g

Date	Specie	Total Beta	P^{32}	Co^{60}	K^{40}	Zn^{65}	Co^{58}	Cs^{137}
Reporting Limits			2	0.6	1	5	0.7	0.7
Hanford (continued)								
9-5	Steelhead	1900	1900	0.6	5	70	0.9	-
9-10	Carp	730	870	-	3	80	-	-
9-10	Carp	1200	1200	2	20	50	0.9	-
10-8	Carp	2200	2200	-	5	130	0.8	-
12-12	Sucker	250	220	0.7	4	30	-	1
12-12	Squawfish	120	81	-	5	50	-	2
Ringold								
1-24	Sucker	300	280	0.6	2	70	1	1
2-13	Sucker	49	41	-	2	50	0.9	1
2-13	Sucker	390	370	0.8	4	60	1	1
2-13	Sucker	120	110	-	5	30	0.7	-
2-13	Sucker	190	180	0.7	4	60	1	2
2-13	Sucker	220	210	-	4	70	1	2
2-13	Squawfish	9	2	-	2	30	-	-
4-24	Ling	6	-	-	3	20	-	0.8
10-27	Steelhead	1300	1200	-	3	100	1	-
11-13	Steelhead	630	730	-	-	110	-	-
Richland								
1-7	Bluegill	20	15	-	-	30	-	-
1-8	Sucker	68	56	0.9	4	50	-	1
4-18	Sucker	120	98	-	7	20	-	-
4-18	Squawfish	12	9	-	7	20	-	1
6-11	Squawfish	27	18	-	3	20	-	1
6-11	Squawfish	120	100	-	5	40	0.7	-
6-11	Squawfish	52	41	-	-	30	-	-
6-11	Squawfish	63	54	-	4	30	-	-
6-11	Squawfish	320	330	-	-	50	-	-
6-11	Squawfish	74	60	-	-	30	-	-
6-11	Sucker	280		-	3	30	-	0.7
9-16	Bluegill	790	720	2	9	70	-	-

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APPENDIX A
TABLE 10 (Continued)

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE
OF MISCELLANEOUS FISH TAKEN FROM THE COLUMBIA RIVER - 1963

Units of pc/g

Date	Specie	Total Beta	P^{32}	Co^{60}	K^{40}	Zn^{65}	Co^{58}	Cs^{137}
Reporting Limits			2	0.6	1	5	0.7	0.7
Richland (continued)								
9-16	Bluegill	2100	1800	-	-	240	2	-
9-16	Bluegill	5900	5100	-	-	300	3	1
10-10	Sucker	810	860	-	3	30	-	-
10-10	Sucker	110	110	-	3	10	-	-
10-10	Sucker	470	480	-	2	20	-	-
10-10	Bluegill	480	430	-	-	40	-	-
11-22	Bluegill	< 26	< 30	-	-	8	-	-
11-22	Carp	15	< 8	-	3	20	-	-
11-22	Carp	67	36	-	3	50	-	-
11-22	Carp	< 10	< 15	-	4	10	-	-
11-22	Carp	82	51	-	3	90	-	-
11-22	Carp	33	22	-	3	40	-	-
12-18	Squawfish	15	< 3	-	3	7	-	-
12-18	Squawfish	21	8	-	4	10	-	-
12-18	Squawfish	25	9	-	3	20	-	-
12-18	Squawfish	19	13	-	4	9	-	-
12-18	Squawfish	14	5	-	3	8	-	-
Burbank								
3-5	Sucker	9	-	-	-	30	-	-
3-5	Sucker	4	-	-	1	-	-	-
3-5	Sucker	20	12	-	4	30	-	0.8
3-5	Sucker	14	3	-	2	40	0.8	1
3-5	Sucker	6	-	-	2	20	-	-
3-5	Chiselmouth	11	4	-	-	50	-	0.7
3-5	Chiselmouth	10	2	-	2	60	-	0.7
3-5	Chiselmouth	12	6	0.8	-	70	-	1
3-5	Chiselmouth	13	4	0.9	2	80	0.8	1
3-5	Chiselmouth	12	< 3	-	-	70	-	1
3-5	Sucker	22	15	-	3	20	-	-
3-5	Sucker	13	8	-	-	20	-	-
3-5	Sucker	25	16	-	-	40	-	-
3-5	Squawfish	7	< 4	-	-	20	-	-

Results less than reporting limit are indicated by a (-).

APPENDIX A
TABLE 10 (Continued)

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE
OF MISCELLANEOUS FISH TAKEN FROM THE COLUMBIA RIVER - 1963

Units of pc/g

Date	Specie	Total Beta	P^{32}	Co^{60}	K^{40}	Zn^{65}	Co^{58}	Cs^{137}
Reporting Limits			2	0.6	1	5	0.7	0.7
McNary (continued)								
3-27	Chiselmouth		22	-	5	60	-	-
3-27	Chiselmouth		37	-	5	40	-	-
3-27	Squawfish		-	-	-	20	-	-
3-27	Squawfish		-	-	2	10	-	-
3-27	Squawfish		-	-	7	50	-	-
3-27	Carp		-	-	4	40	-	-
6-12	Squawfish		-	-	-	20	-	-
6-12	Squawfish		7	-	-	10	-	-
6-12	Squawfish		4	-	3	10	-	-
8-27	Sucker		200	-	2	20	-	-
8-27	Sucker		82	-	2	10	-	-
8-27	Sucker		490	-	3	20	-	-
8-27	Sucker		120	-	2	20	-	-
8-27	Sucker		150	-	3	10	-	-
8-27	Carp		220	-	4	20	-	-
8-27	Sturgeon		4	-	3	8	-	-
8-27	Squawfish		80	-	-	20	-	-
8-27	Squawfish		51	-	-	8	-	-
8-25	Sucker	170	170	-	5	10	-	-
9-25	Sucker	310	270	-	5	20	-	-
9-25	Sucker	240	230	-	6	20	-	-
9-25	Sucker	220	210	-	4	20	-	-
9-25	Sucker	370	320	-	4	20	-	-
10-29	Sucker	200	200	-	4	20	-	-
10-29	Sucker	790	780	-	4	30	-	-
10-29	Sucker	510	520	-	3	30	-	-
10-29	Sucker	440	460	-	4	30	-	-
10-29	Sucker	210	210	-	3	20	-	-
11-19	Sucker	310	340	-	3	20	2	-
11-19	Sucker	160	160	-	3	30	-	-
11-19	Sucker	180	130	-	3	20	-	-
11-19	Sucker	520	400	-	3	30	-	-
11-19	Sucker	370	370	-	3	20	-	-
11-19	Sucker	190	200	-	3	20	-	-

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