Water Load of Uranium Radium, and Gross Beta Activity at Selected Gaging Stations Water Year 1960–61

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By E. C. MALLORY, JR., J. O. JOHNSON, *and* R. C. SCOTT

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By E. C. Mallory, Jr., J. O. Johnson, and R. C. Scott

ABSTRACT

Water samples were collected from 36 rivers during low, medium, and high flows. The drainage areas above the sampling sites represent about 55 percent of continental United States (including 86,000 square miles of Alaska) and 155,000 square miles of Canada. During the 1960–61 water year the total uranium-solute load ranged from about 100 pounds contributed by the Nezinscot River to 695,000 pounds contributed by the Mississippi River. The calculated total uranium-solute load of the rivers sampled was used to estimate that about 2 million pounds of uranium was carried in solution from the continental United States to the oceans during this water year. The calculated radium-solute load for the sampling period ranged from about 2.5×10^{-5} pounds for the Nezinscot River to $25{,}000 \times 10^{-5}$ pounds for the Mississippi River. The gross solute load of radium from the conterminous United States to the oceans for water year 1960–61 was estimated to be about $67{,}000 \times 10^{-5}$ pounds.

INTRODUCTION

Investigations concerning the amount of radioelements in surface waters have both scientific and practical values. Fix (1955) investigated the usefulness of the uranium content of surface waters in the western and southeastern parts of the United States as an aid for the location of uranium deposits. Illsley (1961) used uranium analyses of streams in south-central Idaho to show the suitability of hydrogeochemical techniques for uranium exploration. Landis (1960) determined the uranium content of some surface waters in a part of the central Great Plains. Scott and Voegeli (1961) gave a detailed account of the uranium, radium, and beta activity in surface waters of Colorado. The quantities of radioactive elements in surface waters are especially important if such waters are used for irrigation, food processing, or drinking. For example, the recommended tolerance for radium-226 in drinking water is only 3 pc/l (picocuries per liter) (U.S. Public Health Service, 1962).

This study was made for the following purposes:

1. To determine the amounts of uranium, radium, and gross beta activity in major streams of the United States during water year 1960–61.
2. To estimate the amounts of uranium and radium being transported in solution to the oceans.
3. To furnish background data for future geochemical studies of the naturally occurring radioelements and radioactivity and to provide information from the United States for the studies of global balances of water and water-borne materials conducted as part of the activities of the International Hydrological Decade.

Results of this study are from data collected primarily in water year 1960–61. The data concern uranium, radium, and gross beta activity in major streams draining conterminous United States, Alaska, and small parts of Canada. Most of the radioelements probably originate from natural sources. Some beta activity, as shown later, is evidently not from natural sources.

SAMPLING PROGRAM

Thirty-six sampling sites were selected close to or at Geological Survey stream-gaging stations. Each site was selected to provide representative samples of both natural radioactivity and flow along the sampled streams. Sampling sites near the ocean were above high-tide level. Because industrial radioactive waste was being released into the Columbia River at Hanford, Wash. (Setter and Baker, 1960), the sampling site was located as far as possible downstream from the waste-disposal point. Effects from radioactive material released to the environment by this installation would then be reduced to a minimum. The Mohawk River carries radioactive industrial waste into the Hudson River (U.S. Public Health Service, 1960), therefore, the sampling site was located on the Hudson above its confluence with the Mohawk. Sampling sites or streams having regulated flows were avoided as much as possible.

One hundred and eleven samples were collected. Sampling sites on the Penobscot, Hudson, Delaware, Susquehanna, Altamaha, Apalachicola, Pearl, Red River of the North, Missouri, Red River of the South, Sabine, Neches, Trinity, Brazos, Colorado (Arizona), San Joaquin, Klamath, Columbia and Yukon were Decade stations. Decade Rivers (Roanoke, Cape Fear, Potomac, St. Johns, Suwanee, Mississippi, Rio Grande, and Sacramento) were sampled at other than Decade sites. Nine sampling sites were not on Decade Rivers.

River-drainage areas and sampling sites are shown on plate 1. The river-drainage areas, above the sites where samples were collected, comprise a total drainage area of about 2,100,000 square miles. This area is about 55 percent of the continental United States (including 86,000 square miles of Yukon drainage in Alaska). In addition, about 155,000 square miles of Canada contribute to the flows of the Yukon, Missouri, and Columbia Rivers.

Samples were collected by district personnel of the Water Resources Division. Sampling was to be during low, medium, and high flows of water year 1960–61. This was not easily accomplished because some flows are rather unpredictable and of short duration. The Colorado River is so greatly regulated above the sampling site at Yuma, Ariz., that only seasonal flows were obtained. Seasonal samples of the Colorado were, therefore, collected when low, medium, and high flows normally would have been in progress if there had been no regulation.

During extremely adverse weather, some remotely located stations were inaccessible; hence, some flow data were not obtained. In some places a representative sample was, therefore, collected at a later date.

A 2- or 4-liter sample was collected for radiochemical analysis. A solution of 8 ml of glacial acetic acid and 2 ml of chloroform was immediately added to each sample. The acetic acid helps keep uranium and radium in solution by lowering the pH, and the chloroform inhibits algal and fungus growth. A second sample of similar size was collected for the determination of other chemical constituents. To reduce changes that occur during long storage, samples were shipped a few days after collection and analyzed as soon as possible by the receiving laboratory.

ANALYTICAL METHODS

Chemical and physical properties were determined by regular water-analysis methods described by Rainwater and Thatcher (1960). A table of the physical, chemical, and radiochemical data for all samples collected is included in table 1.

Uranium was analyzed according to the method described by Barker and others (1965). The uranium was determined by evaporating a sample aliquot to dryness, fusing the solids in a fluoride-carbonate flux, and then measuring the intensity of the uranium fluorescence in the fused pellet.

Radium was analyzed according to the method given by Barker and Johnson (1964). The radium was coprecipitated by barium sulfate and determined by measuring the alpha activity of radium and its radioactive descendents in the precipitate.

Gross beta activity was determined by the method described by Barker and Robinson (1963). A sample aliquot was evaporated to dryness, and the beta activity of the residue was measured with a low-background beta counter. Beta activity results are expressed in terms of equivalent amounts of beta activity found in strontium-90-yttrium-90 standards which are prepared as described by Barker and Robinson (1963).

Detailed discussions about the accuracies of these methods are given by the authors. Briefly, the estimated accuracies are as follows:

Element	Concentration	Estimated maximum error
Uranium	0.4 to 4.0 μg/l	0.4 μg/l.
	Above 4.0 μg/l	About 10 percent.
Radium 226	0.1–0.5 pc/l	0.1 pc/l.
	Above 0.5 pc/l	About 20 percent.
Beta activity	0.3–2.0 pc/l	0.3 pc/l.
	Above 2.0 pc/l	About 15 percent.

Planchets with residue prepared for the determination of gross beta activity were also used for gross alpha measurements. Only a small percentage of the alpha particles are detected because the residue is essentially of infinite thickness with respect to the short-range alpha particles. Thus, because of the low gross alpha activity in the samples and the large errors inherent in the determination, statistically reliable data were not obtained and are not published in this paper.

Analytical results are expressed as follows: uranium concentrations are given in micrograms per liter (1 microgram=10^{-6} grams). The minimum detection limit of the uranium method is about 0.4 μg/l (micrograms per liter). Less than detectable amounts of uranium are reported, therefore, as <0.4 μg/l. An average uranium concentration of 0.2 μg/l has been used in calculations for water samples found to contain <0.4 μg/l. Laboratory studies of a large number of dilute surface-water samples have shown use of this figure to be reasonably reliable.

Radium results are described in picocuries per liter (1 picocurie= 10^{-12} curies). One picocurie may also be defined as 3.7×10^{-2} disintegrations per second, or 2.22 disintegrations per minute. The radium method has a minimum detection limit of 0.1 pc/l. Less than detectable amounts were reported as <0.1; for radium averages and other calculations, <0.1 was considered as 0.05, or halfway between zero and 0.1. Three of the samples were only half the size normally collected for radioelement determinations, and using half-size aliquots for radium raised the threshold of detection to 0.2 pc/l. These three samples were considered to have a value of one-tenth when radium calculations were made.

Beta results are also expressed in picocuries per liter. The minimum detection limit for gross beta activity commonly ranges from 0.3 to 1.0 pc/l, because the size of the aliquot used is determined by the specific conductance of the sample. Normally, the greater the conductance the smaller the aliquot and, thus, the lower the sensitivity and the higher the minimum detection limit.

High, medium, and low flows were determined by dividing into thirds the range of the minimum to maximum discharge for each station during wateryear 1960–61. The top, middle, and bottom thirds of the range represent the high, medium, and low flows, respectively. The range of discharge in cubic feet per second for each flow and the length of flow period (number of days) at each river station are shown in table 2. The discharge when a river was sampled was compared with this table to decide whether the sample belonged to high, medium, or low flow periods.

Radiochemical data are shown in table 3 for low, medium, and high flows at each sampling site. Sometimes a flow was sampled on different dates, and then uranium and radium values were averaged. Analyses for duplicate flow samples are shown in table 1.

Uranium and radium values were estimated for eight unsampled medium or high flows so that further calculations could be made. Uranium values for unsampled medium flows were determined by averaging the low- and high-flow uranium values as shown below:

River	Uranium (μg/l)		
	Low flow	Medium flow (averaged)	High flow
Altamaha	<0.4	0.4	0.4
Sabine	<.4	<.4	<.4
Brazos	.7	.45	<.4
Guadalupe	.8	.4	<.4
Columbia	1.1	.8	.5

The radium values for medium flows, obtained in the same way, are as follows:

River	Radium (pc/l)		
	Low flow	Medium flow (averaged)	High flow
Altamaha	0.1	<0.1	<0.1
Sabine	.2	.15	.1
Brazos	.4	.65	.9
Guadalupe	.2	.25	.3
Columbia	.1	.1	.2

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High flows for the Carrabasset, Nezinscot, and Suwannee were not sampled. Because uranium values for the low and medium flows for these three rivers was <0.4 μg/l, uranium values for high flows were considered to be the same.

Radium values for these high flows were extrapolated as shown:

River	Radium (pc/l)		
	Low flow	Medium flow	High flow (extrapolated)
Carrabasset	0.1	<0.1	<0.1
Nezinscot	<.1	<.1	<.1
Suwannee	.1	.3	.3

An extrapolated high-flow radium value of 0.5 pc/l for the Suwanee River would have been high when compared to other rivers in this area, so high flow was given the same value as medium flow.

GROSS BETA ACTIVITY

Gross beta activity in natural waters is now an important determination. Before the advent of manmade nuclear energy, practically all beta activity of natural waters could properly be ascribed to beta-emitting nuclides of the naturally occurring radioactive elements, including potassium-40. This is no longer always true. In periods of nuclear detonations, particularly atmospheric testing, the beta activity of precipitation may be many times as great as when no testing is in process, because most of the radioactive elements produced in atomic detonations and nuclear powerplants are beta emitters. Fortunately, most of the beta-emitting nuclides of fallout decay rapidly or are absorbed in soils so that only a moderate increase of beta activity from nuclear testing occurs in streams. Some of the "long-lived" beta-emitting nuclides produced in nuclear testing and atomic powerplants are strontium-90, cesium-137, cerium-144, and ruthenium-106. "Long-lived" beta-emitting nuclides are detected in surface waters many months after cessation of atmospheric detonations.

The normal beta activity of a river can usually be estimated, within limits, by sampling and determining the beta activity at high, medium, and low flows. Whenever samples contain appreciable amounts of beta activity, they may be checked for type of growth or decay. If periodic beta counting indicates radioactive decay, then a beta-decay curve will show whether or not the beta activity may be attributed to mixed-fission-product fallout or to naturally occurring radionuclides (Eisenbud, 1963). Any sample showing mixed-fission-product activity must be eliminated from consideration when establishing normal background levels unless the proportion of fission-product activity can be measured.

Natural beta activity was found in all samples collected. Beta-activity averages for all rivers (table 3) show no apparent relation to discharge, the averages for low, medium, and high flows being 8.8, 6.9, and 11.6, respectively. In addition, unidentified beta activity, not directly attributable to natural radioelements, was detected; this probably originated as fallout.

Anomalous high beta concentrations were noted for some rivers of the Southwest, Southeast, and Gulf coasts. Decay curves of beta activity were plotted for some of the samples collected in October 1960 and March 1962. The decay curves were made by counting the beta activity of the samples several times over a period of 2 months or longer and then plotting the data on logarithmic graph paper. The estimated naturally occurring beta activity was subtracted, and then the decay data indicated a decay rate similar to that commonly observed for mixed-fission products.

The apparent decay rate was estimated by the formula

$$A=A_0t^{-1.2},$$

Where A= the activity of the sample in counts per minute at any time after formation of the nuclides,

A_0= activity at unit time (counts per minute) after formation of the nuclides,

and t= time in days after formation of the nuclides at which A is measured.

A graphical solution of the counting data indicated that the anomalous beta activity of some rivers was decaying as activity from fission products 4–6 months old at the time of collection. Such fission products probably were formed in nuclear explosions which occurred in northern Russia during the fall and winter of 1961.

Figure 1 illustrates decaying beta activity (after beta activity attributable to natural radionuclides had been subtracted) for two rivers on the South Atlantic slope. Extrapolation of the decay curves indicated that the Roanoke River, which had a total beta activity of about 37 pc/l when first counted (June 25, 1962), probably had an activity of more than 80 pc/l at the time of collection (Mar. 12, 1962). Also shown is a similar decay curve for a sample from the Tar River.

Figure 2 indicates that earlier samples from the Roanoke and Dan Rivers (collected Dec. 19, 1961) had lesser amounts of fission-product activity. Similar decay studies were made for other streams in this

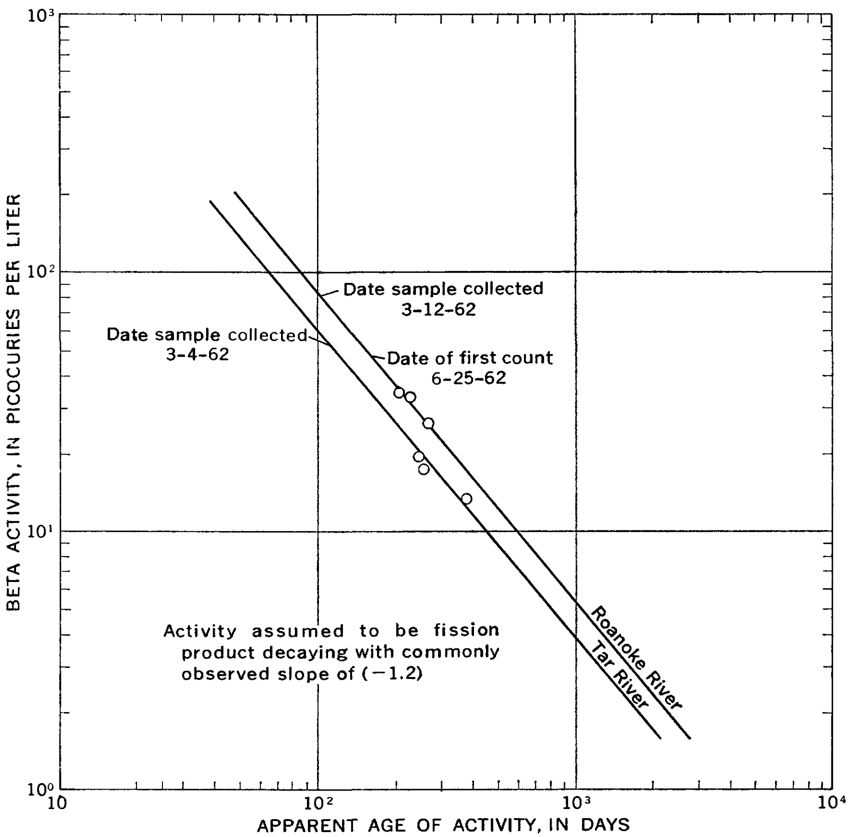

FIGURE 1.—Beta-decay curves for the Roanoke and Tar Rivers.

area. Most of the studies indicated that fission activity was produced by the Russian test series in the fall of 1961. The reason for the higher beta activities of the later samples is that in the spring there ocurs a peak release of stratospheric fallout nuclides to the atmosphere.

The equation $A=A_o\ t^{-1.2}$ (Glasstone, 1957), used in the extrapolation of the fission product activity for figures 1 and 2, seemed to fit the data, as well as other exponents, when correlated to the nuclear test periods of the U.S.S.R. The equation appears to work fairly well for fission products with ages of 1 hour to 200 days. In this study the equation was used to extrapolate the data for older activities (380 days maximum) to the time of the Russian blasts of 1961 with fairly good results. Prior investigations by one of the authors (Johnson) indicate that the equation for fission products from the Nevada test site during atmospheric testing varied from $A=A_o\ t^{-0.8}$ to $A=A_o\ t^{-1.4}$, with the average exponent of t close to -1.2.

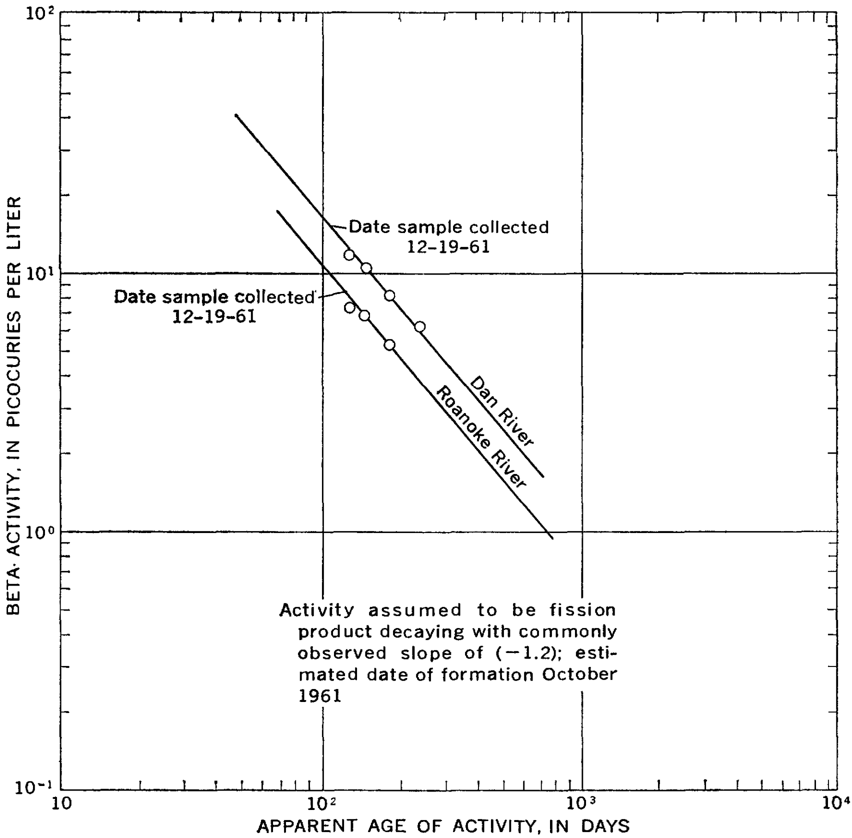

FIGURE 2.—Beta-decay curves for the Roanoke and Dan Rivers.

URANIUM-SOLUTE LOAD

The pounds of uranium carried in solution by each river past the stream-gaging stations during water year 1960–61 was estimated as follows: The total average discharge in cubic feet per second for a flow period was multiplied by the micrograms per liter of uranium found in that flow and by the factor 53.9×10^{-4}. (The conversion factor 6.24×10^{-8} can be used to change micrograms per liter to pounds per cubic foot. The factor 86,400 changes the total discharge in cubic feet per second to cubic feet per day. These two factors can be combined to give the factor 5.39×10^{-4}.) Summations of the total solute loads for low, medium, and high flows for water year 1960–61 are shown in table 4).

In tables 6–8, flow volumes are shown both in cubic feet per second and cubic meters per second. Amounts of materials transported are in both pounds and kilograms. Kilograms and cubic meters per second are not rounded off in these tables because the rounding off process produces totals that do not balance with pounds and cubic feet per second totals.

Total average discharges were determined from data published in the annual releases of basic-data streamflow records and related data for each State by the Geological Survey in cooperation with various respective State agencies.

Samples collected for other projects from the Colorado River between Dewey and Moab, Utah, in the heart of the Colorado Plateau uranium operations, have been analyzed by the Water Resources Division. These analytical data show that uranium concentrations in this region commonly are greater than 20 $\mu g/l$. However, after the river passed through several large resorvoirs, the uranium concentrations at Yuma, Ariz., ranged from 6.6 to 7.6 $\mu g/l$. Dilution accounts for a large part, if not most, of the decrease of uranium in solution. The mean flow of the Colorado River near Cisco, Utah, from October 1960 to September 1961 was 4,260 cfs (cubic feet per second) and, during the same period, the mean flow of the Colorado River near Grand Canyon was 11,960 cfs. Of unevaluated importance in the decrease of uranium concentrations is the extraction of uranium from solution by algae and other biota and the precipitation or ion exchange of uranium with sedimentation in the reservoirs.

The sampling site on the Colorado is at gaging station 9–5210 at Yuma, Ariz. However, to obtain a more realistic figure of the contribution of radioelements to the Gulf of California, the surface-water data for gaging station 9–5222, at San Luis, Ariz., about 26 miles downstream, was used instead. No uranium figures were available for this site, so the ones obtained from Yuma were used in calculations.

RADIUM-SOLUTE LOAD

Radium was measured in picocuries per liter. One picocurie is equivalent to 10^{-12} grams per liter. The following formula was used to calculate the approximate amount of radium carried in solution by each river past the stream-gaging stations during water year 1960–61:

$$\text{Total average flow in cubic feet per second for flow period} \times \text{average radium value} \times 53.9 \times 10^{-10}$$

The conversion factor 6.24×10^{-14}, used to change picocuries of radium per liter to pounds of radium per cubic foot, multiplied by 8.64^4 gives the factor 53.9×10^{-10}.

Summations of solute-radium loads for low, medium, and high flows and the total load for water year 1960–61 are shown in table 5. Radium values are expressed as pounds × 10^{-5} in order to simplify the tables.

Commonly, rivers carry only a few tenths of a picocurie per liter of radium in solution. The samples collected July 20, 1961, from the Colorado River and October 14, 1960, from the San Joaquin River were the only samples in which the radium concentration exceeded 1 pc/l. A possible explanation for these anomalies could be that summer storms or large discharges of irrigation waste water would contribute much suspended material to these rivers. Suspended material carrying adsorbed radium could easily increase the radium concentration of streams through desorption brought about by chemical disequilibrium conditions generated when two very different waters meet.

URANIUM AND RADIUM CONTRIBUTED TO OCEANS

Data determined on the sampled rivers were used to estimate the amount of uranium in solution contributed to the oceans from the conterminous United States. The method of estimation and resulting conclusions are shown in table 6–8. In table 6, the average discharge in cubic feet per second of a sampled river at the sampling site during water year 1960–61 (column 2) was compared with the long-range average discharge at the same site (column 1). Comparing column 2 with column 1 gave the excess or deficiency of flow for a river during water year 1960–61 (column 3). Dividing the total of column 3 by the total of column 1 gave the percentage excess or deficiency of flow of sampled rivers in a major basin area (column 4). The percentage excess or deficiency was used to adjust the total average discharge for major basin areas (column 1 of tables 7 and 8).

In tables 7 and 8, column 2 shows total average discharge at sampling sites of sampled rivers of major basin areas during water year 1960–61 (obtained from column 2 of table 6). Column 1 shows the total average discharge of all the rivers for major basin areas, adjusted according to the percentage excess or deficiency of flow of sampled rivers. Total discharges from major basin areas were obtained from information supplied by Wilson and others (1967). Dividing column 2 by column 1 gives the percentage of major basin discharge carried by sampled rivers (column 3). Column 4, the total amount of uranium or radium carried by sampled rivers for water year 1960–61, is obtained from the last column of table 4 or 5. The estimated total uranium or radium carried from the major basins for this water year (column 5) was obtained by comparing the total uranium or radium carried by the sampled rivers and the percentage of major basin area discharge represented by the sampled rivers.

Calculated total uranium load carried from conterminous United States during water year 1960–61 was about 2 million pounds, and calculated total radium load was about two-thirds of a pound.

SUMMARY

Beta activity, uranium, and radium were determined for 36 major rivers in the continental United States during low, medium, and high flows of water year 1960–61. Total solute-uranium and -radium loads at sampling sites for the year were then estimated. The percentage of major basin-area discharge carried by sampled rivers in the basins was determined. Then, using the total solute load estimates of sampled rivers, the amount of uranium and radium carried from basin areas during the water year was estimated. The totals gave an estimation of the uranium and radium carried in solution from the conterminous United States.

The amounts of uranium and radium derived in this report are presented as estimates, not exact determinations. Obviously, accuracy would have been increased by locating sampling sites closer to the oceans and by sampling more rivers, but practical considerations limited sampling to sites of on-going stream-gaging and water-quality programs.

The research work for this paper has raised other questions. Is there a correlation between increased radium, sediments, and high flows? Do certain geologic formations which lie at the surface of large drainage areas account for high radium or uranium solute loads? How much uranium and radium in solution is being adsorbed by sediments deposited behind large dams? The authors hope that this study has presented facts or suggested questions which will encourage further research.

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TABLES 1–8

TABLE 1.—*Chemical analysis in parts per million and radiochemical analysis in picocuries per liter of river waters on indicated dates*

[L=low, M=medium, H=high]

Sampling site on plate 1	River	Type of flow	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Orthophosphate (PO_4)	Dissolved solids (residue at 180° C.)	Hardness as $CaCO_3$	Specific conductance (μmhos at 25° C.)	pH	Beta-gamma activity (pc/l)	Radium (Ra) (pc/l)	Uranium (U) (μg/l)	Date sampled
											North Atlantic slope basin														
1	Penobscot	L	3.1	0.6	0.28	0.16	6.8	0.2	3.6	0.5	4	0	8.0	1.5	0.2	2.7	------	72	18	65	5.1	4.4	0.1	<0.4	10-19-60
		M	3.6	.3	.06	.0	4.0	1.0	3.7	.6	13	0	9.0	2.0	.0	.5	0.00	37	2	53	6.1	5.6	<.1	<.4	6-21-61
		H	4.6	.2	.40	.00	4.8	1.0	2.2	.8	10	0	7.0	2.8	.1	1.9	.01	42	16	47	5.8	2.9	<.1	<.4	4-25-61
2	Carrabasset	L	22	.0	.00	.00	.0	4.4	2.6	1.6	16	0	9.0	2.0	.1	.3	.00	32	18	45	6.7	2.3	.1	<.4	10-18-60
		L	6.7	.1	1.9	.0	3.6	1.0	2.2	.8	13	0	5.0	2.0	.0	.1	.00	21	13	39	6.6	2.7	<.1	<.4	6-19-61
		M	5.2	.2	.02	.00	2.0	1.0	1.7	.8	8	0	5.0	2.0	.0	.6	.00	32	9	30	6.2	2.0	<.1	<.4	4-12-61
3	Nezinscot	L	20	.0	.03	.00	.0	4.9	2.8	2.0	20	0	7.0	4.0	.1	.0	.02	39	20	55	6.7	3.6	<.1	<.4	10-18-60
		L	5.7	.3	.06	.0	4.8	.7	2.6	1.2	15	0	5.0	3.0	.0	.4	.00	21	15	44	6.6	4.5	<.1	<.4	6- 8-61
		M	6.2	.2	.02	.00	3.2	.5	1.8	.8	7	0	5.0	3.0	.0	.3	.00	34	10	34	6.1	2.2	<.1	<.4	4-14-61
4	Hudson	L	5.0	.89	.37	.00	9.2	1.7	5.8	1.6	24	0	15	6.0	.2	1.0	.10	71	30	96	6.0	2.3	<.1	<.4	8-17-61
		M	6.5	.4	.12	.0	11	5.4	4.2	.8	38	0	17	6.0	.0	1.0	.04	75	55	113	6.3	2.5	<.1	<.4	5-23-61
		H	5.2	.3	.06	.00	7.6	1.9	4.8	.8	21	0	13	3.0	.1	1.4	.10	53	27	72	6.4	2.6	.1	<.4	4-26-61
5	Delaware	L	1.4	.1	.04	.06	17	4.1	3.5	1.3	49	0	24	3.5	.2	2.0	------	82	60	141	7.7	2.8	.5	<.4	10-11-60
		M	3.1	[1].12	[1].20	[1].00	14	4.4	3.4	1.8	38	0	21	5.0	.1	2.6	.00	65	53	127	6.9	7.5	<.1	<.4	5-17-62
		H	3.6	.0	.00	.00	8.6	2.6	2.2	2.4	18	0	17	3.2	.1	2.6	.00	46	32	86	6.6	14	<.1	<.4	4-11-62
6	Susquehanna	L	3.6	[1].1	[1].04	[1].00	31	10	6.6	2.2	67	0	63	8.0	.1	2.7	.08	167	118	281	7.2	5.0	.4	.6	7-19-61
		M	2.1	.2	.08	.00	26	7.5	5.2	2.0	54	0	52	7.0	.0	2.1	.04	133	96	231	6.7	5.6	<.2	<.4	6- 2-61
		H	6.2	.0	.00	.10	21	5.4	3.5	1.4	35	0	39	7.0	.0	4.8	.06	104	75	173	6.5	2.5	<.1	<.4	3-16-61
7	Potomac	L	3.8	.2	.10	.00	34	7.3	8.0	2.4	80	0	51	8.0	.1	.7	.08	157	115	269	7.4	3.3	<.1	<.4	8-21-61
		M	4.6	.65	.50	.15	27	5.8	7.0	2.2	60	0	43	11	.1	2.4	.40	139	91	234	7.2	2.2	<.1	<.4	1- 9-61
		H	5.9	.0	.00	.00	12	3.9	1.8	2.8	26	0	26	2.0	.0	4.0	.06	71	46	112	5.9	5.5	.4	.6	2-20-61
8	Rappahannock	L	14	.2	.03	.62	4.8	2.9	4.3	3.0	24	0	14	1.5	.1	.7	.02	49	24	60	7.0	3.1	<.1	<.4	12-17-60
		M	12	.05	.00	.00	4.8	3.9	2.6	.8	18	0	10	5.0	.1	1.8	.02	33	28	55	6.8	3.4	.1	<.4	4-29-61
		H	11	.29	.00	.00	4.0	2.2	2.3	2.0	12	0	7.7	3.2	.1	5.5	.10	52	19	59	6.4	12	.2	<.4	1-14-63

	St. Lawrence River basin																							
9	Genesee	L	3.6	0.1	0.00	0.00	62	13	21	1.4	137	0	85	42	0.2	2.9	0.04	304	208	521	7.2	6.7	<.1	<0.4	7-26-61
		M	3.6	.3	.20	.00	55	12	15	1.0	131	0	71	26	.1	2.1	.20	260	187	443	7.6	4.2	.3	<.4	5-25-61
		H	4.6	.2	.03	.00	29	7.1	6.2	2.0	78	0	36	11	.0	2.7	.04	154	102	243	8.1	5.4	.3	<.4	5- 3-61
	South Atlantic slope basin																							
10	Roanoke	L	23	0.0	0.00	1.2	11	5.1	5.9	3.2	56	0	8.0	6.0	0.1	0.0	0.10	72	48	122	7.4	1.7	<0.1	<0.4	11-29-60
		M	12	.0	.03	.00	8.4	2.9	5.8	2.8	37	0	7.0	6.0	.0	2.0	.09	56	33	96	6.6	4.3	.2	<.4	6-22-61
		H	10	[1]1.3	[1]3.0	[1].8	6.6	2.3	3.0	2.4	26	0	10	3.2	.2	.0	.00	65	26	71	6.3	37	<.1	<.4	3-12-62
11	Dan	L	20	.1	.03	.06	4.0	3.4	14	2.8	48	0	7.0	8.0	.1	.0	.17	76	24	112	7.3	2.3	<.1	<.4	11-29-60
		M	15	.1	.03	.00	4.8	1.7	7.1	2.0	30	0	7.0	4.0	.0	.6	.10	45	19	77	6.6	5.1	.3	.4	6-22-61
		H	21	.00	.08	.00	4.1	1.3	5.0	3.2	16	0	9.0	4.1	.1	1.7	.00	45	16	54	6.6	19	.1	<.4	3-13-62
12	Tar	L	27	.41	1.1	.00	4.8	2.4	7.9	.0	28	0	3.8	8.2	.1	.7	.60	58	22	85	6.6	12	<.1	<.4	5-19-62
		M	12	.3	1.3	.00	5.6	2.9	4.6	.8	20	0	8.0	7.0	.1	1.0	.08	37	26	64	6.5	3.3	<.2	<.4	4-19-61
		H	11	[1].28	[1]1.2	[1].00	4.8	.7	4.5	2.4	12	0	11	5.0	.3	.0	.10	53	15	55	6.4	21	.1	<.4	3- 4-62
13	Neuse	L	17	.0	.45	1.2	4.8	1.9	9.2	3.2	26	0	9.0	10	.1	.1	.25	63	20	84	6.8	9.6	.1	.4	12- 1-60
		M	7.7	.34	.78	.00	4.1	2.4	5.8	2.0	12	0	13	7.0	.1	2.4	.36	51	20	69	6.3	29	.1	<.4	7- 3-62
		H	9.0	.53	1.2	.00	6.2	.0	5.7	3.6	10	0	12	7.0	.1	.6	.00	76	16	66	6.6	23	.2	<.4	3- 3-62
14	Cape Fear	L	7.5	.2	.13	.72	3.2	1.9	7.2	4.0	24	0	1.0	10	.2	.0	.36	52	16	85	6.9	3.6	<.1	<.4	12- 1-60
		M	9.0	[1].42	[1].88	[1].00	4.0	.7	5.7	1.2	10	0	8.6	6.6	.1	.0	.00	65	13	54	6.4	18	.1	<.4	3- 4-62
		H	7.2	[1]2.9	[1].34	[1].00	3.3	1.5	4.5	3.0	12	0	8.6	6.3	.1	1.4	.28	64	14	65	6.1	26	.2	.4	11-13-62
15	Yadkin	L	13	.0	.06	.00	4.0	1.5	4.7	2.0	20	0	6.0	4.0	.4	1.5	.48	48	16	67	6.4	7.9	.1	<.4	12-15-60
		M	8.8	.0	.02	.00	3.6	.7	3.0	2.4	12	0	7.0	3.0	.0	1.8	.00	23	12	43	6.1	6.9	.6	<.4	6-22-61
		H	7.5	14	.00	.00	2.2	1.5	1.6	3.0	8.4	0	5.2	2.5	.0	2.4	.34	97	12	44	5.8	33	.6	.7	3- 7-63
16	Altamaha	L	12	.0	.00	.80	8.0	1.9	5.8	3.0	38	0	7.0	5.0	.1	.0	.51	59	28	63	7.1	3.5	<.1	<.4	1-20-61
		L	14	.1	.12	.18	9.6	.7	5.2	1.4	36	0	4.5	4.0	.3	1.1	......	62	27	80	7.4	3.5	.1	<.4	10-13-60
		H	8.7	.00	.17	.00	4.8	.9	2.8	2.8	17	0	2.9	4.2	.1	.2	.00	50	16	46	6.4	18	<.1	.4	4- 3-62
17	St. Johns	L	2.0	[1].3	[1].06	1.00	58	25	159	5.2	56	0	79	328	.1	2.4	.24	837	248	1,380	6.7	2.0	.1	.7	7-12-61
		M	12	.0	.13	.00	12	9.7	32	1.9	30	0	9.0	79	.5	1.4	.11	220	70	364	6.8	12	.2	<.4	1- 3-61
		H	3.0	.7	.03	.00	8.0	1.9	21	1.0	26	0	14	24	1.0	1.1	.15	89	28	130	6.6	5.2	.1	<.4	10-7-60

TABLE 1.—*Chemical analysis in parts per million and radiochemical analysis in picocuries per liter of river waters on indicated dates*—Con.

Sampling site on plate 1	River	Type of flow	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Orthophosphate (PO_4)	Dissolved solids (residue at 180° C.)	Hardness as $CaCO_3$	Specific conductance (μmhos at 25° C.)	pH	Beta-gamma activity (pc/l)	Radium (Ra) (pc/l)	Uranium (U) (μg/l)	Date sampled
Gulf of Mexico basin																									
18	Suwannee	L	7.6	0.12	0.10	0.00	51	6.9	4.5	0.6	163	0	23	5.1	0.1	1.2	0.22	185	156	317	7.4	2.6	<0.1	<.4	10-26-61
		L	7.0	.20	.22	.00	31	6.3	4.2	1.0	99	0	15	7.0	.3	.0	.24	140	104	206	7.0	28	.1	<.4	1-22-63
		M	5.1	1.2	.13	.00	23	2.4	2.1	2.5	67	0	3.9	4.0	.2	4.8	1.0	110	67	134	6.9	5.0	.3	<.4	10-12-60
19	Apalachicola	L	8.0	.1	.03	.00	13	1.0	3.8	1.0	48	0	4.0	3.0	.1	1.2	.06	63	37	94	6.7	2.8	<.1	<.4	9-22-61
		L	8.4	.0	.09	.08	12	.5	4.0	1.0	42	0	1.4	3.5	.2	.8	------	56	32	85	7.0	2.3	<.1	<.4	10-12-60
		M																				3.1	<.1	<.4	1-14-66
		H	7.7	.67	.61	.00	3.2	1.9	1.5	2.4	12	0	7.0	2.0	.1	1.8	.26	48	16	46	5.9	3.7	.2	<.4	2-27-61
20	Pearl	L	29	.0	.00	.00	.0	4.9	6.8	2.0	16	0	13	8.0	.5	.0	.00	72	20	105	6.2	16	.2	<.4	10-18-60
		M	13	.05	.00	.00	4.8	1.9	6.6	.6	16	0	13	10	.1	1.2	.06	55	28	80	6.5	2.4	.1	.6	6- 6-61
		H	8.7	[1].62	[1]1.1	[1].00	3.2	.9	3.7	2.4	10	0	5.2	5.5	.1	.0	.00	57	12	43	6.6	20	.3	<.4	3- 9-62
21	Missouri	L																				15	.1	6.6	1-19-65
		M	13	.0	.00	.00	62									2.7	.28	469	241	735	7.9	11	.1	3.5	5-15-61
		M	11	.1	.53	.35	61	21	58	5.8	208	0	165	19	.5	2.1	------	454	227	690	8.2	12	.1	1.8	10-31-60
		M	15	.0	.00	.0	64	18	61	5.4	198	0	177	16	.5	2.6	.26	428	246	710	7.4	10	.1	3.3	6-27-61
		H						21	56	7.0	201	0	164	18	.4							16	>.1	1.3	5-28-65
22	Mississippi	L	22	.0	.00	.00	42	17	27	2.4	154	0	61	32	.3	.0	.02	276	175	487	7.4	12	.1	1.3	10-18-60
		M	7.7	.2	.04	.00	37	11	14	2.8	113	0	44	17	.1	4.0	.16	195	138	328	7.8	6.3	.4	<0.4	7- 5-61
		H	7.2	[1].34	[1].50	[1].00	31	8.4	14	2.4	87	0	37	20	.2	2.8	.18	192	112	300	7.5	24	.2	<0.4	3- 6-62
23	Red	L	10	[1].15	[1].00	[1].00	54	13	67	2.0	142	0	69	105	.2	1.0	.16	360	188	707	7.6	7.9	.2	1.2	6- 1-61
		M	5.0	.6	.03	.00	50	14	72	5.0	144	0	61	108	.2	.0	.22	404	183	697	6.4	13	.2	.9	10-26-60
		H	8.8	.6	.00	.00	25	7.3	20	3.6	81	0	22	32	.0	1.1	.21	177	92	280	7.1	2.6	.5	.6	2-28-61
24	Sabine	L	16	.4	.35	.00	8.8	3.9	26	2.2	31	0	17	39	.0	.9	.08	144	38	225	6.6	4.0	.2	<.4	5-10-61
		H	13	.4	.22	.00	4.8	.5	6.6	2.8	8	0	8.0	12	.2	.0	.16	63	14	80	6.4	4.6	.1	<.4	1-12-61
25	Neches	L	13	.20	.23	.00	11	4.7	22	3.6	24	0	31	34	.2	.00	.00	151	47	230	6.7	17	<.1	<.4	3-29-62
		M	13	.6	.50	.00	7.2	3.9	14	2.4	22	0	19	20	.2	1.4	.09	119	34	145	6.2	8.5	.1	<.4	4- 6-61
		H	17	.2	.27	1.2	3.2	2.4	8.8	2.8	10	0	14	12	.2	.0	.00	79	18	83	6.4	4.3	.1	<.4	1-12-61
26	Trinity	L	14	.00	.00	.00	52	7.8	81	6.0	128	0	77	115	.3	3.2	.66	419	162	706	7.3	24	.1	.5	3-29-62
		M	9.2	.2	.10	.00	42	3.9	21	4.0	121	0	35	22	.3	3.2	.38	211	121	342	7.3	8.7	.3	<.4	4- 5-61
		H	17	.4	.30	1.2	11	5.4	9.5	4.0	40	0	27	11	.2	.0	.26	126	50	155	6.9	6.2	.2	.5	1-11-61

27	Brazos	L	9.2	.1	.00	.00	77	13	63	4.0	195	0	85	89	.3	5.4	.11	460	246	774	7.7	9.4	.5	<.4	4- 4-61
		L	7.7	.00	.00	.00	90	18	126	5.2	199	0	125	192	.2	1.3	.10	672	298	1,130	7.6	32	.2	1.2	3-30-62
		H	9.5	.0	.00	1.0	38	9.2	18	4.2	136	0	34	22	.2	.0	.08	214	133	358	7.7	8.9	.9	<.4	1-11-60
28	Guadalupe	L	15	.0	.03	.00	77	21	28	2.4	291	0	35	43	.2	8.2	.06	390	278	664	7.6	5.0	.3	.8	4- 4-61
		L	13	.03	.00	.00	70	19	38	3.2	260	0	43	59	.2	3.6	.08	346	252	659	7.8	17	.1	.8	3-30-62
		H	12	.3	.20	.33	36	2.2	4.9	3.7	119	0	6.6	5.0	.6	1.9	......	140	98	217	7.8	6.9	.3	<.4	10-29-60
29	Rio Grande	L	26	.1	.04	.06	84	18	242	8.7	258	0	313	203	.5	.2	......	1,030	284	1,600	8.1	15	.2	1.6	10-11-60
		M	26	.1	.44	.32	76	13	102	5.4	211	0	174	81	.4	1.0	......	590	244	908	8.2	13	.2	2.5	11-30-60
		H	26	.1	.00	.00	61	11	62	4.8	175	0	130	34	.5	2.9	.51	434	197	665	7.4	8.3	.4	.9	4-12-61

Colorado River basin

30	Colorado	L	11	0.1	0.16	0.12	123	42	216	5.0	201	0	378	288	0.3	0.8	......	1,200	480	1,860	8.2	24	.2	6.7	12-20-60
		M	18	.1	.03	.00	217	88	518	8.0	233	0	524	885	.4	2.8	.04	2,400	904	3,950	7.9	11	.1	7.6	5-11-61
		H	17	.1	.08	......	166	65	362	7.0	203	0	440	588	.6	2.4	.14	2,000	682	2,960	7.9	17	4.5	6.6	7-20-61

Pacific slope basin

31	San Joaquin	L	30	0.1	0.01	0.00	72	34	172	8.2	183	0	77	350	0.0	4.9	0.55	812	319	1,420	8.0	14	.3	7.1	5- 4-61
		M	28	.0	.00	.00	67	31	164	6.4	171	0	118	268	.0	6.1	.51	796	295	1,400	7.1	11	.1	8.0	3- 9-61
		H	110	.0	.06	.00	40	27	72	6.6	166	0	23	148	.4	.0	.13	552	211	919	7.5	13	1.2	5.1	10-14-60
32	Sacramento	L	33	.0	.03	.00	7.2	8.3	8.8	4.4	80	0	5.0	4.0	.3	.3	.00	94	52	145	7.7	5.1	.1	<.4	10-14-60
		M	25	.0	.00	.00	12	5.8	7.3	1.7	68	0	9.0	5.0	.0	.4	.14	98	54	138	6.9	1.9	<.1	<.4	3-13-61
		H	25	.1	.03	.00	13	6.8	7.6	2.4	74	0	11	3.0	.0	.5	.60	103	60	147	7.5	1.9	<.1	<.4	5-14-61
33	Klamath	L	35	.0	.03	.00	14	11	9.6	1.6	100	0	9.0	6.0	.2	1.1	.47	121	80	194	7.5	4.0	.1	<.4	10-12-60
		M	16	.1	.01	.00	11	5.6	3.8	1.2	60	0	9.0	1.0	.0	.3	.06	81	51	119	7.5	1.8	<.1	<.4	5- 9-61
		H	15	.3	.00	.00	13	7.3	5.6	0.8	70	0	10	4.0	.0	.5	.23	92	62	143	7.1	1.5	<.1	<.4	3- 8-61
34	Columbia	L	17	.0	.00	.00	17	6.3	7.1	1.8	74	0	17	6.0	.0	1.4	.45	112	68	168	6.7	14	<.1	.8	3-31-61
		L	10	.0	.03	.00	23	5.4	11	1.5	93	0	19	5.0	.2	.6	......	118	79	204	7.8	17	.1	1.4	9-30-60
		H	11	.1	.00	.00	14	3.2	2.4	1.6	53	0	11	.0	.0	.9	.08	73	48	111	6.9	7.3	<.2	.5	6- 1-61

Yukon River

35	Yukon	L	7.7	0.1	0.08	0.00	40	9.5	3.2	1.6	142	0	27	2.5	0.1	1.1	0.01	170	139	285	7.6	3.6	.1	1.4	4-19-61
		M	5.9	.6	1.9	.00	30	7.8	2.6	1.4	102	0	27	.5	.1	.2	.06	130	107	211	7.3	2.9	.1	.5	9-17-61
		H	5.0	.4	.03	.00	24	5.8	1.1	.6	84	0	13	3.0	.2	1.1	.04	7	84	163	7.4	3.2	.3	.4	6- 6-61

Red River (North)

36	Red	L	9.8	0.2	0.00	0.00	52	32	21	5.0	271	0	61	14	0.2	4.9	0.76	346	261	581	7.5	11	.4	1.1	7- 8-61
		L	6.5	.2	.08	.11	55	30	19	5.6	294	0	50	9.5	.5	2.3	......	332	260	549	7.6	14	<.1	.7	10-24-60
		M	13	.1	.02	.00	59	28	20	.8	265	0	71	11	.0	2.8	.48	357	262	581	7.8	10	.1	1.4	4-17-61
		H	10	......	.05	......	44	18	12	6.8	153	0	69	8.2	.2	5.5	......	......	184	405	7.0	53	.4	1.3	4-15-64

[1] In solution at time of analysis.

TABLE 2.—*Range of discharge and total time of low, medium, and high flows for each sampling site during water year 1960–61*

Sampling site	River	Low flow		Medium flow		High flow	
		Range (cfs)	Number of days	Range (cfs)	Number of days	Range (cfs)	Number of days
1	Penobscot	3, 500–28, 767	321	28, 767–54, 033	40	54, 033–79, 300	4
2	Carrabassett	65–1, 520	320	1, 520–2, 975	29	2, 975–4, 430	16
3	Nezinscot	12–828	340	828–1, 644	22	1, 644–2, 460	3
4	Hudson	1, 920–26, 580	341	26, 580–51, 240	21	51, 240–75, 900	3
5	Delaware	2, 900–31, 833	345	31, 833–60, 767	18	60, 767–89, 700	2
6	Susquehanna	2, 990–129, 327	347	129, 327–255, 663	15	255, 663–382, 000	3
7	Potomac	455–17, 270	346	17, 270–34, 085	16	34, 085–50, 900	3
8	Rappahannock	103–3, 202	352	3, 202–6, 301	10	6, 301–9, 400	3
9	Genesee	91–4, 494	310	4, 494 8, 897	24	8, 897–13, 300	31
10	Roanoke	860–7, 973	347	7, 973–15, 087	17	15, 087–22, 200	1
11	Dan	820–6, 780	344	6, 780–12, 740	15	12, 740–18, 700	6
12	Tar	278–4, 519	312	4, 519–8, 759	42	8, 759–13, 000	11
13	Neuse	601–5, 101	283	5, 101–9, 600	72	9, 600–14, 100	10
14	Cape Fear	760–11, 673	328	11, 673–22, 587	26	22, 587–33, 500	11
15	Yadkin	1, 170–6, 113	343	6, 113–11, 057	16	11, 057–16, 000	6
16	Altamaha	3, 010–29, 140	327	29, 140–55, 270	18	55, 270–81, 400	20
17	St. Johns	98–3, 632	319	3, 632–7, 166	24	7, 166–10, 700	22
18	Suwannee	6, 780–11, 620	258	11, 620–16, 460	86	16, 460–21, 300	21
19	Apalachicola	8, 850–50, 567	333	50, 567–92, 283	25	92, 283–134, 000	7
20	Pearl	1, 640–29, 660	306	29, 660–57, 680	52	57, 680–85, 700	7
21	Missouri	6, 090–21, 160	96	21, 160–36, 230	236	36, 230–51, 300	33
22	Mississippi	187, 000–650, 667	243	650, 667–1, 114, 333	64	1, 114, 333–1, 578, 000	58
23	Red	5, 300–48, 200	295	48, 200–91, 100	53	91, 100–134, 000	17
24	Sabine	1, 400–18, 400	253	18, 400–35, 400	97	35, 400–52, 400	15
25	Neches	584–13, 856	241	13, 856–27, 128	94	27, 128–40, 400	30
26	Trinity	580–16, 420	288	16, 420–32, 260	34	32, 260–48, 100	43
27	Brazos	932–26, 455	303	26, 455–51, 977	39	51, 977–77, 500	23
28	Guadalupe	750–16, 500	345	16, 500–32, 250	17	32, 250–48, 000	3
29	Rio Grande	9–1, 323	317	1, 323–2, 636	42	2, 636–3, 950	6
30	Colorado	2–2, 038	347	2, 038–4, 074	3	4, 074–6, 110	15
31	San Joaquin	30–550	216	550–1, 070	61	1, 070–1, 590	88
32	Sacramento	4, 600–12, 700	321	12, 700–20, 800	22	20, 800–28, 900	22
33	Klamath	2, 150–37, 100	334	37, 100–72, 050	29	72, 050–107, 000	2
34	Columbia	80, 200–286, 500	312	286, 500–492, 700	23	492, 700–699, 000	30
35	Yukon	15, 000–179, 333	247	179, 333–343, 667	80	343, 667–508, 000	38
36	Red (North)	119–1, 186	286	1, 186–2, 253	54	2, 253–3, 320	25

TABLE 3.—*Radioactive content of river waters*

[NS, not sampled]

Sampling site	River	Approximate location	Beta activity (pc/l)			Radium (pc/l)			Uranium (µg/l)		
			Low flow	Medium flow	High flow	Low flow	Medium flow	High flow	Low flow	Medium flow	High flow
			North Atlantic slope basins								
1	Penobscot	West Enfield, Maine	4.4	5.6	2.9	0.1	<0.1	<0.1	<0.4	<0.4	<0.4
2	Carrabasset	North Anson, Maine	2.5	2.0	[1] NS	.1	<.1	[1] <.1	<.4	<.4	[1] <.4
3	Nezinscot	Turner Center, Maine	4.0	2.2	NS	<.1	<.1	[1] <.1	<.4	<.4	[1] <.4
4	Hudson	Green Island, N.Y	2.3	2.5	2.6	<.1	<.1	.1	<.4	<.4	<.4
5	Delaware	Trenton, N.J	2.8	7.5	14	.5	<.1	<.1	<.4	<.4	<.4
6	Susquehanna	Harrisburg, Pa	5.0	5.6	2.5	.4	<.2	<.1	.6	<.4	<.4
7	Potomac	Hancock, Md	3.3	2.2	5.5	<.1	<.1	.4	<.4	<.4	.6
8	Rappahannock	Remington, Va	3.1	3.4	12	<.1	.1	.2	<.4	<.4	<.4
			St. Lawrence River basin								
9	Genesee	Rochester, N.Y	6.7	4.2	5.4	<0.1	0.3	0.3	<0.4	<0.4	<0.4
			South Atlantic slope basins								
10	Roanoke	Randolph, Va	1.7	4.3	37	<0.1	0.2	<0.1	<0.4	<0.4	<0.4
11	Dan	Paces, Va	2.3	5.1	19	<.1	.3	.1	<.4	.4	<.4
12	Tar	Tarboro, N.C	12	3.3	21	<.1	<.2	.1	<.4	<.4	<.4
13	Neuse	Kinston, N.C	9.6	29	23	.1	.1	.2	.4	<.4	<.4
14	Cape Fear	Tar Heel, N.C	3.6	18	26	<.1	.1	.2	<.4	<.4	.4
15	Yadkin	Yadkin College, N.C	7.9	6.9	33	.1	.6	.6	<.4	<.4	.7
16	Altamaha	Doctortown, Ga	3.5	NS	18	.1	[1] <.1	<.1	<.4	[1] .4	.4
17	St. Johns	Christmas, Fla	2.0	12	5.2	.1	.2	.1	.7	<.4	<.4

See footnote at end of table.

TABLE 3.—*Radioactive content of river waters*—Continued

Sampling site	River	Approximate location	Beta activity (pc/l)			Radium (pc/l)			Uranium (µg/l)		
			Low flow	Medium flow	High flow	Low flow	Medium flow	High flow	Low flow	Medium flow	High flow
		Gulf of Mexico basins									
18	Suwannee	Wilcox, Fla	15	5.0	NS	0.1	0.3	[1] 0.3	<0.4	<0.4	[1] <0.4
19	Apalachicola	Chattahoochee, Fla	2.6	3.1	3.7	<.1	<.1	.2	<.4	<.4	<.4
20	Pearl	Bogalusa, La	16	2.4	20	.2	.1	.3	<.4	.6	<.4
21	Missouri	Nebraska City, Nebr	15	11	16	.1	.1	<.1	6.6	2.9	1.3
22	Mississippi	Vicksburg, Miss	12	6.3	24	.1	.4	.2	1.3	<.4	<.4
23	Red	Alexandria, La	7.9	13	2.6	.2	.2	.5	1.2	.9	.6
24	Sabine	Ruliff, Tex	4.0	NS	4.6	.2	[1] .15	.1	<.4	[1] <.4	<.4
25	Neches	Evadale, Tex	17	8.5	4.3	<.1	.1	.1	<.4	<.4	<.4
26	Trinity	Romayor, Tex	24	8.7	6.2	.1	.3	.2	.5	<.4	.5
27	Brazos	Richmond, Tex	21	NS	8.9	.4	[1] .65	.9	.7	[1] .45	<.4
28	Guadalupe	Victoria, Tex	11	NS	6.9	.2	[1] .25	.3	.8	[1] 0.4	<.4
29	Rio Grande	San Marcial, N. Mex	15	13	8.3	.2	.2	.4	1.6	2.5	.9
		Colorado River basin									
30	Colorado [2]	Yuma, Ariz	24	11	17	0.2	0.1	4.5	6.7	7.6	6.6
		Pacific Coast basins									
31	San Joaquin	Vernalis, Calif	14	11	13	0.3	0.1	1.2	7.1	8.0	5.1
32	Sacramento	Knights Landing, Calif	5.1	1.9	1.9	.1	<.1	<.1	<.4	<.4	<.4
33	Klamath	Klamath, Calif	4.0	1.8	1.5	.1	<.1	<.1	<.4	<.4	<.4
34	Columbia	The Dalles, Oreg	16	NS	7.3	.1	[1] .1	<.2	1.1	[1] .8	.5
		Yukon River									
35	Yukon	Rampart, Alaska	3.6	2.9	3.2	0.1	0.1	0.3	1.4	0.5	0.4
		Red River (North)									
36	Red (North)	Grand Forks, N. Dak	12	10	53	0.2	0.1	0.4	0.9	1.4	1.3
	Averages		8.8	6.9	11.6	0.14	0.16	0.35	.99	.99	.65

[1] Not sampled; value extrapolated (see last part of analytical methods).
[2] Winter flow substituted for low flow. Summer flow substituted for high flow. Spring flow substituted for medium flow.

TABLE 4.—*Uranium transported in solution past sampling sites during water year 1960–61*

Sampling site	River	Low flow		Medium flow		High flow		Total	
		Pounds	Kgs calculated	Pounds	Kgs calculated	Pounds	Kgs calculated	Pounds	Kgs calculated
	North Atlantic slope basins								
1	Penobscot	3,000	1,361	1,800	816	300	136	5,100	2,313
2	Carrabasset	130	59	76	34	64	29	270	122
3	Nezinscot	64	29	29	13	6.7	3	100	45
4	Hudson	3,300	1,497	760	345	220	100	4,280	1,942
5	Delaware	3,300	1,497	790	358	170	77	4,260	1,932
6	Susquehanna	26,000	11,793	2,700	1,225	1,100	499	29,800	13,517
7	Potomac	1,100	499	380	172	550	249	2,030	920
8	Rappahannock	220	100	51	23	25	11	296	134
								46,136	20,925
	St. Lawrence River basin								
9	Genesee	440	200	180	82	350	159	970	441
								970	441
	South Atlantic slope basins								
10	Roanoke	860	390	170	77	24	11	1,054	478
11	Dan	800	363	300	136	100	45	1,200	544
12	Tar	510	231	280	127	130	59	920	417
13	Neuse	1,300	590	530	240	130	59	1,960	889
14	Cape Fear	1,000	454	440	200	340	154	1,780	808
15	Yadkin	950	431	140	64	310	141	1,400	636
16	Altamaha	3,300	1,497	1,600	726	2,800	1,270	7,700	3,493
17	St. Johns	830	376	130	59	220	100	1,180	535
								17,194	7,800

See footnotes at end of table.

TABLE 4.—*Uranium transported in solution past sampling sites during water year 1960–61*—Continued

Sampling site	River	Low flow		Medium flow		High flow		Total	
		Pounds	Kgs calculated	Pounds	Kgs calculated	Pounds	Kgs calculated	Pounds	Kgs calculated
	Gulf of Mexico basins								
18	Suwannee	2,500	1,134	1,200	544	440	200	4,140	1,878
19	Apalachicola	6,600	2,994	1,800	816	880	399	9,280	4,209
20	Pearl	1,700	771	6,600	2,994	500	227	8,800	3,992
21	Missouri	50,000	22,680	119,000	53,977	23,000	10,433	192,000	87,090
22	Mississippi	550,000	249,474	63,000	28,576	82,000	37,194	695,000	315,244
23	Red	38,000	17,236	24,000	10,886	6,300	2,858	68,300	30,980
24	Sabine	1,600	726	2,600	1,179	720	327	4,920	2,232
25	Neches	1,100	499	1,900	862	1,100	499	4,100	1,860
26	Trinity	3,700	1,678	830	376	4,400	1,996	8,930	4,050
27	Brazos	11,000	4,989	1,600	726	1,600	726	14,200	6,441
28	Guadalupe	4,000	1,814	1,600	726	140	64	5,740	2,604
29	Rio Grande	1,100	499	1,000	454	97	44	2,197	997
								[1] 1,017,607	[2] 461,577
	Colorado River basin								
30	Colorado	2,000	907	400	181	2,700	1,225	5,100	2,313
								5,100	2,313
	Pacific slope basins								
31	San Joaquin	2,100	953	2,300	1,043	3,100	1,406	7,500	3,402
32	Sacramento	2,700	1,225	740	336	600	272	4,040	1,833
33	Klamath	4,000	1,814	1,500	680	220	100	5,720	2,594
34	Columbia	250,000	113,397	23,000	10,433	40,000	18,144	313,000	141,974
								330,260	149,803

Yukon River								
35 Yukon	120,000	54,430	54,000	24,494	89,000	40,370	263,000	119,294
							263,000	119,294
Red River (North)								
36 Red (North)	570	259	350	159	470	213	1,390	631
							1,390	631

[1] Subtract 260,300 pounds from this total for Missouri and Red Rivers, which discharge into Mississippi River. This subtraction leaves 757,307 pounds.
[2] Subtract 118,070 pounds from this total for Missouri and Red Rivers, which discharge into Mississippi River. This subtraction leaves 343,507 pounds.

TABLE 5.—*Radium transported in solution past sampling sites during water year 1960–61*

Sampling site	River	Low flow		Medium flow		High flow		Total	
		Pounds times 10^{-6}	Kgs times 10^{-6} calculated	Pounds times 10^{-6}	Kgs times 10^{-6} calculated	Pounds times 10^{-6}	Kgs times 10^{-6} calculated	Pounds times 10^{-6}	Kgs times 10^{-6} calculated
	North Atlantic slope basins								
1	Penobscot	150	68	46	21	7.6	3.4	204	92
2	Carrabasset	6.4	2.9	1.9	.9	1.6	.7	9.9	4.5
3	Nezinscot	1.6	.7	.73	.3	.17	.07	2.5	1.1
4	Hudson	83	38	19	8.6	11	5	113	52
5	Delaware	820	372	20	9	4.3	1.9	844	383
6	Susquehanna	1,750	794	140	64	26	12	1,916	870
7	Potomac	28	13	9.5	4.3	37	17	75	34
8	Rappahannock	5.5	2.5	2.6	1.2	2.5	1.1	11	4.8
								3,175	1,441
	St. Lawrence River basins								
9	Genesee	11	5	27	12	52	24	90	41
								90	41
	South Atlantic slope basins								
10	Roanoke	21	9.5	17	7.7	0.6	0.3	39	18
11	Dan	20	9.1	22	10	5	2.3	47	21
12	Tar	13	5.9	14	6.4	6.3	2.9	33	15
13	Neuse	32	14	26	12	13	5.9	71	32
14	Cape Fear	25	11	22	10	34	15	81	36
15	Yadkin	48	22	41	19	27	12	116	53
16	Altamaha	160	73	20	9.1	35	16	215	98
17	St. Johns	12	5.4	13	5.9	11	5	36	16
								638	289

	Gulf of Mexico basins								
18	Suwannee	125	57	180	82	66	30	371	169
19	Apalachicola	170	77	45	20	88	40	303	137
20	Pearl	170	77	110	50	75	34	355	161
21	Missouri	75	34	410	186	35	16	520	236
22	Mississippi	4,230	1,919	12,600	5,715	8,200	3,719	25,030	11,353
23	Red	640	290	520	236	530	240	1,690	766
24	Sabine	160	73	190	86	36	16	386	175
25	Neches	27	12	97	44	55	25	179	81
26	Trinity	75	34	120	54	180	82	375	170
27	Brazos	630	286	530	240	710	322	1,870	848
28	Guadalupe	99	45	49	22	21	9.5	169	76
29	Rio Grande	14	6.3	8	3.6	4.3	2	26	12
								[1] 31,274	[2] 14,184
	Colorado River basin								
30	Colorado	5.8	2.6	0.5	0.2	180	82	186	85
								186	85
	Pacific slope basins								
31	San Joaquin	9	4.1	2.8	1.3	73	33	85	38
32	Sacramento	130	59	18	8.2	15	6.8	163	74
33	Klamath	200	91	38	17	5.4	2.4	243	110
34	Columbia	2,260	1,025	470	213	990	449	3,720	1,687
								4,211	1,909
	Yukon River								
35	Yukon	880	399	1,100	499	2,600	1,179	4,580	2,077
								4,580	2,077
	Red River (North)								
36	Red (North)	13	5.9	5	2.3	14	6.4	32	14.6
								32	14.6

[1] Subtract 2,210 pounds from this total for Missouri and Red Rivers, which discharge into the Mississippi River. This subtraction leaves 29,064 pounds.
[2] Subtract 1,002 pounds from this total for Missouri and Red Rivers, which discharge into the Mississippi River. This subtraction leaves 13,182 pounds.

TABLE 6.—*Discharge during water year 1960–61 compared to average discharge*

Sampling site	River	1. Average discharge at sampling site as of September 1961: Cfs	1. Cms[1] calculated	2. Average discharge at sampling site during water year 1960–61: Cfs	2. Cms calculated	3. Difference (+ = excess; − = deficiency): Cfs	3. Cms calculated	4. Percent of deficiency (−) or excess (+) from average
	North Atlantic slope basins							
1	Penobscot	11, 610	329	13, 080	371	+1, 470	+42	
2	Carrabasset	694	20	685	19	−9	−1	
3	Nezinscot	303	8. 6	253	7. 2	−50	−1. 4	
4	Hudson	13, 270	388	10, 900	309	−2, 820	−79	
5	Delaware	11, 910	337	10, 780	305	−1, 130	−32	−6. 2
6	Susquehanna	34, 500	977	31, 870	903	−2, 630	−74	
7	Potomac	4, 020	114	4, 241	120	+221	+6	
8	Rappahannock	622	18	750	21	+128	+3	
	Totals	77, 379	2, 191. 6	72, 559	2, 055. 2	−4, 820	−136. 4	
	St. Lawrence River basin							
9	Genesee	2, 779	78. 6	2, 444	69. 1	−335	−9. 5	−12. 1
	Totals	2, 779	78. 6	2, 444	69. 1	−335	−9. 5	
	South Atlantic slope basins							
10	Roanoke	3, 339	95	2, 672	76	−667	−19	
11	Dan	2, 613	74	2, 658	75	+45	+1	
12	Tar	2, 327	66	2, 325	66	−2	0	
13	Neuse	2, 898	82	3, 298	93	+400	+11	
14	Cape Fear	4, 972	141	4, 643	131	−329	−10	+1. 9
15	Yadkin	2, 899	82	2, 988	85	+89	+3	
16	Altamaha	12, 810	363	13, 870	393	+1, 060	+30	
17	St. Johns	1, 431	40	1, 491	42	+60	+2	
	Totals	33, 289	943	33, 945	961	+656	+18	

Gulf of Mexico basins							
18 Suwannee	10, 260	291	10, 590	300	+330	+9	+7. 8
19 Apalachicola	21, 360	605	23, 670	670	+2, 310	+65	
20 Pearl	8, 909	252	11, 288	320	+2, 379	+68	
22 Mississippi	560, 200	15, 863	584, 200	16, 543	+24, 000	+680	
24 Sabine	8, 878	251	12, 410	351	+3, 532	+100	
25 Neches	6, 522	185	10, 410	295	+3, 888	+110	
26 Trinity	7, 450	211	10, 440	296	+2, 990	+85	
27 Brazos	7, 558	214	16, 130	457	+8, 572	+243	
28 Guadalupe	1, 654	47	3, 865	109	+2, 211	+62	
29 Rio Grande	1, 358	38	605	17	−753	−21	
Totals	634, 149	17, 957	683, 608	19, 358	+49, 459	+1, 401	
Colorado River basin							
30 Colorado	388	10. 98	382	10. 81	−6	−0. 17	−1. 5
Totals	388	10. 98	382	10. 81	−6	−0. 17	
Pacific slope basins							
31 San Joaquin	4, 532	128	604	17	−3, 928	−111	−5. 4
32 Sacramento	9, 902	280	10, 220	290	+318	+10	
33 Klamath	17, 220	488	14, 700	416	−2, 520	−72	
34 Columbia	195, 200	5, 528	189, 000	5, 352	−6, 200	−176	
Totals	226, 854	6, 424	214, 524	6, 075	−12, 330	−349	
Yukon River							
35 Yukon	111, 400	3, 155	131, 500	3, 724	+20, 100	+570	+18. 0
Totals	111, 400	3, 155	131, 500	3, 724	+20, 100	+570	
Red River (North)							
36 Red (North)	2, 267	64. 2	763	21. 6	−1, 504	−42. 6	−66. 3
Totals	2, 267	64. 2	763	21. 6	−1, 504	−42. 6	

[1] Cms, cubic meters per second.

TABLE 7.—*Estimated uranium contributed to oceans from conterminous United States and Yukon River*

Major basin area	1 Total average discharge for major basin areas adjusted for water year 1960–61		2 Total average discharge at sampling sites of sampled rivers during water year 1960–61		3 Percent of major basin-area discharge carried by sampled rivers	4 Total uranium carried by sampled rivers for water year 1960–61		5 Estimated total uranium carried from major basin area for water year 1960–61	
	cfs	cms calculated	cfs	cms calculated		Pounds	kgs calculated	Pounds	kgs calculated
North Atlantic Slope basins	218,800	6,192	73,000	2,066	33.4	46,140	20,929	138,140	62,659
St. Lawrence River basin	[1] 134,000	3,792	2,400	68	1.8	970	440	53,890	24,444
South Atlantic Slope basins	128,500	3,637	34,000	962	26.4	17,190	7,797	65,114	29,535
Total uranium carried to Atlantic Ocean								257,144	116,638
Gulf of Mexico basins	956,000	27,055	684,000	19,357	71.5	757,300	343,504	1,059,060	480,379
Colorado River basin	382	10.8	382	10.8	100	5,100	2,313	5,100	2,313
Pacific Slope basins	472,000	13,358	215,000	6,084	45.6	330,260	149,803	724,254	328,514
Total uranium carried to Pacific Ocean								729,354	330,827
Red River (North)	763	21.6	763	21.6	100	1,390	630	1,390	630
Total uranium carried in solution from conterminous United States during water year 1960–61								2,046,948	928,474
Yukon River to Rampart, Alaska	131,500	3,721	131,500	3,721	100	263,000	119,294	263,000	119,294

[1] Represents 58.3 percent of United States contribution to total discharge of St. Lawrence River during water year 1960–61 past gaging station at Ogdensburg, N.Y., (230,000 cfs).

TABLE 8.—*Estimated radium contributed to oceans from conterminous United States and Yukon River*

Major basin area	1 Total average discharge for major basin areas adjusted for water year 1960–61		2 Total average discharge at sampling sites of sampled rivers during water year 1960–61		3 Percent of major basin-area discharge carried by sampled rivers	4 Total radium carried by sampled rivers for water year 1960–61		5 Estimated total radium carried from major basin area for water year 1960–61	
	cfs	cms calculated	cfs	cms calculated		Pounds $\times 10^{-5}$	kgs $\times 10^{-5}$ calculated	Pounds $\times 10^{-5}$	kgs $\times 10^{-5}$ calculated
North Atlantic Slope basins	218,800	6,192	73,000	2,066	33.4	3,175	1,440	9,506	4,312
St. Lawrence River basin	[1] 134,000	3,792	2,400	68	1.8	90	40.8	5,000	2,268
South Atlantic Slope basins	128,500	3,637	34,000	962	26.4	638	289.4	2,417	1,096
Total radium carried to Atlantic Ocean								16,923	7,676
Gulf of Mexico basins	956,000	27,055	684,000	19,357	71.5	29,064	13,138	40,649	18,438
Colorad River basin	382	10.8	382	10.8	100	186	84	186	84
Pacific Slope basins	472,000	13,358	215,000	6,084	45.6	4,211	1,910	9,235	4,189
Total radium carried to Pacific Ocean								9,421	4,273
Red River (North)	763	21.6	763	21.6	100	32	14.5	32	14.5
Total radium carried in solution from conterminous United States during water year 1960–61								67,025	30,402
Yukon River to Rampart, Alaska	131,500	3,721	131,500	3,721	100	4,580	2,077	4,580	2,077

[1] Represents 58.3 percent of United States contribution to total discharge of St. Lawrence River during water year 1960–61 past gaging station at Ogdensburg, N.Y. (230,000 cfs).