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HEALTH PHYSICS REGIONAL MONITORING

Semiannual Report,

January through June 1960

October 1960

WORKS TECHNICAL DEPARTMENT

E. I. du PONT de NEMOURS & COMPANY

EXPLOSIVES DEPARTMENT - ATOMIC ENERGY DIVISION

SAVANNAH RIVER PLANT

DPSP 60-25-26

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HEALTH PHYSICS REGIONAL MONITORING

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E. I. du Pont de Nemours and Company
Explosives Department - Atomic Energy Division
Savannah River Plant

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Abstract

Radioactivity in the Plant environs was measured during the six-month period ending June 30, 1960. Nonvolatile beta releases from Reactor Areas to effluent streams and alpha releases from stacks in the Separations Areas increased during the report period. No significant amounts of radioactivity were detected in the environment as a result of Plant discharges. Arrival of fresh bomb debris from a French nuclear weapon test was noted.

Introduction

Under a program established by the Du Pont Company in June 1951, the Savannah River Plant site and surrounding region are systematically monitored for radioactivity. The regional monitoring program accumulates information that is useful both as a measure of the effectiveness of Plant controls and as an authoritative record of environmental conditions. This report, covering the period from January through June 1960, is one of a series of reports relating to the regional monitoring program.

Data Reporting

Survey data were averaged for the six-month period and compared with the previous six-month averages ("Health Physics Regional Monitoring Semiannual Report," DPSPU 60-11-9, June 1960). In reporting data, "Avg" or "Total" refers to the average or total for this six-month report period, while "Prev Avg" or "Prev Total" refers to the average or total for the preceding six-month period. Unless otherwise specified, "Max" refers to the greatest concentration observed in a single sample collected during the report period.

Sensitivity and Standard Deviation of Laboratory Analyses

The sensitivity of laboratory analyses refers to the minimum amount of radioactivity that can be detected by the radiochemical analytical techniques in use. It is based on statistical counting error (90% confidence level) and is influenced by sample size, counter efficiency, and counter background. No self-absorption corrections have been applied.

The standard deviations, calculated from spike recovery values, are applicable to the six-month averages of data in this report.

Analysis	Sample	Sensitivity	Standard Deviation, %	Spike Value
Alpha	Water	$0.17 \pm 0.03 \times 10^{-15}$ c/ml	6	45×10^{-15} c/ml
	Mud	$0.17 \pm 0.03 \times 10^{-12}$ c/g	-	-
	Vegetation	$0.09 \pm 0.02 \times 10^{-12}$ c/g	-	-
	Air	$0.03 \pm 0.01 \times 10^{-14}$ µc/cc	-	-
Beta	Water	$6.9 \pm 0.5 \times 10^{-15}$ c/ml	-	-
	Mud	$6.9 \pm 0.5 \times 10^{-12}$ c/g	-	-
	Vegetation	$3.5 \pm 0.3 \times 10^{-12}$ c/g	-	-
	Biological Specimens	$4.6 \pm 0.4 \times 10^{-12}$ c/g*	-	-
	Air	$1.2 \pm 0.1 \times 10^{-14}$ µc/cc	-	-
TBP Extraction	Water	$0.18 \pm 0.08 \times 10^{-15}$ c/ml	11	45×10^{-15} c/ml
	Mud	$0.20 \pm 0.09 \times 10^{-12}$ c/g	16	45×10^{-14} c/g
	Vegetation	$0.02 \pm 0.009 \times 10^{-12}$ c/g	11	4.5×10^{-12} c/g
Radioiodine	Water	$13.0 \pm 0.7 \times 10^{-15}$ c/ml	11	300×10^{-15} c/ml
	Vegetation	$1.0 \pm 0.1 \times 10^{-12}$ c/g	14	20×10^{-12} c/g
	Air	$3.7 \pm 0.3 \times 10^{-14}$ µc/cc	-	-
	Milk	$140 \pm 7 \times 10^{-15}$ c/ml	10	3000×10^{-15} c/ml
Tritium	Water	$3.8 \pm 0.3 \times 10^{-12}$ c/ml	8	2500×10^{-12} c/ml
Radiocesium	Water	$4.7 \pm 1.0 \times 10^{-13}$ c/ml*	5	675×10^{-13} c/ml
Radiostrontium	Water	$6.0 \pm 1.3 \times 10^{-15}$ c/ml*	17	250×10^{-15} c/ml
Strontium-90	Water	$0.086 \pm 0.02 \times 10^{-15}$ c/ml	8	4.1×10^{-15} c/ml

* Approximate average; sample size varied.

Summary

Radioactivity released to the environment by stacks and effluent streams included approximately 0.3 curie alpha, 717 curies of nonvolatile beta and 6 curies of radioiodine. Approximately 165,000 curies of tritium were released by the 100-Area stacks and water effluents.

Nonvolatile beta radioactivity discharged from the 100-Area disassembly basins increased from 508 curies to 650 curies. Larger admixtures of fission products (primarily Ce-141) were released from L and K Areas in contrast to the predominant shorter lived isotope (Np-239) associated with reactor discharges during the preceding six months.

Leaks into both 200-Area segregated cooling water systems resulted in increased radioactivity in Four Mile Creek. The estimated nonvolatile beta discharges from F and H Areas during the report period were 1.8 curies and 1.3 curies, respectively, as compared with 0.5 curie and 0.1 curie during the last report period.

Nonvolatile beta and tritium releases resulting from 100-Area discharges were detectable in the Savannah River at points below the Plant; it was estimated that the Plant contributed 119 curies of nonvolatile beta and 50,000 curies of tritium to the flow of radioactivity in the river at the Highway 301 crossing during the six-month period.

The routine survey of the R-Area seepage basin area was intensified following detection of the migration of radioactivity from the basins into surrounding soil strata and ground water. Analyses of vegetation from the seepage basin area indicated that deep-rooted plants had assimilated radioactivity from the soil. Terrestrial animals collected near the basin system and in R Area showed considerable radiocesium and radiostrontium uptake in the muscle tissues and bones, respectively.

Radioactivity was detected in aquatic specimens including waterfowl collected from Par Pond as well as from fish, algae, shrimp and crayfish collected from the reactor effluents and the Savannah River. Radiocesium was the primary gamma emitter found in the fleshy tissues of specimens collected from R, P, and L-Area effluents. Radiostrontium and traces of Zn-65 were detected in fish collected from all of the reactor effluent streams. Concentrations detected in Savannah River fish were limited to low-level nonvolatile beta radioactivity in the bones.

Nonvolatile beta stack releases from F Area decreased, while alpha activity increased as a result of filter leaks in B-Line recovery. Radioiodine releases remained at a low level. Decreased stack releases from H Area were observed throughout the period. Environmental effects due to stack-released radioactivity were negligible.

Bomb fallout from the French nuclear test, which was detonated on February 13, was first observed at SRP in rainwater samples collected during the week ending February 24. An approximate twofold increase in nonvolatile beta activity and radioiodine was detected in vegetation samples collected during March.

Tritium releases to the environment totaled 480,500 curies as compared to a total of 462,900 curies released during the previous report period. Stack releases contributed 454,600 curies while the effluent streams contributed 25,900 curies.

Radioactivity Releases

Plant Discharge

100 AREAS

The major source of radioactive waste discharged from the 100 Areas to Plant effluent streams was disassembly basin water which is purged at the rate of 1000 to 2000 gpm. Some radioactive waste was also released in thermal shield water which is purged occasionally to prevent a buildup of corrosion products.

Radioactivity discharged from disassembly basins increased during this report period primarily because of the type of fuel elements processed in L and K Areas. Although the primary isotope released during previous report periods was Np-239 (due primarily to fuel element failures), larger amounts of fission products (primarily Ce-141 with a 32-day half life) were released from L and K Areas.

A summary of the nonvolatile beta releases from the 100 Areas to Plant streams is shown in the following table.

	Nonvolatile Beta Releases, curies					
Area →	R	P	L	K	C	Total for All Areas
			Thermal Shield Water			
Total	-	58	2	-	-	60
Previous Total	22	-	-	8	-	30
			Disassembly Basin Water			
Total	84	35	297*	147**	87	650
Previous Total	127	64	65	56	196	508

* Includes 110 curies of isotopes with half lives greater than 15 days.

** Includes 39 curies of isotopes with half lives greater than 15 days.

Alpha radioactivity discharged in the 100-Area effluent streams was estimated to be approximately 0.3 curie and is attributed almost entirely to the naturally occurring radioactivity in cooling water.

Tritium discharged to the effluent streams because of the entrainment of moderator on fuel elements during discharge operations totaled approximately 25,000 curies, as compared to 21,000 curies during the previous six-month period.

Tritium released by moderator losses through 100-Area stacks totaled 140,000 curies as compared to 87,000 curies released during the previous report period.

200 AREAS

The major releases of radioactivity from the 200 Areas during this report period were from the 200-foot stacks which disperse filtered canyon building air to the atmosphere. In addition, small amounts of radioactivity were released to Four Mile Creek as a result of sporadic leaks in the segregated cooling water systems in both 200 Areas. Estimated releases of nonvolatile beta to Four Mile Creek from F and H Areas were 1.8 curies and 1.3 curies, respectively.

Nonvolatile beta radioactivity releases from the F-Area stack decreased during the six-month period. Radioiodine releases remained essentially the same (at approximately 1 curie/month) as those observed during the last half of the previous report period. Stack-released alpha radioactivity increased in F Area as the result of a filter breakthrough in B-Line recovery which occurred in June (9 of the total 21 millicuries were released during this month). Maximum daily releases of 1 mc occurred on both June 26 and June 29. All stack releases from H Area decreased during the report period because of the cessation of certain operations.

The 200-Area stack releases for the period are summarized in the following table.

	Stack-Released Radioactivity			
	F Area		H Area	
	Total	Prev Total	Total	Prev Total
Nonvolatile Beta, mc				
$Ru^{103,106}$	3361	7,130	142	144
$Sr^{89,90}$	5	245	1	29
$Ce^{141,144}$	110	1,362	25	60
Cs^{137}	15	39	1	47
$Zr\text{-}Nb^{95}$	122	2,230	37	58
Total →	3613	11,006	206	338
Alpha, mc	21*	14	1	1
I-131, c	6	86	-	-

* 72% plutonium.

300 AREA

The estimated release of natural uranium from 300 Area to Tims Branch was 260 pounds or 85 mc.

700 AREA

Releases of radioactivity from Building 773-A (Savannah River Laboratory) stacks included approximately 38 μc alpha, 30 mc nonvolatile beta, 0.5 mc radioiodine and 3500 curies of tritium. An additional 3100 curies of tritium were released from TNX stacks.

Bomb Fallout

Deposition of nonvolatile beta on the Plant site during the six-month period was estimated to be 90 millicuries per square mile. The concentration of filterable beta in air averaged 18×10^{-14} μc/cc as compared with 26×10^{-14} μc/cc during the previous six months. Although this concentration is the lowest level ever observed on the Plant site, bomb fallout originating from a French nuclear test influenced the radioactivity content in other environmental samples (principally rainwater).

The first appearance of fresh bomb debris at SRP from the French nuclear test, detonated on February 13, was observed in rainwater samples collected during the week ending February 24. Daily

measurements showed that the heaviest deposition occurred during the 24-hour period ending February 25. While the results obtained from vegetation sampling do not reflect individual peaks of fallout radioactivity as accurately as rainwater sampling, an approximate twofold increase of nonvolatile beta activity and radioiodine was detected in vegetation samples collected during March. The effects of the nuclear test on concentrations of short-lived materials in rainwater and vegetation samples are shown in figures 1 and 2. The slight influence of bomb fallout observed in air probably results from "washout" or from the cleaning of air by the large amounts of rainfall (one-inch average per week) during February 17 through March 19.

Survey Results

Gamma Radiation Levels

A summary of 412 readings made with Landsverk L-65 pocket chambers and a modified L-60 electrometer is given in the following table.

Location	Dose Rate, mr/24 hours	
	Avg	Prev Avg
F Area	2.18	1.30
H Area	0.97	0.90
R Area	.56	.76
P Area	.50	.64
L Area	.58	.70
K Area	.56	.62
C Area	.49	.60
Aiken Airport	.40	.43
Allendale	.42	.58
400 Area	.48	.66
300/700 Area	.73	.79
TC Area	.51	.56
Waynesboro	.38	.50
Dunbarton Fire Tower	.41	.44
Williston	.27	.51
Williston Gatehouse	.36	.46
Talatha Gatehouse	.36	.44
Bush Field	.30	.34
Barnwell	.29	.33
Sardis	.32	.39
Langley	.33	.51
Green Pond Church*	.36	.45
Military Recreation Site*	.36	.33
Jackson*	0.38	0.41

* Previous averages represent a 3½-month period. These monitoring stations were added during the previous report period.

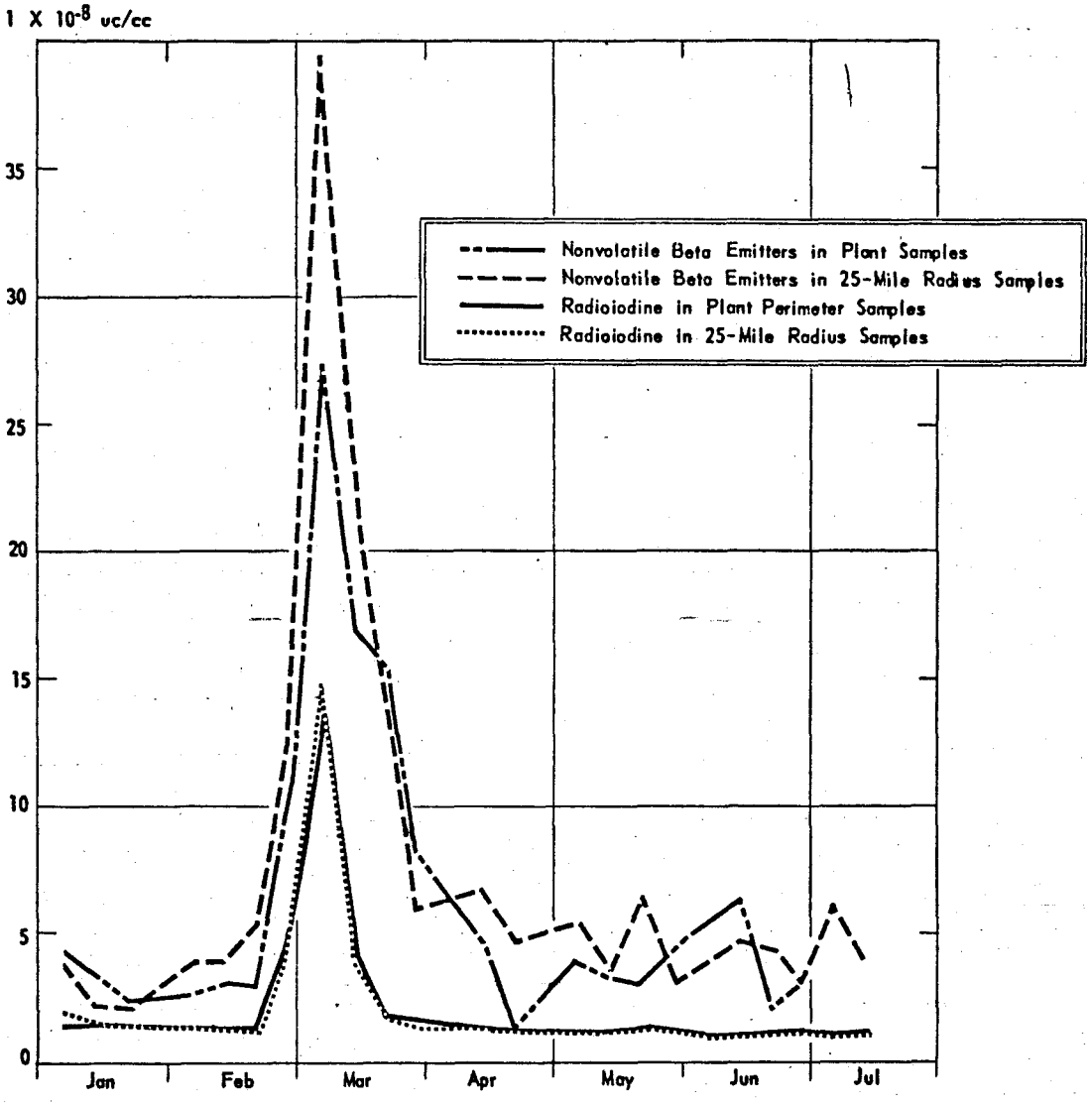

FIGURE 1. RADIOACTIVITY IN RAINWATER SAMPLES

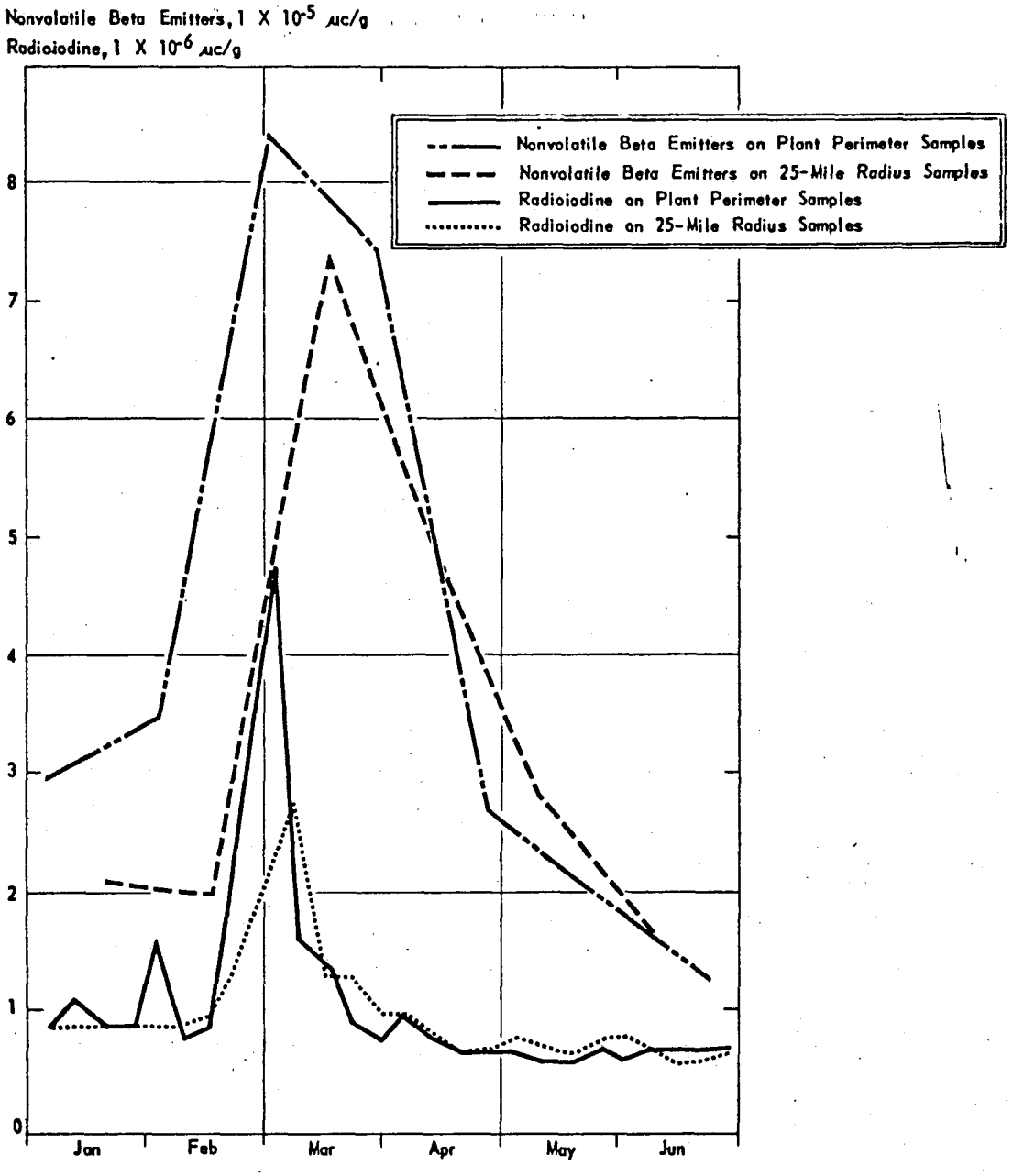

FIGURE 2. RADIOACTIVITY ON VEGETATION

The high radiation levels in F Area resulted from increased radiation levels at the solvent cleanup facility.

Atmosphere

Air samples were collected weekly from the 18 air monitoring stations shown in figure 3.

Radioactivity in the atmosphere was determined by:

- Counting 459 two-inch-diameter air filters for alpha and beta activity.
- Chemically analyzing 511 two-inch-diameter silver nitrate treated air filters for radioiodine.
- Counting the number of particles collected on 485 two-inch-diameter air filters.

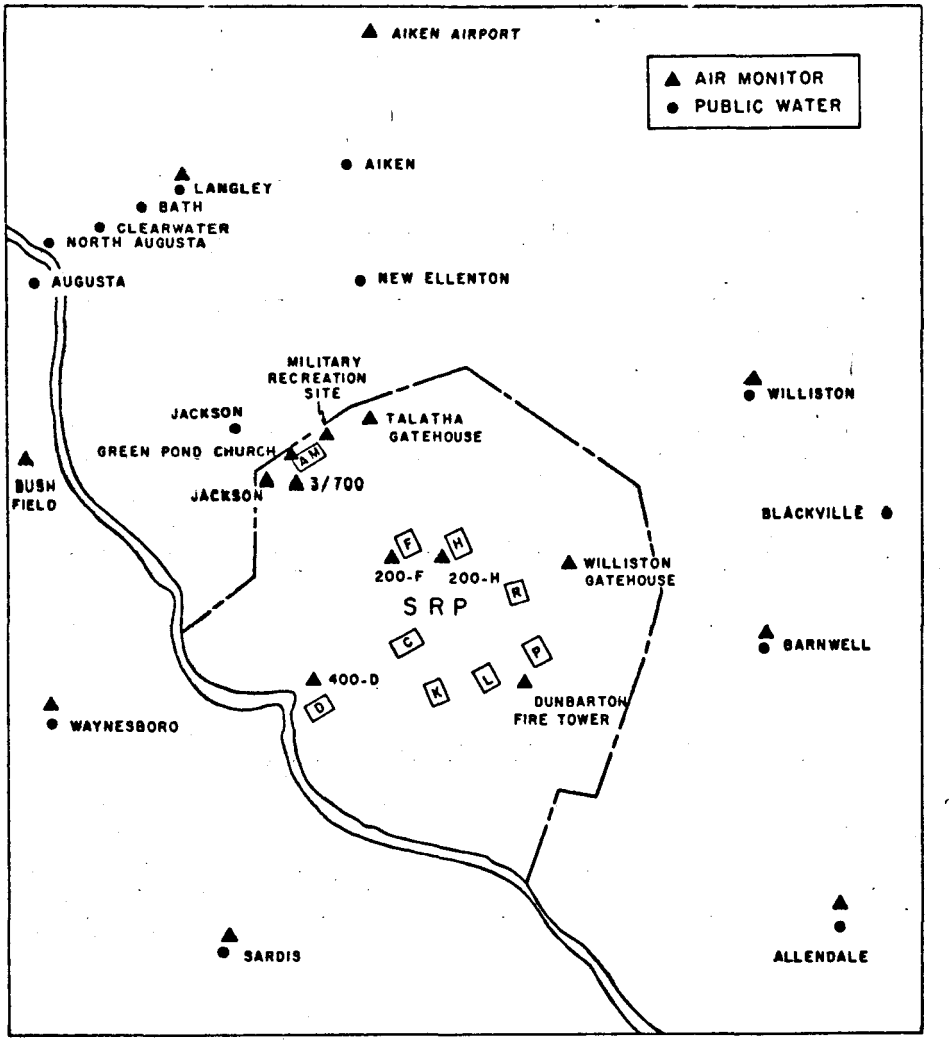

FIGURE 3. CONSTANT AIR MONITORING STATIONS AND PUBLIC WATER SAMPLING LOCATIONS

Results of the samples are shown in the following table.

Atmospheric Radioactivity

Location	Alpha, 1 × 10^{-14} μc/cc*			Filterable Beta, 1 × 10^{-14} μc/cc*			Radioactive Particles, particles/1000 M^3			Radioiodine, 1 × 10^{-14} μc/cc		
	Max	Avg	Prev Avg	Max	Avg	Prev Avg	Max	Avg	Prev Avg	Max	Avg	Prev Avg
F Area	1.3	0.4	0.1	88	32	32	17.9	4.5	1.2	27	8	111
H Area	0.2	0.1	0.1	30	20	25	5.1	0.3	0.1	30	6	20
3/700 Area	0.2	0.1	0.1	49	18	31	2.9	0.5	0.4	5	4	17
Talatha Gatehouse	0.2	0.1	0.1	30	19	26	1.5	0.2	0.2	4	4	12
Williston Gatehouse	0.2	0.1	0.1	30	20	31	1.5	0.3	0.4	6	4	6
Dunbarton Fire Tower	0.2	0.1	0.1	33	20	29	1.5	0.2	0.1	6	4	4
400 Area	8.6	0.4	0.1	168	23	29	3.0	0.3	0.1	8	4	10
Aiken Airport	0.2	0.1	0.1	24	15	33	1.5	0.3	0.1	7	4	5
Allendale	0.2	0.1	0.1	33	19	24	4.4	0.3	0.3	5	4	4
Waynesboro	0.2	0.1	0.1	28	19	28	2.9	0.2	0.3	6	4	5
Langley	0.1	0.1	0.1	16	11	17	1.5	0.1	0.1	8	4	4
Williston	0.1	0.1	0.1	23	13	20	1.5	0.1	0.1	6	4	4
Barnwell	0.2	0.1	0.1	25	16	21	4.4	0.2	0.1	4	4	4
Sardis	0.2	0.1	0.1	25	12	18	0.0	0.0	0.1	4	4	4
Bush Field	0.2	0.1	0.1	26	15	25	1.5	0.1	0.1	5	4	7
Green Pond Church**	0.2	0.1	0.1	24	15	22	2.9	0.3	-	5	4	34
Military Recreation Site**	0.1	0.1	0.1	42	18	30	1.6	0.1	-	7	4	10
Jackson**	0.2	0.1	0.1	30	20	15	1.5	0.1	-	5	4	4

* Three days decay allowed for radon and thoron daughters.

** Previous averages represent a 3½-month period. These monitoring stations were added during the previous report period.

The maximum alpha and filterable beta radioactivity levels recorded at F Area and 400 Area occurred during the week ending June 13. The increased radioactivity resulted from air contamination which originated during the unloading of the high level waste trailer in F Area on June 6. The radioactivity recorded in air samples collected in F Area does not reflect the period of high atmospheric contamination because of an inoperative air sampler (building power failure) at the monitoring station during the incident and 12 hours thereafter. Pulse height analyses of the 200-F and 400-D environmental samples containing the highest concentrations (air, rainwater and particles) show that the gamma activity consisted predominantly of Zr-Nb^{95} with trace amounts of $Ru^{103,106}$ and that the alpha activity consisted of a single isotope with a 5.45 Mev emission energy.

Particulate Fallout

Adhesive papers were collected weekly and radioautographed. Results from 1404 adhesive papers and the locations from which they were collected are shown in the following table.

Location	Particles/Ft^2/Week		
	Max	Avg	Prev Avg
F Area	151	4.2	0.3
F Area (at 1-mile radius)	34	2.1	0.5
H Area	47	2.4	0.2
H Area (at 1-mile radius)	32	1.6	0.2
Burial Ground	38	2.2	0.3
R Area	49	2.3	0.3
P Area	47	2.4	0.1
L Area	52	1.6	0.2
K Area	47	1.4	0.2
C Area	65	2.0	0.3
On-Plant Air Monitor Locations*	56	2.7	0.2
Off-Plant Air Monitor Locations*	81	2.8	0.2

* Excluding monitor locations in F and H Areas.

The maximum number of radioactive particles detected in air by radioautographs (excluding F Area) occurred during the period of heaviest bomb fallout (weeks ending February 24 and March 1). Maximum deposition in F Area was observed during the week ending June 13

when a leak occurred during the unloading of the high level waste trailer.

Rainwater

Rainwater is collected continuously at each monitoring location. Results of samples collected and analyzed weekly are shown in the following table.

Radioactivity in Rainwater

Location	No. of Samples	Alpha, 1×10^{-15} c/ml			Nonvolatile Beta, 1×10^{-15} c/ml			Radioiodine, 1×10^{-15} c/ml		
		Max	Avg	Prev Avg	Max	Avg	Prev Avg	Max	Avg	Prev Avg
F Area	22	87.4	4.6	0.6	1400	170	63	100	27	78
H Area	22	1.6	0.9	0.8	310	81	48	160	25	44
300/700 Area	22	2.0	0.9	0.7	490	110	82	180	23	21
Talatha Gatehouse	22	3.1	0.9	0.5	600	110	55	130	21	15
Williston Gatehouse	21	2.1	0.6	0.5	160	43	52	130	21	16
Dunbarton Fire Tower	21	0.7	0.5	0.3	140	36	40	110	20	23
400 Area	22	1.3	0.6	0.5	270	45	52	180	25	34
Aiken Airport	21	1.7	0.8	0.6	350	90	69	68	19	14
Allendale	18	0.9	0.5	0.5	230	39	71	180	23	13
Waynesboro	23	1.6	0.6	0.5	400	67	60	160	22	15
Langley	19	1.7	0.6	0.5	330	92	85	100	21	17
Williston	20	0.9	0.4	0.4	280	53	53	110	22	14
Barnwell	20	1.4	0.5	0.3	460	79	48	230	26	16
Sardis	19	1.0	0.5	0.5	730	72	74	130	23	17
Bush Field	21	1.6	0.6	0.4	400	110	86	126	21	13
Green Pond Church*	17	1.9	0.9	0.4	380	70	24	87	19	32
Military Recreation Site*	19	1.2	0.6	0.3	480	73	26	120	19	17
Jackson*	19	1.1	0.5	0.3	440	61	12	94	18	15

* Previous averages shown for these sites represent 3½-month averages. Stations were added during the previous report period.

Radioactivity deposited on the Plant site, estimated from rainwater analyses and rainfall measurements, is shown in the following table. During weeks when no rain occurred, nonvolatile beta deposition was estimated from the total amount of radioactivity collected in an open pan of water located near Building 735-A

	Nonvolatile Beta, mc/mile^2	Radioiodine,* mc/mile^2
January	6	4
February	36	24
March	23	6
April	11	7
May	7	3
June	7	4
Total →	90	48
Previous Total →	101	46

* Radioiodine was detected in only 22 samples out of approximately 110 analyzed (excluding F & H samples) and 18 of these were the result of bomb fallout.

Vegetation

There were 494 vegetation samples analyzed for alpha and nonvolatile beta activity, and 1352 samples analyzed for radioiodine. Sample locations are shown in figures 4 and 5. Results are shown in the following table.

	Alpha, 1×10^{-12} c/g			Nonvolatile Beta, 1×10^{-12} c/g			Radioiodine, 1×10^{-12} c/g		
Location	Max	Avg	Prev Avg	Max	Avg	Prev Avg	Max	Avg	Prev Avg
F Area (at 1-mile radius)	0.8	0.2	0.1	94	48	34	12.6	2.9	6.4
H Area (at 1-mile radius)	0.7	0.2	0.1	120	48	31	4.0	2.1	2.4
Plant Perimeter	0.6	0.2	0.1	84	33	28	5.0	1.1	1.0
25-Mile Radius	0.8	0.2	0.1	74	34	25	2.8	1.0	0.8

Milk

Samples were collected weekly from Talatha, Snelling, Aiken, North Augusta, and Langley. Of 130 samples analyzed for radioiodine, the average concentration was less than 150×10^{-15} c/ml.

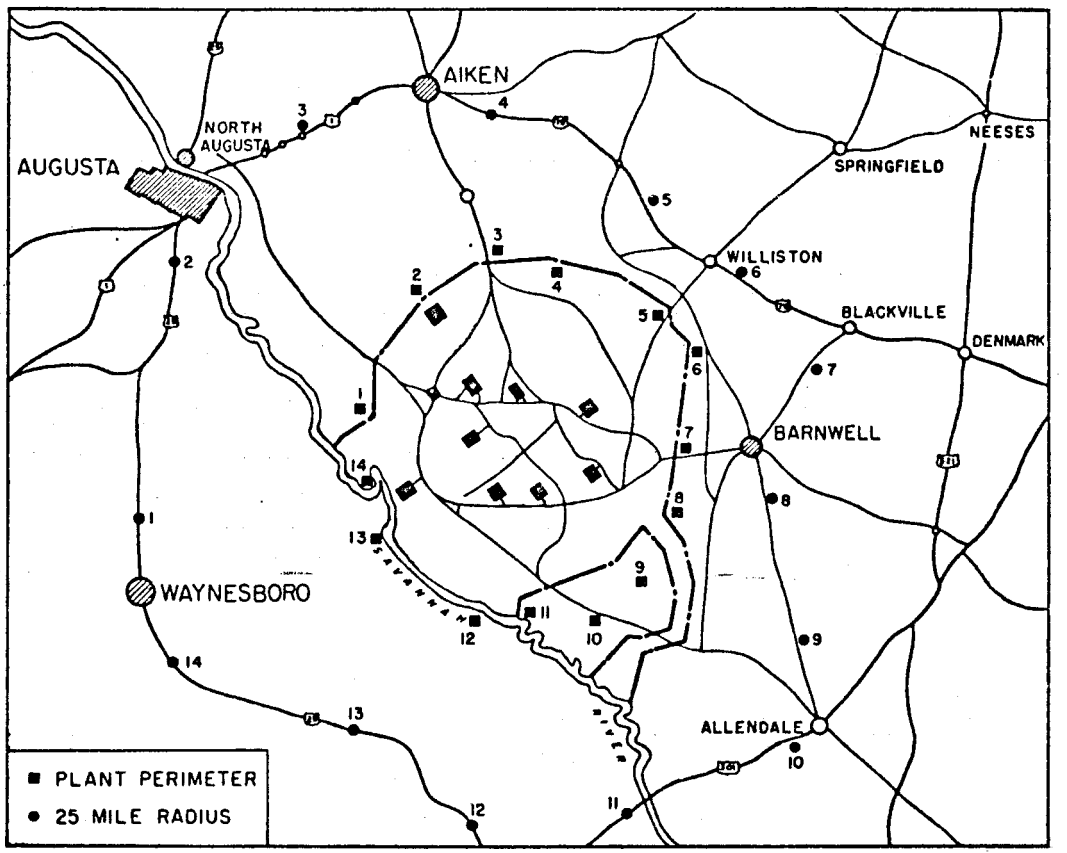

FIGURE 4. VEGETATION SAMPLE LOCATIONS

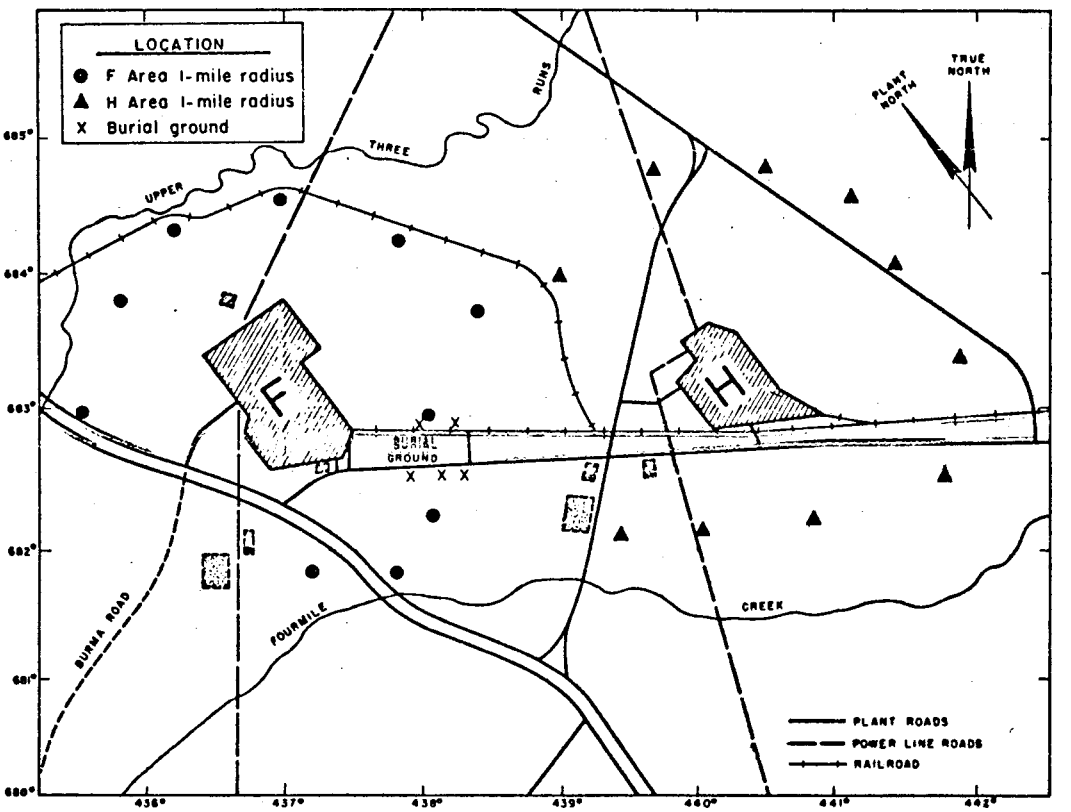

FIGURE 5. VEGETATION SAMPLE LOCATIONS IN F AND H AREAS

Regional milk produced by dairy herds and by "family" cows was analyzed for Sr-90 content quarterly. The averages are shown in the following table.

	Sr-90 in Milk, μμc/ℓ			
	1959		1960	
Type Sample	July	December	March	June
"Family" Cow	22.6	23.4	26.3	22.4
Local Dairy	18.1	-	13.2	11.5
Major Distributor	-	13.7	12.1	10.0

Streams and the Savannah River

Weekly water and mud samples were collected at the stream locations shown in figure 6. Analyses of 597 water samples and 568 mud samples are summarized in the following tables.

TIMS BRANCH

	Radioactivity in Water, 1 × 10^{-15} c/ml					
	Alpha			Nonvolatile Beta		
Location	Max	Avg	Prev Avg	Max	Avg	Prev Avg
2*	520	50	17	670	150	100
3**	2000	520	310	3800	840	600
4	53	23	23	180	80	75

* Tritium concentration at location 2 averaged 5 × 10^{-12} c/ml with a maximum of 10 × 10^{-12} c/ml.

** Maximum alpha and nonvolatile beta concentrations at location 3 (300-Area effluent) occurred in samples collected on March 31 and May 5, respectively.

	Radioactivity in Mud, 1 × 10^{-12} c/g					
	TBP Extractable Alpha			Nonvolatile Beta		
Location	Max	Avg	Prev Avg	Max	Avg	Prev Avg
2	33	16	58	140	40	76
3	540	170	140	2800	300	180
4	28	15	22	37	14	23

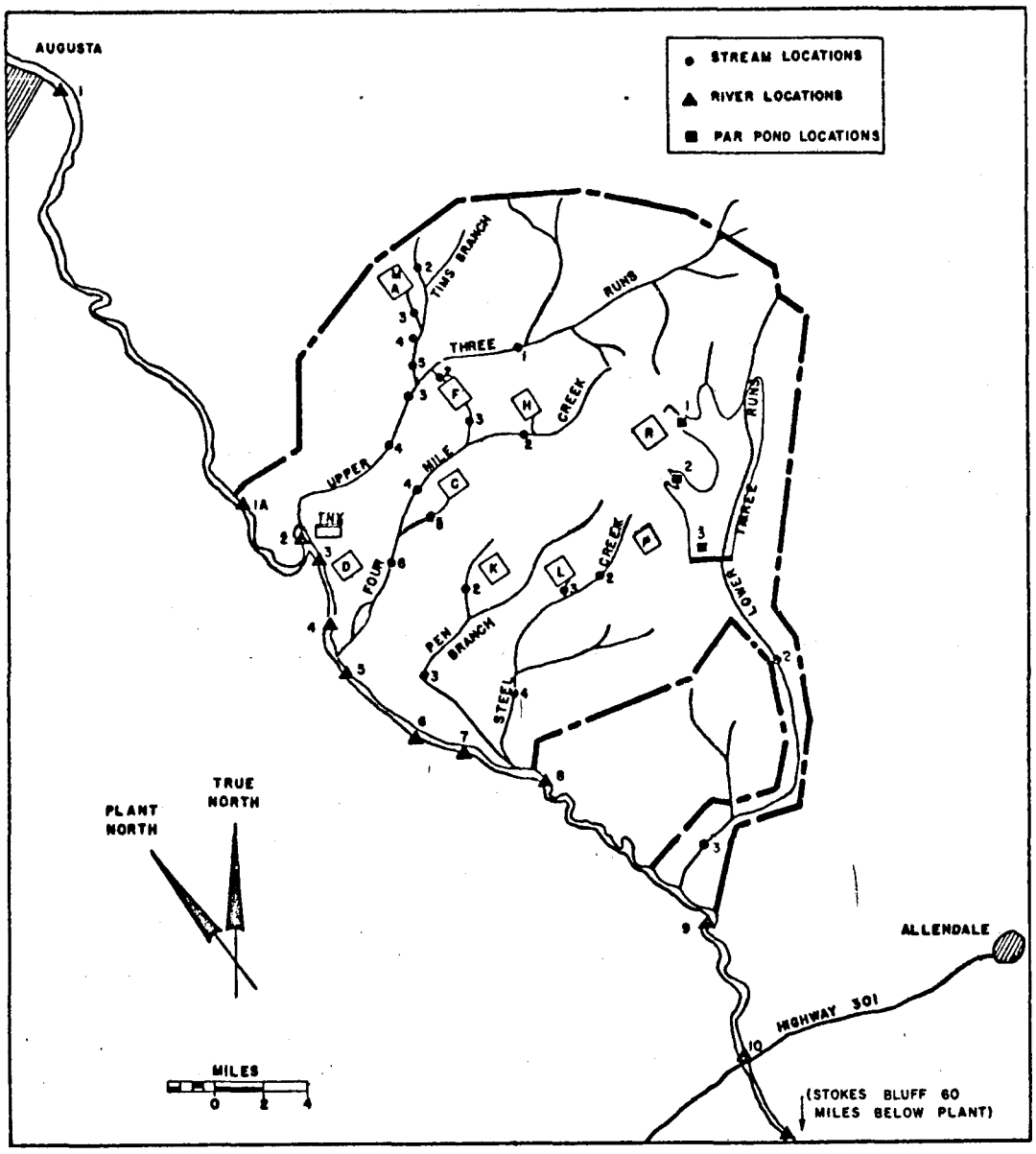

FIGURE 6. STREAM AND RIVER SAMPLE LOCATIONS

UPPER THREE RUNS

Analyses of water and mud samples are shown in the following table.

Location	Alpha			Nonvolatile Beta		
	Max	Avg	Prev Avg	Max	Avg	Prev Avg
	Radioactivity in Water, 1×10^{-15} c/ml					
1A (Control)	6.1	3.2	3	18	9	12
1 (Control)	3.8	2.0	2	52	14	9
2	140	26	3	3800	420	200
3	9.7	3.5	2	42	13	12
4	2.5	1.7	1	33	9	11
	Radioactivity in Mud, 1×10^{-12} c/g					
1A (Control)	1.2	0.4	0.4	22	9	8
1 (Control)	1.9	0.6	0.5	26	11	14
2	2.1	1.1	0.5	1300	350	36
3	3.3	1.0	0.8	56	16	14
4	1.6	0.5	0.4	22	10	9

Radioactivity measured at location 2 (F-Area storm sewer) is partially attributed to the drainage of contaminated ground water which was pumped from a trench located on the east side of Building 221-F. The trench was excavated (February) through radioactive soil for equipment installation. The maximum alpha activity in water (with an associated nonvolatile beta concentration of 1200×10^{-15} c/ml) occurred in a sample collected on February 18. This was attributable to natural uranium, whereas an increased alpha content (85×10^{-15} c/ml) occurring on June 30 was identified as Pu-239. The maximum nonvolatile beta activity in water and mud was observed on April 21. Pulse height analysis showed the gamma activity in the mud to be predominantly $Ru^{103,106}$ with trace amounts of $Zr\text{-}Nb^{95}$.

FOUR MILE CREEK

Analyses of water and mud samples are summarized in the following table.

Location	Alpha			Nonvolatile Beta		
	Max	Avg	Prev Avg	Max	Avg	Prev Avg
	Radioactivity in Water, 1×10^{-15} c/ml					
2	6.8	1.3	1.2	2,500	300	35
3	110	12	2.3	11,000	3600	1100
4	32	1.8	0.6	1,600	320	68
5	1.1	0.7	0.6	17,000	1100	1200
6	1.1	0.5	0.4	3,200	400	350
	Radioactivity in Mud, 1×10^{-12} c/g					
2	0.9	0.3	0.3	120	22	9
3	2.1	0.4	0.5	1,700	280	70
4	0.6	0.3	0.3	180	29	9
5	1.1	0.5	0.5	33	13	16
6	1.1	0.6	0.9	510	71	180

Increased concentrations of radioactivity in water at location 2 (H-Area effluent) during May accounted for approximately 80% of the six-month averages. Specific analyses of water samples taken from the H-Area delaying basin on May 5 indicated that the radioactivity being released consisted of mixed fission products (primarily $Ce^{141,144}$). This effluent was diverted to the seepage basin system during the period of highest activity (May 9 through May 20).

Increased radioactivity in water shown at location 3 (F-Area segregated cooling water effluent) reflects releases from the system throughout the report period. The two highest nonvolatile beta concentrations observed in this effluent to date ($11,000 \times 10^{-15}$ c/ml and $10,000 \times 10^{-15}$ c/ml) occurred during the weeks ending April 21 and June 30. Contaminated algae from the floor and walls of the delaying basin may have contributed to the high concentration observed in April, since an investigation indicated that approximately 90% of the activity in the stream water was attributed to suspended material greater than 0.5 micron in diameter. Algae and associated scale collected from the delaying basin contained 3.3 μc/g of mixed fission products. The high concentration in June was due to waste released from the 281-3F retention basin in addition to contaminated water from the cooling water system. Alpha activity (primarily Pu-239) during this period increased approximately 50-fold. The nonvolatile

beta activity during the entire report period consisted primarily of Ce-144 with lesser amounts of Ru-106, Cs-137 and Zr-Nb^{95}.

The continued releases of radioactivity to these cooling water effluents in F and H Areas increased the radioactivity levels observed at location 4.

Three high weekly concentrations of radioactivity, which were detected immediately following reactor discharges in C Area during January, March, and April, accounted for approximately 90% of the six-month average at location 5 (C-Area effluent). Of the total 87 curies of nonvolatile beta activity released (primarily Np-239) during these operations, 7 curies are attributed to isotopes with half lives greater than 15 days (primarily Ce-141).

Analyses for selected specific isotopes follow.

	Radioactivity in Water											
	Tritium, 1×10^{-12} c/ml			Radioiodine, 1×10^{-15} c/ml			Radiostrontium, 1×10^{-15} c/ml			Radiocesium, 1×10^{-15} c/ml		
Location	Max	Avg	Prev Avg	Max	Avg	Prev Avg	Max	Avg	Prev Avg	Max	Avg	Prev Avg
3	-	-	-	-	-	-	1900	600*	-	760	170	-
5	-	-	-	-	-	-	240	25	18	52	11	46
6	1100	91	64	420	49*	-	68	16	11	28	7	6

* Five-month average.

PEN BRANCH

Analyses of water and mud samples are shown in the following table.

	Alpha			Nonvolatile Beta		
Location	Max	Avg	Prev Avg	Max	Avg	Prev Avg
	Radioactivity in Water, 1×10^{-15} c/ml					
2	1.3	0.5	0.6	17,000	1200	1800
3	1.0	0.4	0.4	3,000	360	250
	Radioactivity in Mud, 1×10^{-12} c/g					
2	0.9	0.5	0.6	250	53	53
3	0.7	0.3	0.2	110	17	19

Approximately 80% of the average concentration of nonvolatile beta in water at location 2 (K-Area effluent) was due to samples collected during two weeks of the report period. High concentrations (7000 × 10^{-15} c/ml and 17,000 × 10^{-15} c/ml during the weeks ending April 7 and April 14, respectively) were due to reactor discharges in K Area. An estimate of waste discharged from this area during the period April 3 through April 24 indicated a release of 122 curies of nonvolatile beta, including 26 curies of long-lived activity (>15 day half life, primarily Ce-141 with lesser amounts of Cr-51). A total of 38 curies of long-lived nonvolatile beta activity were released from K Area during the entire report period. The radiostrontium release during the same period was 0.86 curie of which 0.04 curie was Sr-90.

Analyses for selected specific isotopes follow.

	Radioactivity in Water											
	Tritium, 1 × 10^{-12} c/ml			Radioiodine, 1 × 10^{-15} c/ml			Radiostrontium, 1 × 10^{-15} c/ml			Radiocesium, 1 × 10^{-15} c/ml		
Location	Max	Avg	Prev Avg	Max	Avg	Prev Avg	Max	Avg	Prev Avg	Max	Avg	Prev Avg
2	-	-	-	-	-	-	850	62	19	82	14	8
3	260	28	98	1600	150*	-	160	22	12	64	8	6

* Five-month average.

STEEL CREEK

Analyses of water and mud samples are shown in the following table.

	Alpha			Nonvolatile Beta		
Location	Max	Avg	Prev Avg	Max	Avg	Prev Avg
	Radioactivity in Water, 1 × 10^{-15} c/ml					
2	1.5	0.9	0.8	4,500	350	350
3	1.1	0.5	0.6	24,000	2700	780
4	1.0	0.5	0.4	3,200	530	120
	Radioactivity in Mud, 1 × 10^{-12} c/g					
2	2.0	0.8	1.1	49	26	38
3	1.2	0.4	0.4	450	110	32
4	1.1	0.5	0.6	370	91	54

The major portion of the radioactivity measured in Steel Creek water at location 3 (L-Area effluent) resulted from high concentrations observed following reactor discharges during January (beginning January 25) and May. Estimates of the total nonvolatile beta radioactivity released from L Area during February and May were 153 curies and 128 curies, respectively. A total of 110 curies of fission products and neutron-induced activities, with half lives greater than 15 days, were released from L Area during the entire six-month period. Of this total, 53 curies were released in February, 42 curies in May, and 11 curies in June. The May release included 2.6 curies of radiostrontium, of which 0.04 curie was Sr-90.

Of the total contribution from P Area (35 curies) to the nonvolatile beta activity observed at Steel Creek location 2, approximately 10 curies were long-lived isotopes.

Analyses for selected specific isotopes follow.

	Radioactivity in Water											
	Tritium, 1×10^{-12} c/ml			Radioiodine, 1×10^{-15} c/ml			Radiostrontium, 1×10^{-15} c/ml			Radiocesium, 1×10^{-15} c/ml		
Location	Max	Avg	Prev Avg	Max	Avg	Prev Avg	Max	Avg	Prev Avg	Max	Avg	Prev Avg
2	-	-	-	-	-	-	25	9	16	190	26	48
3	-	-	-	-	-	-	1800	250	10	2200	100	6
4	540	89	44	1100	86*	-	250	47	15	25	8	11

* Five-month average.

PAR POND

Analyses of water and mud samples are shown in the following table.

Location	Alpha Max	Alpha Avg	Alpha Prev Avg	Nonvolatile Beta Max	Nonvolatile Beta Avg	Nonvolatile Beta Prev Avg
	Radioactivity in Water, 1×10^{-15} c/ml					
1	1.1	0.7	0.5	660	220	260
2	1.0	0.6	0.4	76	56	68
3	1.6	0.8	0.5	220	67	83
	Radioactivity in Mud, 1×10^{-12} c/g					
1	1.5	0.3	0.2	19	9	13
2	0.7	0.2	0.2	10	7	8

The radioactivity recorded at location 1 reflects R-Area effluent discharge to Par Pond. Of the 84 total curies of nonvolatile beta discharged to Par Pond, an estimated 14 were fission products having half lives greater than 15 days.

Analyses of samples for selected specific isotopes follow.

	Radioactivity in Water											
	Tritium, 1×10^{-12} c/ml			Radioiodine, 1×10^{-15} c/ml			Radiostrontium, 1×10^{-15} c/ml			Radiocesium, 1×10^{-15} c/ml		
Location	Max	Avg	Prev Avg	Max	Avg	Prev Avg	Max	Avg	Prev Avg	Max	Avg	Prev Avg
1	1100	260	110	180	49*	-	85	21	10	61	24	37
2	160	110	66	-	-	-	18	7	8	25	12	28
3	160	110	73	-	-	-	15	8	10	28	14	33

* Five-month average.

LOWER THREE RUNS

Analyses of water and mud samples are shown in the following table.

Location	Alpha Max	Alpha Avg	Alpha Prev Avg	Nonvolatile Beta Max	Nonvolatile Beta Avg	Nonvolatile Beta Prev Avg
	Radioactivity in Water, 1×10^{-15} c/ml					
2	1.0	0.4	0.3	55	32	63
3	1.2	0.4	0.3	50	20	49
	Radioactivity in Mud, 1×10^{-12} c/g					
2	0.6	0.3	0.2	27	11	10
3	0.7	0.4	0.3	30	12	13

Results of analyses for selected specific isotopes follow.

	Radioactivity in Water								
	Tritium, 1×10^{-12} c/ml			Radiostrontium, 1×10^{-15} c/ml			Radiocesium, 1×10^{-15} c/ml		
Location	Max	Avg	Prev Avg	Max	Avg	Prev Avg	Max	Avg	Prev Avg
2	-	-	-	13	8	9	42	13	30
3	42	14	23	16	6	11	16	8	16

Radioactivity measured in Lower Three Runs reflects only the discharge from Par Pond.

SAVANNAH RIVER

Samples of river water were collected weekly at the locations shown in figure 6. Continuously collected samples were obtained from locations 1A and 10. Monthly mud samples from locations 1 through 9 as well as weekly samples from locations 10 and 11 were analyzed for TBP extractable alpha.

Analyses of 311 water samples for alpha and nonvolatile beta, 111 mud samples for TBP extractable alpha, and 309 mud samples for nonvolatile beta are summarized in the following tables.

	Radioactivity in Water, 1×10^{-15} c/ml					
	Alpha			Nonvolatile Beta		
Location	Max	Avg	Prev Avg	Max	Avg	Prev Avg
1	1.0	0.4	0.3	9	7	9
1A	0.7	0.3	0.3	9	7	9
2	1.5	0.7	0.4	15	8	9
3	0.8	0.5	0.4	18	8	9
4	0.8	0.5	0.4	31	9	17
5	0.9	0.5	0.2	23	10	54
6	0.9	0.6	0.4	43	11	11
7	0.9	0.5	0.3	21	9	13
8	0.9	0.4	0.4	540	44	34
9	0.9	0.5	0.3	210	32	17
10	0.9	0.4	0.4	110	22	14
11	0.9	0.4	0.4	63	15	13

Location	Radioactivity in Mud, 1 × 10^{-12} c/g					
	TBP Extractable Alpha			Nonvolatile Beta		
	Max	Avg	Prev Avg	Max	Avg	Prev Avg
1	2.9	1.7	1.8	39	17	16
1A	4.9	2.2	1.2	33	17	18
2	3.8	2.3	2.4	29	11	16
3	4.0	2.7	2.0	28	16	18
4	3.1	2.1	1.8	42	20	20
5	3.6	1.7	2.1	33	18	24
6	3.2	1.7	1.5	28	12	12
7	4.8	2.2	1.8	25	16	17
8	4.2	1.9	1.8	37	23	27
9	1.5	0.9	1.2	26	12	12
10	4.2	2.5	2.1	32	16	17
11	2.4	0.8	0.7	14	8	9

Radioactivity released to Steel Creek from L Area was detected in the Savannah River as evidenced by the maximum concentrations in water shown at locations 8, 9, 10, and 11. These concentrations occurred in samples collected on May 17, the period following an L-Area shutdown.

Analyses of water samples for selected specific isotopes are summarized in the following table.

Location	Radioactivity in Water											
	Tritium, 1 × 10^{-12} c/ml			Radioiodine, 1 × 10^{-15} c/ml			Radiostrontium, 1 × 10^{-15} c/ml			Radiocesium, 1 × 10^{-15} c/ml		
	Max	Avg	Prev Avg	Max	Avg	Prev Avg	Max	Avg	Prev Avg	Max	Avg	Prev Avg
1A	6	4	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	21	6	5	19	4	4
9	-	-	-	-	-	-	14	4	4	7	4	3
10	15	7	8	22	14	13	4	3	3	6	3	3
11	35	7	7	-	-	-	9	4	3	7	3	3

Strontium-90 concentrations in river water collected at locations 1A and 10 are shown in the following table.

Location	Sr-90 in Savannah River Water, 1 × 10^{-9} μc/ml	
	Avg	Prev Avg*
1A	0.48	0.66
10	0.82	1.27

* Four-month average.

FLOW OF RADIOACTIVITY IN EFFLUENT STREAMS AND RIVER

Results of water samples collected at the Road A intersection of each reactor effluent stream showed the following number of curies flowing past each sample location.

The flow of radioactivity past river locations 1A (control) and 10 (10 miles downstream from Plant) is presented for comparison.

	Radioactivity in Water, curies/6 months				
Location	Nonvolatile Beta	Tritium	Radioiodine	Radiostrontium	Radiocesium
Four Mile Creek (Location 6)	47	9,700	5	2	1
Pen Branch (Location 3)	31	3,200	13	3	1
Steel Creek (Location 4)	135	23,000	15	13	2
Lower Three Runs (Location 3)	1.2	1,000	-	0.4	0.8
Total at Road A Locations →	214	37,000	33	18	5
River 1A (Control)	58	-			
River 10 (Highway 301)	177	50,000			

The accuracy of the estimated tritium flow at the river location was impaired during February and March when river water flow rates were unusually high and the tritium concentrations were at or less than the sensitivity of the analytical procedure. The overestimation of tritium flow during these months accounts for the higher six-month total observed in the river than the total detected in the streams at Road A.

CHEMICAL WATER QUALITY OF LOWER THREE RUNS CREEK AND THE SAVANNAH RIVER

A routine survey program was initiated during October 1959 to determine the chemical quality of the Savannah River water. The following table shows the water quality analyses of the Savannah River both upstream (location 1A) and downstream (location 10) from the Plant site for the past six months. Water quality analyses (beginning in February 1960) at location 3 on Lower Runs Creek are also presented. All data except those for dissolved oxygen represent the average analyses of composite water samples which are collected weekly. The dissolved oxygen values reflect the average of weekly determinations of the oxygen content only at the time of collection.

	Chemical Quality of Water								
	Lower Three Runs			River Upstream			River Downstream		
	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
Color (A. P. H. A.)	50	20	33	50	15	28	45	20	27
pH	9.30	6.86	7.38	9.70	6.52	8.40	9.88	6.50	7.90
Methyl Orange, ppm $CaCO_3$	41.80	12.10	19.21	42.00	6.60	14.56	19.60	7.28	13.60
Dissolved Oxygen, ppm	12.50	6.50	8.80	11.88	7.18	9.57	10.61	5.08	8.05
Sulfide, ppm S	<0.20	-	-	<0.20	-	-	<0.20	-	-
Hardness, ppm $CaCO_3$	35.00	14.39	22.85	24.00	6.54	10.47	17.10	9.27	11.29
Conductivity, µmhos	94.1	33.3	57.2	448.00	28.7	57.0	56.0	36.2	42.9
Total Iron, Fe	0.8	0.1	0.4	1.25	0.05	0.33	2.60	0.02	0.47
Total Dissolved Solids, ppm	70.6	32.8	47.5	206.4	27.2	49.4	64.8	30.0	44.4
Chloride, ppm Cl	8.60	0.90	2.83	32.00	0.45	3.31	10.60	0.75	2.66
Nitrate, ppm N	0.04	0.04	0.04	0.05	<0.01	0.04	0.06	<0.01	0.04
Sulfate, ppm SO_4	5.70	<0.02	1.62	23.80	<0.02	2.75	4.55	<0.02	1.85
Nitrite, ppm N	0.002	<0.001	0.001	0.002	<0.001	0.001	0.002	<0.001	0.001
B. O. D., ppm	2.17	0	0.73	20.63	0	1.50	9.59	0	1.02
Lignin, ppm	6.45	2.20	4.40	9.3	<0.5	2.64	7.1	0.7	2.93
Surfactant, ppm	0.33	<0.01	0.05	0.42	<0.01	0.06	0.38	<0.01	0.06

The comparatively high maximum values detected at the river upstream control location occurred during the week ending April 26. These abnormal results indicate that the river above the Plant was affected by pollution during this period. The downstream location was not affected during the same collection period and subsequent analyses showed the upstream location returned to normal. Apparently the pollution was local in nature and of short duration.

DISSOLVED OXYGEN PROFILES OF THE SAVANNAH RIVER. Special dissolved oxygen surveys of the Savannah River extended from the Butler Creek entry to the Highway 301 bridge, these were made on April 1 and June 24 to obtain dissolved oxygen profiles during periods of high and normal river flows, respectively. Data show that the dissolved oxygen content in river water generally increased as it passed the Plant site during a period of low temperature and high flow. However, during a period of median temperature and normal flow the oxygen concentrations showed a slight decrease as the river passed the Plant site. Minor variations detected in the oxygen content of river water during these surveys partially reflect the variations in river water temperatures.

River Location	River Mile	Water Temp, °C 6/24	Water Temp, °C 4/1	Dissolved Oxygen, ppm 6/24 Surface	Dissolved Oxygen, ppm 6/24 Bottom	Dissolved Oxygen, ppm 4/1 Surface	Dissolved Oxygen, ppm 4/1 Bottom
Butler Creek	203	21	16	8.0	8.2	6.6	6.5
Spirit Creek	198	21	15	7.7	8.0	8.3	7.3
Silver Bluff	189	21	15	8.2	8.1	9.1	8.3
Grays Landing	184	22	15	8.1	8.3	9.1	8.5
Station A1A	175	22	16	8.2	8.2	8.3	7.8
Hancock Landing	165	22	15	8.2	8.0	9.0	9.5
Griffin Landing	160	22	15	7.8	7.8	8.8	8.8
Brighams Landing	157	22	15	7.7	7.8	9.0	8.8
Steel Creek	155	24	15	7.2	7.3	8.7	8.7
Little Hell Landing	144	25	*	7.6	7.8	6.6	8.5
Lower Three Runs	140	25	14	7.3	7.2	9.5	9.3
Johnsons Landing	135	25	14	7.5	7.4	9.8	9.8
Highway 301	129	25	14	7.6	7.4	10.0	9.7

* Not recorded at this location.

Plant Drinking Water

Samples of drinking water were collected monthly from operating areas and quarterly from other domestic water systems. Analyses of 100 samples are summarized in the following table.

Location	Radioactivity in Water: Alpha, 1 x 10^{-15} c/ml Max	Alpha Avg	Alpha Prev Avg	Nonvolatile Beta, 1 x 10^{-15} c/ml Max	Nonvolatile Beta Avg	Nonvolatile Beta Prev Avg
F Area	10.8	6.7	3.7	55	22	16
H Area	5.8	4.6	4.6	47	25	17
300/700 Area	1.1	0.8	0.6	8	7	9
400 Area	2.7	1.2	0.5	8	7	7
TNX	1.3	0.9	0.8	16	9	9
Pump House 1*	0.9	0.8	0.3	17	12	7
Pump House 2*	0.9	0.7	0.4	7	7	7
R Area	0.4	0.2	0.2	12	9	8
P Area	1.0	0.6	0.2	11	8	7
L Area	0.7	0.5	0.2	8	7	8
K Area	0.4	0.3	0.4	8	7	7
C Area	0.4	0.2	0.5	9	7	8
Par Pond - Pump House	0.2	0.2	0.2	12	8	7
TC-1*	5.1	2.8	1.6	12	9	8
Classification Yards	1.1	0.5	0.4	8	7	7
Central Shops*	0.5	0.5	0.4	7	7	1
Barricade 1*	2.3	1.8	1.8	7	7	7
Barricade 2*	11.5	6.2	15.3	32	28	17
Barricade 3*	0.1	0.1	0.2	7	7	7
Barricade 4*	4.4	3.8	1.9	7	7	7
Barricade 5*	0.2	0.2	0.1	7	7	7
Donora Station Well	0.5	0.2	0.4	8	7	7**
Burial Ground Domestic Well	1.6	0.5	0.3	11	7	8**

* Quarterly samples.

** Four-month averages.

Analyses of the samples in the preceding table showed no detectable tritium concentration.

As in the past, the comparatively high alpha and beta activity found in F Area, H Area and Barricade 2 drinking water was attributed primarily to naturally occurring radioactivity.

Public Water Supplies

Samples of public drinking water were collected monthly from the 14 surrounding towns shown in figure 3. Analyses of 98 samples collected during the report period are summarized in the following table.

	Radioactivity in Water					
	Alpha, 1×10^{-15} c/ml			Nonvolatile Beta, 1×10^{-15} c/ml		
Location	Max	Avg	Prev Avg	Max	Avg	Prev Avg
Allendale	0.3	0.2	0.2	8	7	8
Sardis	0.1	0.1	0.1	10	8	7
Waynesboro	0.4	0.2	0.2	9	7	7
Augusta	0.2	0.2	0.2	8	7	8
North Augusta	0.9	0.4	0.7	9	7	8
Clearwater	0.9	0.4	0.2	8	8	8
Bath	4.3	2.4	1.5	15	9	8
Langley	2.6	1.8	1.5	8	7	8
Jackson	4.4	3.1	2.8	10	8	8
New Ellenton	1.3	0.8	0.8	8	7	10
Aiken	1.7	1.1	1.7	13	8	8
Williston	1.1	0.8	0.6	8	7	7
Blackville	0.4	0.2	0.2	8	7	9
Barnwell	0.4	0.2	0.3	8	7	7

Analyses of the samples in the preceding table showed no detectable tritium concentration.

Ground Water

Ground water was monitored by analysis of water samples collected from drilled, cased wells near F and H Areas (ZW wells) and at the burial ground. Locations of the wells are shown in figures 7 and 8.

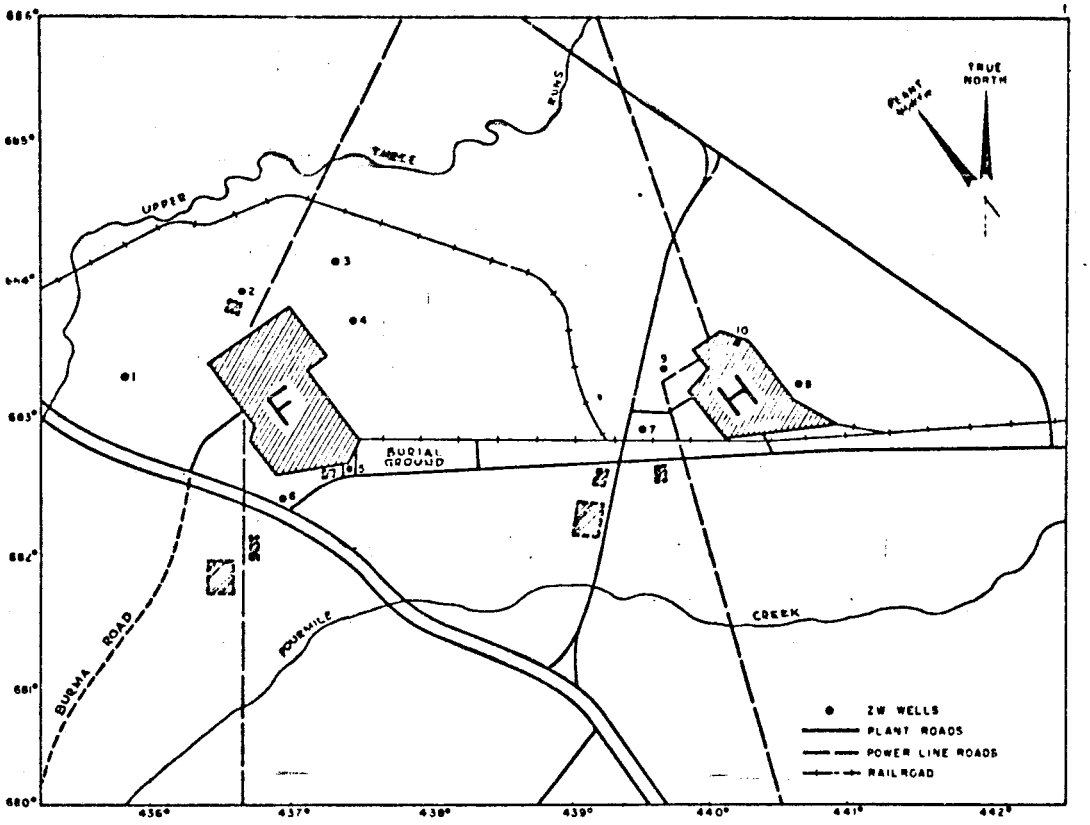

FIGURE 7. ZW WELLS, F AND H AREAS

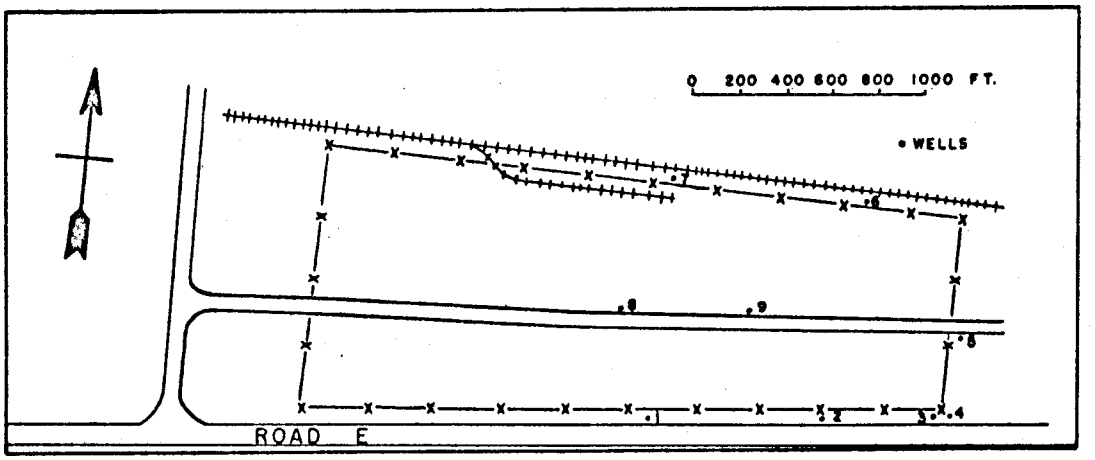

FIGURE 8. BURIAL GROUND WELLS

ZW WELLS, F AND H AREAS

Analyses of 28 samples are summarized in the following table.

Location	Radioactivity in Ground Water: Alpha, 1×10^{-15} c/ml			Nonvolatile Beta, 1×10^{-15} c/ml		
	Max	Avg	Prev Avg	Max	Avg	Prev Avg
1	0.7	0.6	0.5	7	7	7
2	2.1	0.8	0.5	7	7	8
3	2.3	0.8	1.0	7	7	8
4	2.2	0.7	0.9	7	7	11
5	0.8	0.8	0.4	8	8	8
6	1.6	0.5	0.6	8	7	8
7	1.2	0.4	0.3	8	8	10
8	1.1	0.5	0.4	11	8	7
9	3.2	0.8	0.4	10	8	8
10	2.2	0.8	0.6	9	8	8

BURIAL GROUND WELLS

Analyses of 54 samples are summarized in the following table.

Location	Radioactivity in Ground Water: Alpha, 1×10^{-15} c/ml			Nonvolatile Beta, 1×10^{-15} c/ml		
	Max	Avg	Prev Avg	Max	Avg	Prev Avg
1	0.5	0.4	0.3	7	7	7
2	1.4	0.5	0.4	15	8	8
3	0.9	0.5	0.3	7	7	8
4	1.4	0.7	0.5	7	7	8
5	0.7	0.4	0.4	8	7	7
6	0.5	0.4	0.4	8	7	7
7	0.5	0.4	0.3	9	8	8
8	1.6	1.2	1.0	12	9	10
9	0.6	0.4	0.4	9	8	9

Seepage Basins

100 AREAS

Alpha activity discharged to the 100-Area seepage basins was negligible. Nonvolatile beta activity discharged to the basins is shown in the following table.

Area →	Nonvolatile Beta Discharged to 100-Area Seepage Basins, curies				
	R	P	L	K	C
Total	-	58	1.5	3.1	61
Previous Total	3	59	2	17	14

R AREA. The R-Area seepage basins and monitoring wells are shown in figure 9. Nonvolatile beta concentrations in basin water are shown in the following table.

	Nonvolatile Beta in Water, 1×10^{-10} c/ml				
	Basin 2	Basin 3	Basin 4	Basin 5	Basin 6
Avg	4	2	1	2	0.2
Previous Avg	7	3	2	9	0.4

The Sr-90 concentrations measured in seepage basin water are shown in the following table.

	Sr-90 in Water, 1×10^{-10} c/ml			
	Basin 2	Basin 3	Basin 4	Basin 5
Avg	2	0.9	0.5	0.7
Previous Avg	4	2	1	4

In November 1957,

, releasing an estimated 15,000 to 20,000 curies of fission products to the emergency basin in Building 105-R. To minimize the release of activity to the Lower Three Runs - Savannah River system, emergency basin water was pumped into seepage basins excavated in an abandoned construction area north of the reactor building. In December 1959, radioactive vegetation was discovered growing near the seepage basins. As a result, the routine survey program of the seepage basin area was expanded in an effort to determine the cause and extent of the migration of radioactivity from the basin system. Highly radioactive vegetation and major soil contamination was confined to the immediate vicinity of backfilled basin 1.

Results of subsurface surveys, conducted by hand augering 49 test walls, indicated that the movement of radioactivity in groundwater was more rapid in the sandy soils surrounding basins 1 and 3, than

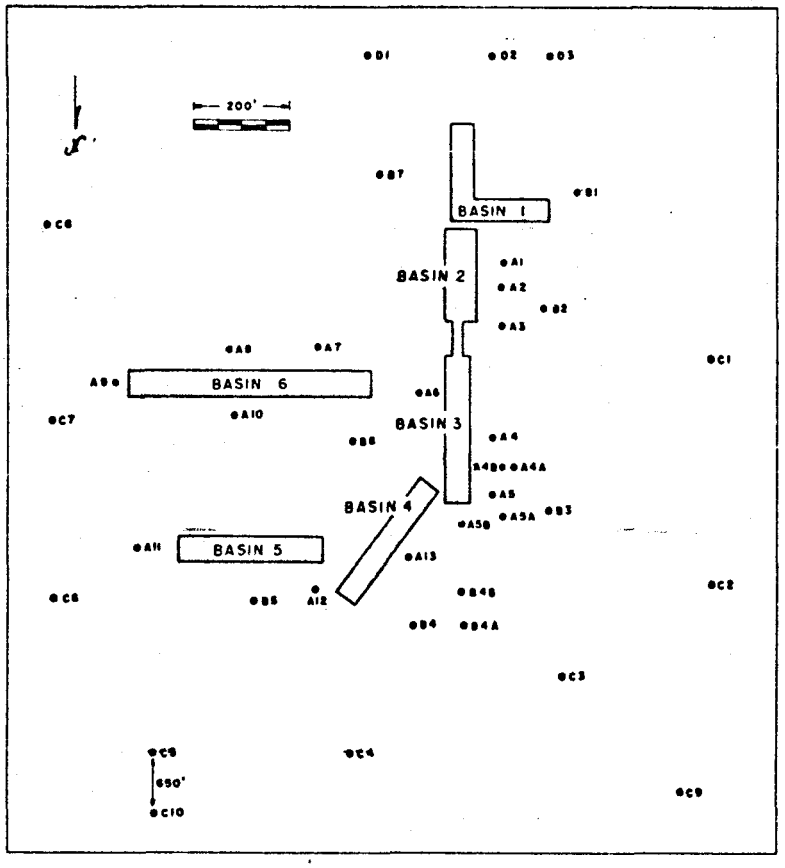

FIGURE 9. R-AREA SEEPAGE BASINS AND MONITORING WELLS

in the clay strata enveloping the remainder of the basins. Specific radiochemical analyses of groundwater from permanent monitoring wells and test wells indicated that greater than 90% of the radioactivity moving outward from the basins is attributable to $Sr\text{-}Y^{90}$.

Biological specimens collected in the area showed an uptake of radioactivity, mainly Cs-134 and Cs-137 in the muscle tissue, and radiostrontium in the bones.

A more detailed study of the radiation levels observed in the area and the recommendations made to minimize further movement of radioactivity from the system are included in DPSPU 60-33.

The maximum nonvolatile beta concentration observed in 234 water samples collected from permanent monitoring wells near the seepage basins was $43{,}000 \times 10^{-15}$ c/ml in well A-4 which is located 50 feet from basin 3. Nonvolatile beta concentrations up to 200×10^{-15} c/ml were observed in wells located south of basin 1 as compared to a maximum of 39×10^{-15} c/ml during the previous six months.

P AREA. Releases of radioactivity to the P-Area seepage basins resulted from disassembly of failed fuel elements and the handling of Chalk River fuel elements. An estimated 0.2 curie of Sr-90 was discharged to the basins from the latter source.

L AREA. Release of radioactive waste to the L-Area basin resulted from flushing of a purification filter change tank. Approximately 75% of the activity was attributed to $Zr\text{-}Nb^{95}$.

K AREA. Radioactive waste released to the K-Area basin resulted from disassembly of failed fuel elements.

C AREA. Radioactivity releases from C-Area were attributed to disassembly of failed fuel elements in the monitor basin and subsequent cleanup of the basin by vacuuming.

700 AREA. Waste discharged to the 700-Area seepage basins included approximately 14 mc alpha and 44 mc nonvolatile beta in 3.05×10^6 liters of water. Analyses of 6 water samples collected from basin 1 are summarized in the following table.

Radioactivity in Water					
Alpha, 1×10^{-12} c/ml			Nonvolatile Beta, 1×10^{-12} c/ml		
Max	Avg	Prev Avg	Max	Avg	Prev Avg
0.96	0.28	0.55	5.6	2.3	1.5

TNX

TNX and CMX discharge waste to a seepage basin which overflows to the Savannah River. Analyses of 26 water samples collected from the basin are summarized in the following table.

Radioactivity in Water					
Alpha, 1×10^{-12} c/ml			Nonvolatile Beta, 1×10^{-12} c/ml		
Max	Avg	Prev Avg	Max	Avg	Prev Avg
11.7	6.0	7.2	52	16	20

200 AREAS

The F and H seepage basin and monitoring well systems are shown in figure 10.

F AREA. During the report period, the average liquid input to the basin system was 2.34×10^5 liters/day of waste and 0.19×10^5 liters/day of rain. The average seepage and evaporation rate was 4.06×10^5 liters/day.

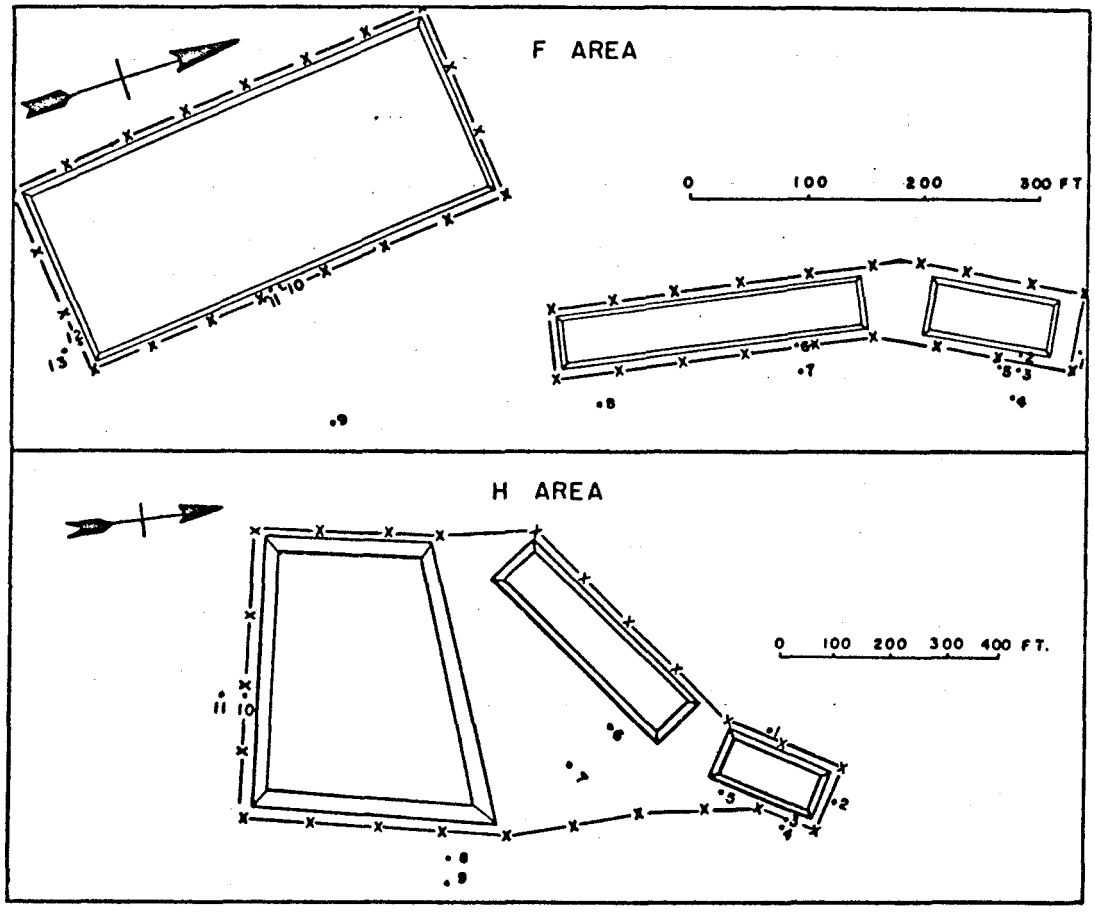

FIGURE 10. SEEPAGE-BASIN MONITORING WELLS IN F AND H AREAS

Waste released to the system is shown in the following table.

Radioactivity Released in 4.25×10^7 Liters of Water

	Alpha Emitters, mc			Beta Emitters, c	
	Total	Prev Total		Total	Prev Total
Uranium	298	248	$Ru^{103,106}$	54.3	28.4
Plutonium	396	303	$Sr^{89,90}$	0.7	1.7
	-	-	$Zr\text{-}Nb^{95}$	98.7	45.1
	-	-	$Ce^{141,144}$	7.3	10.1
	-	-	Cs^{137}	0.6	0.6
	-	-	I^{131}	3.3	18.1
Total →	694	551		164.9	104.0

Analyses of 38 samples collected from the basins are summarized in the following table.

	Radioactivity in Water								
	Alpha, 1×10^{-12} c/ml			Nonvolatile Beta, 1×10^{-12} c/ml			Radioiodine, 1×10^{-12} c/ml		
Basin No.	Max	Avg	Prev Avg	Max	Avg	Prev Avg	Max	Avg	Prev Avg
1	38	14	14	9200	2900	1319	270	79	107
2	18	11	17	1800	1500	909	39	21	25
3	11	8	10	790	680	508	-	-	9

H AREA. During the report period, the average liquid input to the basin system was 1.60×10^5 liters/day of waste and 0.75×10^5 liters/day of rain. The average seepage and evaporation rate was 1.82×10^5 liters/day.

Waste released to the system is shown in the following table.

Radioactivity Released in 2.91×10^7 Liters of Water

	Alpha Emitters, mc			Beta Emitters, c	
	Total	Prev Total		Total	Prev Total
Uranium	9	19	$Ru^{103,106}$	12.7	28.9
Plutonium	9	24	$Sr^{89,90}$	0.3	0.3
	-	-	$Zr\text{-}Nb^{95}$	31.3	11.5
	-	-	$Ce^{141,144}$	4.4	5.6
			Cs^{137}	0.4	0.2
	-	-	I^{131}	0.3	0.1
Total →	18	43		49.4	46.6

Analyses of 38 water samples collected from the basin are summarized in the following table.

Basin No.	Radioactivity in Water: Alpha, 1 × 10^{-12} c/ml Max	Alpha Avg	Alpha Prev Avg	Nonvolatile Beta, 1 × 10^{-12} c/ml Max	Nonvolatile Beta Avg	Nonvolatile Beta Prev Avg	Radioiodine, 1 × 10^{-12} c/ml Max	Radioiodine Avg	Radioiodine Prev Avg
1	0.42	0.12	.95	2000	510	1020	33	4.2	2.9
2	1.11	0.34	2.1	740	340	656	-	-	-
3	0.69	0.47	.86	78	57	94	-	-	-

MONITORING WELLS, F AREA. Analyses of 138 samples are summarized in the following table.

Well No.	Distance from Basin, Ft	Radioactivity in Water: Alpha, 1 × 10^{-15} c/ml Max	Alpha Avg	Alpha Prev Avg	Nonvolatile Beta, 1 × 10^{-15} c/ml Max	Nonvolatile Beta Avg	Nonvolatile Beta Prev Avg	Radiostrontium, 1 × 10^{-15} c/ml Max	Radiostrontium Avg	Radiostrontium Prev Avg
1*	34	1900	528	14,000	190,000	82,000	320,000	29,000	9,000	79,000
2	5	2.4	1.4	3.6	140	85	330	-	-	-
3	29	0.6	0.3	.4	97	34	8	-	-	-
4	73	1.2	0.5	.9	145	35	9	-	-	-
5*	24	1.5	0.4	6.8	3,500	1,300	4,800	-	-	500
6*	6	310	100	91	36,000	20,000	38,000	21,000	8,000	17,000
7*	46	600	100	630	16,000	3,300	34,000	3,300	600	7,000
8	63	0.9	0.7	0.9	9	8	8	-	-	-
9	150	0.7	0.4	0.9	10	8	11	-	-	-
10*	9	6600	3000	5,860	420,000	200,000	350,000	36,000	14,000	55,000
11	9	0.5	0.3	0.9	26	14	23	-	-	-
12*	29	7600	2400	3,300	460,000	120,000	220,000	44,000	14,000	53,000
13*	58	3500	2200	1,170	190,000	73,000	190,000	42,000	11,000	56,000

* Wells into perched water table.

Continued high concentrations of nonvolatile beta were observed in the perched water table underneath the F-Area seepage basins; however, the isotopic content of the activity has changed ($Sr\text{-}Y^{90}$ accounted for 60% of the total activity during the previous report period as compared to 30% during this report period, whereas the $Ru\text{-}Rh^{106}$ fraction has increased from 40% to 70%).

MONITORING WELLS, H AREA. Analyses of 70 samples are summarized in the following table.

Well No.	Distance from Basin, Ft	Radioactivity in Water: Alpha, 1 X 10^{-15} c/ml Max	Alpha Avg	Alpha Prev Avg	Nonvolatile Beta, 1 X 10^{-15} c/ml Max	Nonvolatile Beta Avg	Nonvolatile Beta Prev Avg
1	24	44	20	720	2,300	1,100	27,000
2	25	0.9	0.5	0.4	9	7	9
3	15	0.6	0.4	0.4	380	200	120
4	45	0.5	0.4	0.4	10	8	10
5*	13	28	25	15	18,000	14,000	9,900
6	6	0.9	0.3	0.9	324	110	16
7	66	0.4	0.3	0.9	8	7	42
8	18	0.6	0.3	0.4	87	69	19
9	78	0.6	0.4	0.4	16	11	10
10	19	0.5	0.3	0.4	18	10	140
11	79	0.4	0.2	0.4	200	140	180
A-37	-	3.7	2.8	0.9	1,200	1,000	600
A-38	-	6.9	4.6	2.7	1,300	1,000	900
A-39	-	2.9	2.2	0.9	1,100	860	1,000
A-40	-	0.8	0.5	0.4	850	660	580
A-41	-	0.7	0.5	0.4	470	280	270

* Average concentration of Sr-90 in well number 5 was 4 X 10^{-12} c/ml. Maximum concentration was 7 X 10^{-12} c/ml.

Wells A-37 through A-41 are located about 12½ feet apart, a few feet uphill from a swamp bordering the H-Area effluent. They were installed in the zone of the most rapid movement of seepage basin water into the swamp. Tritium was detected in water from all of these wells. The average concentration from analyses of 49 samples was 2.8 X 10^{-8} c/ml with a maximum of 6.5 X 10^{-8} c/ml. Specific analyses of water from well A-37 indicated that the Sr-90 and Y-90 concentrations remained essentially unchanged during the report period (0.6 X 10^{-12} c/ml in January; 0.4 X 10^{-12} c/ml in June), while the $Ru^{103,106}$ concentration increased from 0.3 X 10^{-12} c/ml in January to 2.4 X 10^{-12} c/ml in June.

Biological Specimens

TERRESTRIAL

The terrestrial animal sampling program was expanded during this period following the detection of high concentrations of radioactivity in domestic cats found in R Area. Animal traps were set around the R-Area seepage basin system, the apparent source of radioactivity. Thirty specimens including 5 domestic cats, 3 field mice, 4 foxes, 4 racoons, 2 field rats, 9 rabbits, 2 wild dogs and one bobcat were collected within a half-mile radius of the seepage basins. The main gamma emitters in the fleshy tissues were Cs-134 and Cs-137. Although the radioactivity in the bones was primarily radiostrontium, radiocesium and radiocerium were also detected. External radioactivity on the fur included all of the isotopes listed. Longitudinal and cross sectional radioautographs of the thigh bone of an adult domestic cat showed a relatively uniform distribution of radioactivity. The nonvolatile beta concentrations found in the bones and flesh of these specimens are shown in the following table.

Specimens	No. of Samples	Nonvolatile Beta, 1×10^{-12} c/g			
		Bones		Flesh	
		Max	Avg	Max	Avg
Domestic Cats	5	32,600	17,760	20,400	4,900
Field Mice	3	11,000	5,900	6,400	3,100
Foxes	4	1,200	325	10	8
Raccoons	4	300	100	10	10
Field Rats	2	110	70	35	25
Rabbits	9	100	40	20	8
Dogs	2	20	20	5	4
Bobcat	1	-	10	-	10

Seventeen terrestrial specimens including 3 domestic cats, 2 raccoons, 10 rabbits, 1 deer and 1 fox were collected at random on the Plant site and analyzed for radioactivity. The nonvolatile beta concentrations found in the bones and flesh of these specimens are shown in the following table.

Specimens	No. of Samples	Nonvolatile Beta, 1×10^{-12} c/g			
		Bones		Flesh	
		Max	Avg	Max	Avg
Domestic Cats	3	45	25	4	3
Raccoons	2	20	20	15	10
Rabbits	10	40	20	15	4
Fox	1	-	20	-	3
Deer	1	-	10	-	4

AVIAN

Twenty specimens of aquatic waterfowl, including 3 herring gulls, 3 pied-billed grebes, 11 green-winged teals and 3 mallards were collected from Par Pond for radioanalysis. The nonvolatile beta concentrations found in the bones and flesh of these specimens, shown in the following table, approximate the concentrations found in similar species during the winter of 1959. The concentrations in the gulls and grebes were higher since they are primarily ichthyophagous; whereas, the teals and mallards are herbivorous.

Species	No. of Samples	Nonvolatile Beta in Par Pond Waterfowl, 1×10^{-12} c/g			
		Bones		Flesh	
		Max	Avg	Max	Avg
Gull	3	25	20	50	40
Grebe	3	45	35	20	15
Teal	11	25	15	15	10
Mallard	3	20	15	10	7

AQUATIC

A total of 858 aquatic samples including 538 fish, 288 algae, 9 shrimp, 8 clams, 12 oysters and 3 crayfish were collected from the reactor effluents and the Savannah River. Since R, P, and L reactor effluent systems contained the highest concentrations of long-lived radioisotopes, primary emphasis was placed on the collection of samples from these systems. Savannah River algae and fish were collected routinely near the mouth of each effluent stream, at the Highway 301 bridge and at Stokes Bluff.

REACTOR EFFLUENT. Fish collected from all four of the reactor effluent streams contained significant concentrations of radiostrontium (Sr-89, Sr-Y^{90}) in the bones, and trace concentrations of radiozinc (Zn-65) in the fleshy tissues. Par Pond, Lower Three Runs and Steel Creek fish also contained radiocesium ($Cs^{134,137}$) in the flesh. Radiostrontium and radiocesium concentrations in the bones and flesh of reactor effluent fish were higher by factors of 10^4 and 10^3, respectively, than found in effluent water.

Nonvolatile beta concentrations in reactor effluent fish decreased slightly during the report period with the exception of those collected from Lower Three Runs, 6 miles below the Par Pond dam. Fish were collected from Upper Three Runs to provide control samples. Nonvolatile beta concentrations found in fish collected from the effluent streams are shown in the following table.

		Nonvolatile Beta in Effluent Fish, 1×10^{-12} c/g					
		Bones			Flesh		
Location	No. of Samples	Max	Avg	Prev Avg	Max	Avg	Prev Avg
Upper Three Runs	24	25	15	10	10	4	4
Steel Creek and Pen Branch	42	1170	415	485	145	50	70
Par Pond	172	635	150	165	90	30	35
Lower Three Runs							
1 Mile Below Dam	74	545	175	210	105	35	70
6 Miles Below Dam	32	500	225	220	155	45	40
14 Miles Below Dam	32	365	85	110	85	25	35

Lower Three Runs crayfish and shrimp, collected 14 miles below the dam, contained significant concentrations of nonvolatile beta radioactivity. The maximum nonvolatile beta concentrations measured in crayfish were 525×10^{-12} c/g in the shells and 20×15^{-12} c/g in the flesh. The maximum nonvolatile beta found in whole shrimp was 110×10^{-12} c/g, higher by a factor of 2 than detected during the previous report period.

Algae samples collected from effluent streams at the Road A intersections concentrated the nonvolatile beta in the water by a factor of 10^3. The increased concentrations in Four Mile, Pen Branch, and

Steel Creek algae and the decreased concentration in Lower Three Runs algae, reflect changes in the radioactivity levels of effluent water during this period. The nonvolatile beta found in algae samples collected weekly are shown in the following table.

Effluent	Nonvolatile Beta in Effluent Algae, 1×10^{-12} c/g		
	Max	Avg	Prev Avg
Upper Three Runs	185	50	50
Four Mile Creek	7,600	1500	1250
Pen Branch	10,500	1950	1325
Steel Creek	42,000	6800	1200
Lower Three Runs	120	65	125

SAVANNAH RIVER. Savannah River fish, collected near the mouth of each Plant effluent, at the Highway 301 bridge crossing and at Stokes Bluff, generally contained low level concentrations of nonvolatile beta in the bones with no significant radioactivity in the flesh. The nonvolatile beta concentrations detected in these fish are shown in the following table.

River Location	No. of Samples	Nonvolatile Beta in River Fish, 1×10^{-12} c/g					
		Bone			Flesh		
		Max	Avg	Prev Avg	Max	Avg	Prev Avg
Above Upper Three Runs	13	15	14	-	5	4	-
Upper Three Runs	14	25	13	12	5	3	4
Four Mile Creek	35	175	25	30	6	4	3
Steel Creek and Pen Branch	14	105	35	28	10	5	6
Lower Three Runs	20	45	20	18	6	4	6
Highway 301	12	25	15	22	5	4	4
Stokes Bluff	33	30	15	12	5	4	4

The nonvolatile beta concentrations found in Savannah River algae collected near the mouth of each reactor effluent were lower than those measured during the previous period. Radioactivity released by Plant operations was detectable in river algae as far downstream as Stokes Bluff, 60 miles below the Plant site. The radioactivity measured in river algae is shown in the following table.

River Location	Nonvolatile Beta in River Algae, 1×10^{-12} c/g		
	Max	Avg	Prev Avg
Above Upper Three Runs	135	35	35
Upper Three Runs	40	30	40
Four Mile Creek	105	45	55
Steel Creek and Pen Branch	375	85	125
Lower Three Runs	320	70	120
Highway 301	420	80	65
Stokes Bluff	65	65	60

In addition to the routine collections of algae and fish, special collections of aquatic biota are made at irregular intervals from locations as far removed from the Plant as Savannah, Georgia. Results of analyses of these samples showed no abnormal quantities of radioactivity. The nonvolatile beta measured in Savannah River clams, oysters, and fish are shown in the following tables.

Nonvolatile Beta Emitters in Clams, 1×10^{-12} c/g*

Upstream from Plant				At Plant Boundry				Downstream from Plant			
Shell		Flesh		Shell		Flesh		Shell		Flesh	
Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg
20	17	3	3	7	6	2	2	15	12	3	3

* Collected from the Savannah River during June 1960.

Nonvolatile Beta Emitters in Fish, 1×10^{-12} c/g*

Bone		Flesh	
Max	Avg	Max	Avg
35	15	5	4

* Collected from Union Creek (vicinity of Port Wentworth, Georgia) during May 1960.

Nonvolatile Beta Emitters in Oysters, 1×10^{-12} c/g

Date	Location	Shell		Flesh	
		Max	Avg	Max	Avg
May 1960	May River	7	6	3	2
June 1960	Edisto Island	7	5	2	2

Tritium

Releases due to Plant operations and the concentrations measured in environmental samples are summarized in the following tables.

100 AREAS

	Tritium Released, curies/6 months						
	R	P	L	K	C	Total	Prev Total
Stack	25,000	28,000	18,000	31,000	36,000	138,000	86,000
Stream	5,300	4,400	5,700	2,100	7,600	25,000	20,300

200 AREAS

400 AREA

Tritium released to effluent streams from this area totaled 400 curies.

SAVANNAH RIVER LABORATORY

Tritium releases from the Savannah River Laboratory are summarized below.

Stack Releases, curies/6 months	
773-A	TNX
3500	3100

ATMOSPHERIC

Results of 622 water vapor samples and 389 rainwater samples collected continuously at each of the monitoring stations are shown in the following table. Rainwater concentrations and rainfall measurements indicate a deposition on the Plant of approximately 25 curies of tritium per square mile as compared with 27 curies per square mile during the previous report period.

	Atmosphere Tritium, 1×10^{-9} µc/cc*			Rainwater Tritium, 1×10^{-12} c/ml		
	Max	Avg	Prev Avg	Max	Avg	Prev Avg
F Area	1.75	0.46	0.75	450	63	12
H Area	5.72	1.36	1.62	1405	176	63
3/700 Area	0.39	0.15	0.54	63	11	8
Talatha Gatehouse	0.63	0.17	0.67	20	6	12
Williston Gatehouse	1.08	0.27	0.29	48	11	7
Dunbarton Fire Tower	1.05	0.27	0.33	91	16	12
400 Area	0.76	0.20	0.71	66	17	19
Aiken Airport	0.35	0.08	0.11	12	5	5
Allendale	0.15	0.07	0.10	7	4	5
Waynesboro	0.26	0.08	0.30	52	8	6
Langley	0.18	0.07	0.10	8	5	5
Williston	0.69	0.14	0.16	17	5	5
Barnwell	0.40	0.14	0.10	6	4	5
Sardis	0.32	0.09	0.48	16	6	4
Bush Field	0.31	0.10	0.17	8	5	6
Green Pond Church	1.03	0.14	0.33	14	5	8
Military Recreation Site	2.19	0.19	0.33	14	5	15
Jackson	0.44	0.12	0.18**	25	6	5**

* Concentration in water converted to concentration in air by use of appropriate humidity values.

** Three-month averages.

MILK

Milk samples were collected weekly from Talatha, Snelling, Aiken, North Augusta and Langley, South Carolina. Results of 125 samples are shown in the following table.

	Tritium in Milk, 1×10^{-12} c/ml		
	Max	Avg	Prev Avg
Talatha	12	6	9
Snelling	13	7	5
Langley	8	5	7
Aiken	14	6	6
North Augusta	8	5	5

GROUND WATER

Results of 36 samples of ground water collected from twelve Z wells, 19 samples from ten ZW wells, and 54 samples from nine burial ground wells are shown in the following table. The location of each Z well is shown in figure 11, (refer to figures 7 and 8 for the location of ZW and burial ground wells).

	Tritium in Ground Water, 1×10^{-12} c/ml								
	Z Wells			ZW Wells, F and H Areas			Burial Ground Wells		
Well No.	Max	Avg	Prev Avg	Max	Avg	Prev Avg	Max	Avg	Prev Avg
1	28	24	50	4	4	4	8	5	4
2	14	10	6	4	4	4	9	5	4
3	4	4	4	35	34	26	5	4	4
4	*	-	4	42	42	32	217	186	290
5	*	-	-	51	51	15	45	37	40
6	*	-	6	61	57	79	6	5	4
7	*	-	-	135	116	80	5	4	4
8	12	11	7	4	4	4	5	4	5
9	*	-	-	48	46	34	10	6	8
10	*	-	-	4	4	4			
11	71	64	81						
12	18	16	12						
13	8	6	5						
14	*	-	15						
15	104	99	108						
16	*	-	-						
17	4	4	4						
18	30	26	23						
19	4	4	4						
20	5	4	4						
20A	*	-	4						

* Wells occluded by debris.

H-AREA EFFLUENT AND THE SAVANNAH RIVER

Water samples obtained from Four Mile Creek location 2 (H-Area effluent were analyzed weekly for tritium content. The average concentration was 120×10^{-12} c/ml (maximum 275×10^{-12}c/ml), compared to 110×10^{-12} c/ml (maximum, 170×10^{-12} c/ml) during the previous six months period. Tritium activity measured at Savannah River location 10 (downstream from the Plant) totaled 50,300 curies compared to 31,800 curies during the previous six-month period. See figure 6 for stream and river sample locations.

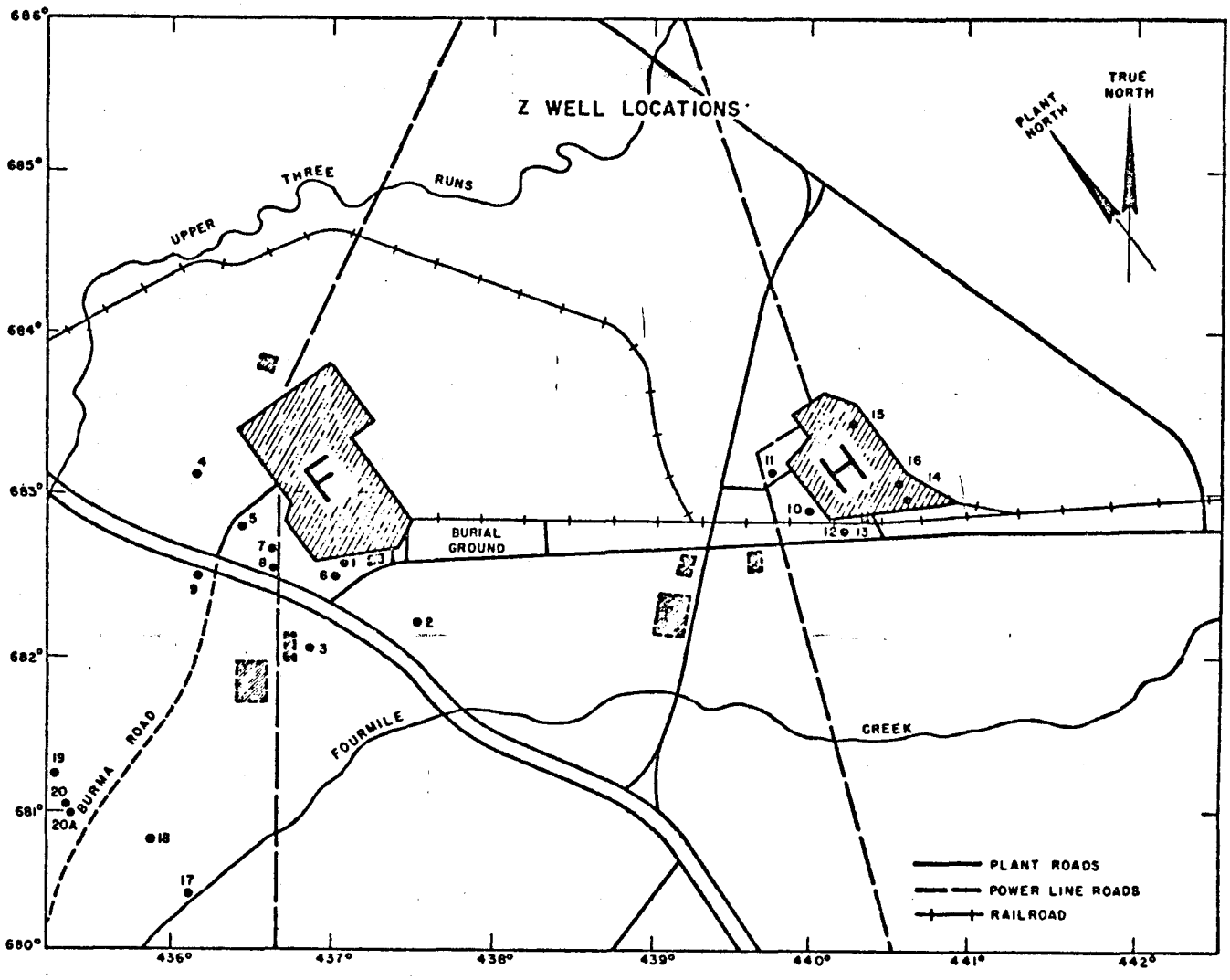

FIGURE 11. Z WELL LOCATIONS