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HEALTH PHYSICS DIVISION

WASTE DISPOSAL SECTION

Preliminary Report

On

DISCHARGES OF RADIOACTIVITY INTO WHITE OAK CREEK AND THE CLINCH RIVER - JANUARY 1 TO NOVEMBER 27, 1948

By: Lloyd R. Setter

O A K R I D G E N A T I O N A L L A B O R A T O R Y

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During the year 1948 fairly reliable records were available on the White Oak Dam opening and the lake elevation so that the flow into the Clinch River could be estimated. The importance of the White Oak Creek Drainage System in the disposal of wastes at Oak Ridge National Laboratory and the method of estimating the flow of water discharged at White Oak Dam are discussed in a previous report (1).

Normally samples of overflow of the White Oak Dam into the Clinch River are collected daily during the working week. These samples are tested by gamma immersion counters and three 50 ml. portions evaporated to dryness in dishes and counted for beta-gamma activity. The beta-gamma activity was converted to curies per unit volume by assuming 3.7×10^{10} disintegrations per second per curie. Where the activity per unit volume changed from, say Friday to Monday, a proportional value was assumed for days of no test. The curies per day of radioactivity discharged were then calculated from the flow and the concentration.

The method of estimating the flow and hence the quantity of radioactivity discharged is subject to two errors which occasionally are of considerable magnitude. First, the Dam overflow is normally through a gate opening which acts as a weir and from

which accurate flows could be calculated if it were not for two screens, one placed a few feet upstream from the gate and one downstream a few feet. The screens cause a considerable loss of head when debris has been allowed to collect, as immediately following a rainstorm. Thus, during a small percentage of the time, the actual flow through the gate is somewhat less than the recorded value.

Secondly, depending upon the magnitude of a rain and the runoff characteristics, the concentration of activity in the overflow of the Dam is likely to change rapidly and sampling at least hourly would be required to get a true estimate of the quantity of activity. This tendency was noticed following the February and July rains. In order to appraise this factor, the rain of November 19 was studied more intensively by collecting samples at intervals of 30 minutes to four hours during the flood flows and for two days afterward.

Both errors have their greatest effect during or following rains of considerable magnitude. Fortunately heavy rains are infrequent but, nevertheless, it is important to analyze them critically.

Results

A summary of the monthly results is presented in Table 1 which shows the maximum, minimum and average curies of radioactivity discharged daily from the settling basin or from the East and West Ponds into the White Oak Creek and thence into White Oak Lake; and the maximum, minimum and average curies discharged from the lake into the Clinch River. The data for the quantity of activity discharged into the White Oak Creek were taken directly from the

Table 1

RADIOACTIVITY INTO AND OUT OF WHITE OAK CREEK DISPOSAL SYSTEM

Month	Radioactive Substances Discharged Into White Oak Creek System			Radioactive Substances Discharged Into Clinch River			Ratio Of Average Curies Discharged In Clinch River To Total Waste
	Max. C/Day	Min. C/Day	Ave. C/Day	Max. C/Day	Min. C/Day	Ave. C/Day	Percentage
Jan.	5.2	0.1	1.03	2.12	0.16	0.53	51.2
Feb.	6.6	0.1	2.51	21.6	0.32	2.47	98.4
March	6.4	1.2	2.97	3.6	0.59	1.35	45.5
April	6.5	1.4	2.72	3.63	0.65	1.56	58.1
May	6.96	1.75	3.72	2.62	0.0	1.16	31.1
June	11.72	1.23	3.06	1.42	0.0	0.57	18.6
July	3.62	0.21	1.18	5.05	0.12	0.62	52.5
Aug.	7.02	1.08	2.7	1.13	0.34	0.65	24.1
Sept.	6.13	1.41	3.07	1.21	0.0	0.66	21.5
Oct.	11.82	0.4	2.59	0.97	0.0	0.62	23.9
Nov. 1 - 7	3.98	2.34	3.1	8.06	0.42	2.65	85.5
7 - 14	13.35	1.84	4.7	4.70	0.0	1.39	29.6
14 - 21	6.14	1.4	2.86	31.54	0.14	5.79	202.4
21 - 28	4.43	1.58	2.89	3.98	0.05	1.44	49.8

Operations Weekly Progress Reports while the Area Monitoring Group analyzed and, for the most part, computed the activity in the White Oak Dam overflow.

Any day by day variation in the radioactivity going to the White Oak Creek is a result of O.R.N.L. operations, whereas the radioactivity leaving the lake is a composite result of the activity entering, the hold up or detention time resulting in radioactive decay, the absorption of radioactivity on clay or other particles which settle or are otherwise retained in the lake, and, finally, the scouring action of storm waters in sweeping out soluble radioactive constituents and contaminated silt or eluted substances.

It will be noted that during February, July, and again in November one or more rains of considerable intensity caused a radioactive discharge of unusual magnitude for a few hours or a few days duration while during dry weather conditions a substantial reduction in the radioactivity was achieved in the White Oak Creek and Lake disposal system. During the "wet" months or intense rains the monthly average efficiency of the disposal system fell to values of zero to 50 percent as against 75 to 80 percent efficiency during "dry" months.

The overall picture of the efficiency of the White Oak Creek and Lake disposal system by a cumulative summation of the radioactivity entering and leaving the system each month beginning January 1, 1948, is shown in Table 2. According to the last column in Table 2 the poor removal during "wet" months or intense rains offsets the good removals obtained during the "dry" weather conditions to give an eleven month average efficiency of about 55.4 percent. From January 1 to November 27, 1948, a total of

Table 2

THE CUMMULATIVE RADIOACTIVITY ENTERING AND LEAVING THE WHITE OAK SYSTEM

Period	Discharge of Activity Into White Oak Lake	Discharge of Activity Into Clinch River	Cummulative Discharge Into White Oak Lake	Cummulative Discharge Into Clinch River	Net Activity Retained Or Decayed in Lake	Net Removal Of Activity By The White Oak System
	Curies	Curies	Curies	Curies	Curies	Percentage
Jan.	32.1	15.8	32.1	15.8	16.3	50.7
Feb.	72.9	71.7	105.0	87.5	17.5	16.8
March	92.1	41.8	197.1	129.3	67.8	24.4
April	84.3	47.3	281.4	176.6	104.8	37.3
May	115.3	36.0	396.7	212.6	184.1	46.5
June	91.9	17.0	488.6	229.6	259.0	53.1
July	36.6	20.7	525.2	250.3	274.9	52.4
Aug.	70.2	20.1	595.4	270.4	325.0	54.6
Sept.	92.0	19.7	687.4	290.1	397.3	57.8
Oct.	80.4	19.2	767.8	309.3	458.5	59.8
Nov. 1 - 7	18.7	13.3	786.5	322.6	463.9	58.9
7 - 14	33.1	9.7	819.5	332.4	487.1	59.4
14 - 21	20.0	40.5	839.5	372.9	466.6	55.5
21 - 27	20.1	10.1	859.6	383.0	476.6	55.4

860 curies had been discharged into White Oak Creek of which 476.6 curies were retained by the disposal system and 383 curies or 44.6 percent were discharged into the Clinch River.

The Daily Variations Of Radioactivity Discharged Into The White Oak Creek And The Clinch River

A limit of 5 curies of radioactivity per day has been a derived permissible discharge into the White Oak Creek. The Operations data indicate that on the whole a small fraction of this limit was discharged and on only 25 out of 331 days was the limit exceeded by 0.1 curies to less than 3 times 5 curies. Although this, or a similar limit, is a desirable standard to guide the Operations Department it bears little relation to the concentration of radioactive waste which may be discharged to the Clinch River. The two major reasons for this are, first, the scouring action of rains which may flush large quantities of radioactivity present in the White Oak Creek into the Clinch River in a relatively short time, and, secondly, the variable flow of the Clinch River which is largely controlled by the operation of the turbines at Norris Dam. Consequently, the dilution water available at the mouth of White Oak Creek comes in waves and may vary as much as 25 fold in a single 24 hour period. Thus the dilution afforded by the Clinch River during local rains depends on the time of the rain with respect to the wave of Clinch River flow. It is therefore obvious that the Clinch River may, at low flow, be charged with high quantities of radioactive wastes.

A study of the daily discharge of radioactive wastes from White Oak Lake into the Clinch River indicates that in the

first 331 days of 1948 the radioactivity exceeded 10 curies per day on 3 days and exceeded 5 curies per day on 8 days. Often the discharge is only a fraction of a curie and on only 34 days or about 10 percent of the time did the discharge exceed 2.0 curies per day.

The monthly distribution of relatively high radioactive discharges of White Oak Lake is as follows:

Month	Number of Days	
	Exceeding 2 curies Less than 5 curies	Exceeding 5 curies
Jan.	1	
Feb.	4	4
March	7	
April	7	
May	3	
July	1	1
Nov.	3	3

Discharge to the Clinch River in excess of 5 curies per day happened only during flood stages of the White Oak Creek. By flood stages is meant periods following intensive rainfall which caused the lake elevation to rise above the coffer dam. During the eleven months study the coffer dam overflowed on seven days due to four rainy periods. Each of the four stormy periods will be analyzed separately.

Flood Of February 12, 1948

On February 12, an intermittent intense rainfall of 2.22 inches fell between 4 A.M. and 9 A.M. More rain (2.47 inches) fell between 4 P.M. and 7 A.M. February 13. The third rain of

1.37 inches fell between 5 P.M. and midnight of February 13. The pertinent data resulting from this rainy period are given in Table 3.

The table shows the maximum hourly overflow of White Oak Dam in cubic feet per second (Column 2); the average rate of flow during a 24 hour interval (Column 3); and the radioactivity in curies i.e., counts per minute of beta-gamma activity per 50 ml. times the flow in appropriate units, assuming one curie is equivalent to 3.7×10^{10} disintegrations per second. The probable maximum radioactivity after intimate mixing with the Clinch River flow was calculated in milli microcuries per liter or microcuries per 1000 liters (Column 7) based on the daily discharge of curies and the flow of the Clinch as recorded in Column 5. The probable average radioactivity in the Clinch River after intimate mixing was calculated in milli microcuries per liter (Column 8) based on a total estimated flow (Columns 5 plus 6) which includes tributaries between the Scarboro Gaging Station down stream to below the mouth of White Oak Creek. It should be understood that the maximum concentration of radioactivity in any small sample of Clinch water will be the maximum concentration in the White Oak Dam overflow until intimate mixing has occured. This may take from a few to ten or more miles of water travel depending on stream characteristics and thermal density differences. The maximum concentrations will usually hug the right bank and possibly under-ride the surface waters in summer.

Flood of July 14, 1948

On July 14 an intense rain of 2.2 inches fell between

Table 3

FLOOD OF FEBRUARY 12 - 15, 1948

Date	Overflow of W.O.Dam Max.Rate c.f.s.	Overflow of W.O.Dam Ave.Rate c.f.s.	Activity Discharge Into Clinch R. Curies	Flow* of Clinch R. At Scarboro c.f.s.	Flow** of Tributaries Cl.mi.39.0 to mi.20.8 c.f.s.	Prob.Max. Activity In Clinch R. mμc/l1	Prob.Ave. Activity In Clinch R. mμc/l1
2 - 12	340	192	7.3	8110	1920	0.368	0.29
2 - 13	940	544	21.6	19100	5440	0.462	0.36
2 - 14	400	217	11.5	21000	2170	0.224	0.20
2 - 15	151	122	5.1	9050	1220	0.230	0.20
2 - 16	-	41	1.7	3380	410	0.206	0.18

NOTE: (*) The flow in Column 5 is the T.V.A. official flow of the Clinch River at the Scarboro gaging station. No adjustment has been made for the time of water travel nor the tributary dilution in calculating the probable maximum radioactivity in milli micro curies per liter from this flow as shown in Column 7.

(**) The local tributary flow between the Scarboro gaging station and Clinch mile 20.7 was estimated from the ratio of the drainage area between stations to the drainage area of White Oak Creek, i.e., 63 to 6.17 square miles or a factor of 10 times the flow of White Oak Creek.

2:30 and 3:30 P.M. The lake level rose rapidly in spite of a lowering of the gate to wide open. By 6:00 P.M. flood stage had been reached and persisted for 3 hours. Thereafter the lake was drawn down to about the same level as before the storm. The gate was then raised (11:30 A.M. July 15).

The results of this rain are presented in Table 4. The columns in Table 4 have the same basis as those in Table 3. The data show that on a 24 hour average basis the concentration of radioactivity was estimated to be somewhat greater than the February flood. It is apparent, also, that the hourly discharge due to this flash flood caused much more severe "slugging" of the Clinch River. The hourly discharge data shows that a total of 5 million cubic feet of water (about one half the contents of the lake) which contained 5 curies of radioactivity were discharged between 6 P.M. and midnight on July 14. An inspection of the hourly Clinch River flow at the Townsite Gaging Station (Clinch mile 41.3) shows that, if allowance for time of travel to White Oak Creek be made, a flow of from 1700 to possibly 3200 c.f.s. was available for dilution. Assuming immediate intimate mixing, a concentration of not less than 4.8 to 2.5 milli microcuries per liter persisted during the six hours of maximum slugging.

Floods Of November 19 And Of November 28, 1948

On November 18, a light rain of 0.1 inches fell between 10 P.M. and midnight. This was followed on November 19, by a rain of 3.1 inches which fell between 5 A.M. and 4 P.M. There was no rain on November 20, but on November 21, a shower of 0.1 inch fell between 9 P.M. and 12 midnight and a rain of 0.3 in. fell between 1 A.M. and 10 A.M. November 22. Beginning at 2 A.M.

Table 4

FLOOD OF JULY 14, 1948

Date	Overflow of W.O.Dam Max.Rate c.f.s.	Overflow of W.O.Dam Ave.Rate c.f.s.	Activity Discharge Into Clinch R. Curies	Flow* of Clinch R. At Scarboro c.f.s.	Flow** of Tributaries Cl.mi.39.0 to mi.20.8 c.f.s.	Prob.Max. Activity In Clinch R. mμc/l	Prob.Ave. Activity In Clinch R. mμc/l
7 - 13	-	6.2	0.1	4520	62	0.036	0.036
14	330	64.6	5.1	3940	646	0.53	0.45
15	152	53.0	3.5	3580	530	0.40	0.35
16	-	3.9	0.25	3170	39	0.032	0.032

NOTE: (*) and (**) same as Table 3.

November 28 and until 4 A.M. November 29, a total of 3.8 inches of precipitation was recorded.

Flood discharges of the Dam were reached at 9:20 P.M. November 19, and persisted until midnight. Flood stages were again attained at 7 A.M. November 28 and persisted until 6 P.M. November 29.

During the first flood, arrangements were made by W. D. Cottrell (Area Monitoring Group) with the cooperation of other groups of the Survey-Monitoring Section, to have samples collected at about four hour intervals or more frequently from 9:20 A.M. July 19, to the afternoon of July 22. Only a few extra samples besides the routine samples were obtained at later dates. These samples were analyzed by the Waste Disposal group for beta-gamma counts associated with the sediment removed by centrifuging for 5 minutes and the soluble and colloidal solids in the centrifuged supernates.

A summary of the daily results from November 15, to November 30, is presented in Table 5. The results show two periods of high curie discharge. These were between the 19th and 21st and again betwen the 26th and 30th of the month. Due to the variable discharge the resulting concentration in the Clinch River varied from 0.48 to 1.62 or a weighted average of 1.11 milli microcuries per liter over a 72 hour period beginning November 19, at 12:01 A.M. for the first flood and a variation of 0.48 to 0.57 or a weighted average of 0.55 milli microcuries per liter for the second flood over a period of 72 hours beginning 12:01 A.M. November 26.

Although the 24 hour average concentration is probably

Table 5

FLOODS OF NOVEMBER 19 AND NOVEMBER 28, 1948

Date	Overflow of W.O.Dam Max.Rate c.f.s.	Overflow of W.O.Dam Ave.Rate c.f.s.	Activity Discharge Into Clinch R. curies	Flow* of Clinch R. At Scarboro c.f.s.	Flow** of Tributaries Cl.mi.41.3 to mi.20.8 c.f.s.	Prob.Max. Activities In Clinch R. muc/ml	Prob.Ave. Activity In Clinch R. muc/ml
15	-	0.6	0.14	-	-	-	-
16	-	1.5	0.42	-	-	-	-
17	-	2.2	0.51	-	-	-	-
18	-	2.2	0.47	1580	54	0.12	0.12
19	416	172.0	31.54	3320	4300	3.70	1.62
20	156	101.0	7.44	3660	2500	0.81	0.48
21	53	35.0	3.60	1000	875	1.42	0.76
22	39	22.9	1.06	520	572	0.80	0.38
23	-	0.5	0.05	2710	475	0.007	0.006
24	-	1.0	0.10	2760	370	0.015	0.013
25	-	1.3	0.17	2300	290	0.030	0.027
26	21.1	7.8	1.10	690	195	0.64	0.50
27	31.6	29.7	4.28	2840	740	0.61	0.48
28	547.0	265.0	18.57	6650	6610	1.14	0.57
29	235.0	150.0	3.53	11100	3740	0.13	0.10
30	81.0	47.5	3.50	high	-	-	-

* The drainage area between Clinch 20.7 and Clinch 41.3 was estimated at 154 sq.miles or a flow of 25 times that of White Oak Creek.

more significant it has been calculated that during the peak flow of the White Oak Creek (12:01 to 2 P.M. July 19) when 3.5 curies of activity were discharged per hour, the estimated flow of the Clinch River at the mouth of the Creek was 3000 to 3400 c.f.s. It is estimated that the resulting concentration of radioactivity, after thorough mixing with the Clinch water, would be 11.43 milli microcuries per liter. After this initial slug the rate of radioactive discharge decreases and the dilution afforded by the flow of local tributaries would possibly compensate for the low flow (500 to 1000 c.f.s.) of the Norris discharge as recorded at the Townsite Pumping Station.

Further studies are needed on the water impounded in the Clinch River by Watts Bar Dam in order to estimate conditions downstream below Clinch mile 20.8. The normal river velocities of 2 to 3 miles per hour above impoundage, depending on stage height, will be lowered to less than 2 miles per hour as the effective cross sectional area increases. These calculations will be made at a later date and they probably could be verified or corrected by adequate river sampling and testing for radioactivity following storms such as the four floods of 1948 reported herein. The extent of "slugging" of the Clinch River and the time and distance before intimate mixing are factors which appear sufficiently important to require further study under the lack of control now afforded by the White Oak Dam system.

Activity Associated With Particulate Matter In The Overflow Of White Oak Dam

It was mentioned that during the storm of November 19,

samples of the overflow were centrifuged to separate the bulk of the particulate or suspended matter from the liquor and each fraction was tested for radioactivity. The results of this study are presented in Table 6. The Table shows the pH, the suspended solids or matter removed by centrifuging 5 minutes, as estimated in parts per million or mg.per liter from the light transmission in a photometer, the soluble and colloidal solids in the supernate after centrifuging (subject to considerable error), the radioactivity associated with the suspended solids in counts per minute per ml. of mother liquor at ten percent geometry, the radioactivity associated with the soluble or supernate liquor in similar units, the summation of the two latter tests or the total activity per ml. and, in the last column, the percentage of total activity associated with the soluble or supernate fraction.

The results show that there was no significant change in the pH during the first flood, but that the second flood, November 28 and 29, showed a remarkable lowering of the pH value during the peak flood flow. The estimate of suspended solids shows an increase of sediment in samples 9 to 15 corresponding to the flood flow range and a decrease thereafter. It is suspected that gravimetric determinations would have shown greater deviations since the turbidity of samples from No. 9 were more settleable i.e. particulates of greater size and weight. A good correlation between the photometer and the weight of matter was not available for this study.

The total activity of the samples show high levels of activity persisting during maximum flood flows followed by a fourfold decrease as the lake contents overflowed or were diluted by

Table 6

CHEMICAL AND RADIOACTIVITY ANALYSES OF FLOOD FLOWS - STORMS OF NOVEMBER, 1948

Sample	Date	Hour	pH	Suspended Solids	Soluble & Colloidal Solids	RADIOACTIVITY			
						Suspended Matter	Soluble Matter	Total	In Supernate
				p.p.m.	p.p.m.	cts/min/ml	cts/min/ml	cts/min/ml	Percentage
1	11-19	9:20A	7.5	172	-	2.80	20.30	23.10	88
3		9:50	7.5	144	-	2.48	19.34	21.82	88.6
5		11:45	7.5	135	-	2.53	21.12	23.65	89.2
7		2:00P	7.5	145	-	5.07	17.16	22.23	77.2
9		4:30P	7.2	377	-	6.41	5.90	12.31	47.9
11		6:35	7.3	479	137	6.04	5.90	11.94	49.4
12		10:37	7.3	316	-	3.90	6.18	10.08	61.4
13	11-20	2:34A	7.3	260	-	3.14	5.32	8.46	62.8
14		6:38	7.1	230	-	3.10	5.26	8.36	62.8
15		10:30	7.3	192	-	3.06	3.54	6.60	53.6
16		2:31	7.2	144	96	3.27	3.98	7.25	54.8
17		7:00	7.3	133	307	3.27	4.04	7.31	55.2
18		10:45	7.3	132	-	3.28	4.36	7.64	57.8
19	11-21	2:30A	7.3	166	-	3.04	4.20	7.26	58.1
20		6:30	7.3	134	-	2.98	5.50	8.48	65.0
21		10:30	7.3	155	107	2.70	4.88	7.58	64.4
22		3:04P	7.3	147	-	2.76	5.08	7.84	64.7
23		5:35	7.5	136	-	4.41	7.10	11.51	61.7
24		10:17	7.5	113	113	3.19	6.90	10.09	68.4
25	11-22	2:30A	7.5	140	-	3.00	5.32	8.32	64.0
26		6:30	7.5	128	119	2.75	2.46	5.21	47.2
26	11-23	-	-	-	-	-	-	10.12	-
26	11-24	-	-	-	-	-	-	9.60	-
26	11-25	-	-	-	-	-	-	-	-
26	11-26	-	-	-	-	-	-	13.5	-
26	11-27	-	-	-	-	-	-	13.1	-
27	11-28	9:30A	7.2	-	-	5.57	7.6	13.17	57.6
28		2:15P	6.5	-	-	2.36	1.6	3.96	40.3
29	11-29	10:30A	6.9	-	-	1.04	0.96	2.00	48.0
30		3:00P	7.0	-	-	0.90	0.92	1.82	50.5

rain water. Three days after the first storm the activity increased (almost doubled) supposedly due to a diffusion of lake embayment or shore waters of higher activity into the main channel and the contribution of wastes from daily operations. Following the second storm the lake was flushed relatively free of suspended radioactivity.

The last column shows that while 88 - 89 percent of the activity was associated with the clear liquor on the morning of November 19, as little as 40 percent was associated with the clear liquor following the first flood flow.

The Effect Of Floods On Purging White Oak Lake

A detailed analysis of the impounded wastes was made before, during, and after the November floods to determine the extent of purging of contaminated muds from the White Oak Creek and Lake bottom.

A relatively low quantity of radioactive wastes had been added per day prior to November 11. Due to abnormal operations resulting in relatively high quantities of wastes being discharged into the White Oak Creek system the flow was impounded in the Lake by changing the gate from a setting of 3.5 to 1.7 thus raising the Lake level 1.8 feet. This resulted in impounding 1.6 million cubic feet of additional water with little overflow at the Dam.

The pertinent routine data of the Operations Division and the Area Monitoring Group were used to compute the wastes into, out of, and impounded in the lake from November 11, to November 18, 1948. The results are presented in Table 7. The curies of settling basin effluent (Column 3) less the curies

Table 7

RADIOACTIVITY IMPOUNDED IN WHITE OAK LAKE BEFORE STORM

November 11, to 18, 1948

Date	Capacity Of Lake	RADIOACTIVITY		
		Added To Creek From S.B.	Lost In Overflow Of Dam	Net Activity Impounded In Lake
	Mil.cu.ft.	Curies	Curies	Curies
11	10	-	-	23.0
11		2.05	-	25.05
12		13.35	-	38.4
13		8.16	-	46.56
14		6.14	-	52.70
15		4.44	.14	57.00
16		2.16	.42	58.74
17		1.7	.51	59.93
18	11.6	-	.47	59.46

which overflowed the dam (Column 4) where accumulated and added to the curies impounded in the lake on November 11 (Column 5). It was assumed that activity impounded in the lake had a mean concentration equal to the overflow of the dam. Thus a total of 59.46 curies theoretically remained in the lake on November 18. However, the estimated curies present in the lake water on November 18, was 32.5 curies. Thus 27 curies or 46.7 percent of the activity of the added wastes has been lost due to decay, absorption by mud, retention of precipitates, or errors of measurement. Based on the decay values of the dam overflow the loss due to decay amounts to a few curies but the measurements, particularly the capacity of the lake and the curies of waste discharged, may be subject to considerable error.

Although some 40 - 45 percent of the activity of the added wastes may be associated with the sediment in the creek and lake when the dam overflow is closed, it is likely that little of the wastes would settle during the flood flows. For this reason it has been assumed that there was no decrease of activity by sedimentation. After inspecting the data and observing that some 40 to 89 percent of the activity in the dam overflow water was associated with the clear liquor and the remainder associated with suspended matter, much of which was settleable, it was further assumed that the wastes entering the lake would have 70 percent of the activity associated with the centrifuged supernate and 30 percent associated with particulates which might be settleable under quiescent conditions.

Knowing the volume of water which overflowed the dam and the activity which was associated with the suspended and

soluble (supernate), a balance sheet of wastes into and out of the lake was computed for the period November 18, to December 1. The results are presented in Table 8.

The net activity of supernate (largely soluble) present in the liquid of the lake on the November 18, was 28.7 curies less 0.41 curies discharged over the dam (Column 3) plus 70 percent of the 1.4 curies discharged from the settling basin (Column 4) or 29.27 curies. On November 18, the net activity was 29.27 less 23.7 curies over the dam plus 70 percent of 2.26 discharged from the settling basin or a residual of 7.15. This process was continued on through November where 3.77 curies is the calculated residual as against 4.34 curies found when the impounded water is calculated as having an activity equal to that discharged over the Dam.

The net activity of the suspended solids was similarly computed. For example, on November 18, the 3.8 curies associated with particulate matter less the 0.06 curies associated with particulates that were discharged, plus 30% of 1.4 curies added leaves a net impounded activity of 4.16 curies. On November 19 the net or residual activity was computed to be 4.16 less 9.4 plus 30% of 2.26 or a negative value of 4.56 curies. This negative value increases through November 21 and indicates a pick up of contaminated mud or precipitates from the creek or lake bed. Between November 21 and November 26, the negativity of residual activity associated with the suspended solids decreases somewhat and shows that the radioactive wastes associated with suspended particulates are decaying, or settling out of the liquid at a faster rate or being added at a slower rate. From November 26, to the end of the

Table 8

RADIOACTIVITY (CURIES) IMPOUNDED DURING AND AFTER NOVEMBER STORMS

	Discharged Over Dam		Added To Lake From Settling Basin *	Net Activity In Lake		
Date	Suspended	Supernate		Suspended	Supernate	Total
18	-	-	-	3.8**	28.7**	32.5**
18	0.06	0.41	1.4	4.16	29.27	
19	9.4	23.7	2.26	-4.56	7.15	
20	3.1	4.3	1.92	-7.08	4.19	
21	1.1	2.0	1.71	-7.67	3.39	
22	0.42	0.64	1.58	-7.59	4.85	
23	0.02	0.03	4.43	-6.30	6.92	
24	0.04	0.06	3.39	-5.34	9.26	
25	0.07	0.10	3.49	-4.33	11.6	
26	0.44	0.66	3.13	-3.85	13.14	
27	1.73	2.56	2.33	-4.94	13.28	
28	9.27	9.30	1.55	-13.65	3.98	
29	1.45	1.46	1.93	-14.58	3.92	
30	1.75	1.75	2.33	-16.40	3.77	
1	-	-	-	4.33**	4.34**	8.67**
Balance				-20.73	0.57	

* - Arbitrarily assumed that 70% remains in supernate and 30% in suspended.

** - Computed to be impounded in lake.

month the second storm flow caused a further pick-up of muds probably due to scouring velocities. During the last two weeks of November it is estimated that a total of about 20 curies of waste which had been associated with bottom muds were discharged over the Dam. Further studies of the decay rate of settling basin effluents may indicate that more than 20 curies of waste associated with the muds were scoured out of the lake. For example, in Table 7 it was shown that 46.4 percent of the added activity could be accounted for in the impounded water under quiescent flow conditions. If under storm flow conditions perhpas 25 percent of the added activity of 31.45 curies were lost by decay or precipitation before reaching the lake there remains about 8 curies of activity. Of this some would be accounted for as associated with particulate matter and the greater part would be prosumed to arise from the soluble radioactivity elutriated from sediments.

Summary and Conclusions

A study was made of the radioactive wastes discharged into the White Oak Creek, and the wastes which are retained, detained, or decayed in the creek or in the impounded lake of some ten million cubic feet capacity. This study also includes the wastes discharged from the lake over a dam into the Clinch River and the resulting concentrations in the Clinch River water.

The study covers the period January 1, through November, 1948, and includes four major rains which caused flood flows over the dam.

The White Oak Creek and Lake receives the surface drainage from an area of 6.17 square miles and the relatively small

amount of domestic and process wastes from O.R.N.L. The general mountainous nature of the drainage area and the high intensity of many rains result in high rates of runoff and consequently a flooding of the impounding dam. During the eleven-month study there were four rains of intensity such as to cause floods and various degrees of flushing of impounded wastes from the lake.

The floods cause a "slugging" of the Clinch River for short intervals and impaired the effectiveness of the White Oak Creek disposal system. Thus 70.4 to 81.4 percent of the wastes are removed during dry weather months, 55.5 to 68.9 percent are removed during moderately wet months and negative removals are obtained during flooding periods for an overall eleven-month removal of 55.4 percent of the added wastes.

It has been shown that concentrations of at least 11.43 milli microcuries per liter in Clinch River occured during a two-hour period when a flood in White Oak Creek coincided with low hourly flows of the River. Over a period of days following each flood the average concentration of radioactive wastes, exclusive of dilution with impounded Watts Bar reservoir waters, was computed to vary from 0.3 to 1.62 milli microcuries per liter. During dry weather flows the concentration of radioactivity in the Clinch River is usually a small fraction of these maximum values.

The study is somewhat limited in accuracy by a number of factors. Some of the more important shortcomings of the basic data would be improved by:

1. Combining the process waters into a common discharge flume for recording the flow and the constant monitoring of the

waste concentration.

2. Improving the physical conditions at the White Oak Dam overflow gate to allow a more accurate estimate of the flow discharged into the Clinch River.

3. The constant monitoring of the White Oak Lake overflow or the collection of 15-minute samples just before, during and after a flood flow when the concentration of activity is changing rapidly.

4. The collection of samples over frequent intervals at various downstream Clinch River stations to define "slugs" of radioactivity during flood stages, and distances downstream where thorough mixing with the Watts Bar reservoir water occurs.

5. Obtaining more hydraulic data on the Watts Bar Reservoir in order to compute downstream dilution factors under different conditions of flow.

In this study no attempt has been made to interpret the data in terms of the potential hazards involved but rather to assemble and present the information which is now available.

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O.R.N.L. - The Survey-Monitoring Section assisted by the collection of weekend and off-hour samples and otherwise in the collection and assembly of the data presented. In particular, the Area Monitoring Group, under W. D. Cottrell, was responsible for local weather records, the collection and analyses of daily water samples, and the compilation of data concerning the operation and overflow at White Oak Dam.

The Operations Division supplied data on the wastes discharged into White Oak Creek.

Roane-Anderson Co. - The Utilities Division, principally through Plin D. Bleasdale, of the Water Section, supplied hourly or two-hour stage heights of the Clinch River at the Townsite Pumping Station.

T.V.A. and U.S.G.S. - The Hydraulic Data Section of T.V.A. supplied rating charts of the discharge of the Clinch River at the Pumping Station. From the rating charts and stage heights the hourly flow pattern for normal and flood flows was computed. The Hydraulic Data Section also supplies the daily records of the Clinch River flow from the U.S.G.S. Gaging Station at Scarboro.

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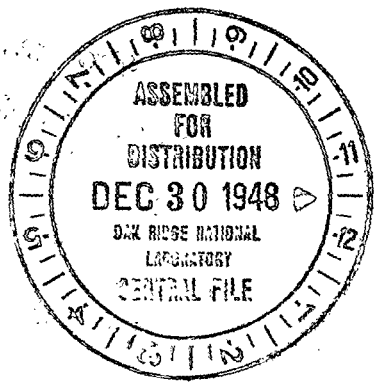
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