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STATUS REPORT NO. 3 ON CLINCH RIVER STUDY

Editor
R. J. Morton

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Errata

STATUS REPORT NO. 3 ON CLINCH RIVER

Issued
November 21, 1962

1. A corrected copy of Fig. 13, p. 65, has been printed on gummed paper. Please attach directly to the old page in your copy of the report.

2. Minor corrections are as follows:

Page 7, par. 1, line 1. - Third word should be spelled Loudoun.
Page 7, par. 2, line 2. - End of line should be pages ix and x.
Page 17, par. 1, line 6.- May 27, instead of May 7.
Page 19, par. 1, line 3.- June 17, instead of July 17, 1961.
Page 42, line 3. - September 10 instead of 24.
Page 67, par. 3, line 7, (TRM 496.6). - Delete parentheses.
Page 72, last par., line 4.- 812 instead of 821.
Page 113, top of page.- Heading was omitted:

APPENDIX B

MAPS OF CLINCH AND TENNESSEE RIVERS

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HEALTH PHYSICS DIVISION

STATUS REPORT NO. 3 ON CLINCH RIVER STUDY

Clinch River Study Steering Committee

EDITOR

R. J. Morton

CONTRIBUTING AUTHORS

H. H. Abee
S. I. Auerbach
P. H. Carrigan
M. A. Churchill
A. G. Friend
B. J. Frederick
W. T. Lammers
E. P. Mathews
D. J. Nelson
D. B. Porcella
E. G. Struxness
T. Tamura

DATE ISSUED

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Current Membership

CLINCH RIVER STUDY STEERING COMMITTEE

E. G. Struxness, Chairman, Health Physics Division, Oak Ridge National Laboratory, P. Box X, Oak Ridge, Tennessee

J. S. Cragwall, Surface Water Branch, Water Resources Division, U. S. Geological Survey, 823 Edney Building, Chattanooga, Tennessee

A. G. Friend, Division of Radiological Health, Robert A. Taft Sanitary Engineering Center, 4676 Columbia Parkway, Cincinnati 26, Ohio

F. E. Gartrell, Health and Safety Division, Tennessee Valley Authority, Edney Building, Chattanooga, Tennessee

Glenn Gentry, Tennessee State Game and Fish Commission, Cordell Hull Building, Nashville, Tennessee

S. Leary Jones, Tennessee State Department of Public Health and Tennessee Stream Pollution Control Board, Cordell Hull Building, Nashville, Tennessee

W. G. Belter, (ex officio), Division of Reactor Development, U. S. Atomic Energy Commission, Washington 25, D. C.

Vincent Schultz, (ex officio), Division of Biology and Medicine, U. S. Atomic Energy Commission, Washington 25, D. C.

C. S. Shoup, (ex officio), Research and Development Division, U. S. Atomic Energy Commission, Oak Ridge Operations, P. O. Box E, Oak Ridge, Tennessee

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The Clinch River Study has continued as a cooperative project in which essential parts of the work are performed by a number of groups in the Laboratory and other agencies represented on the Steering Committee. The committee recognizes and appreciates the participation of the agencies and the investigators named below:

STAFF INVESTIGATORS PARTICIPATING

For the OAK RIDGE NATIONAL LABORATORY, Health Physics Division
Applied Health Physics Section

H. H. Abee
W. D. Cottrell

Ecology Section

S. I. Auerbach
D. J. Nelson

Radioactive Waste Disposal Section

E. R. Eastwood
J. A. Payne
W. E. Parker
T. Tamura

For the U. S. GEOLOGICAL SURVEY, Water Resources Division

R. M. Richardson
B. J. Frederick
J. P. Monis
P. H. Carrigan
E. P. Mathews
R. J. Pickering

For the TENNESSEE VALLEY AUTHORITY, Health and Safety Division

M. A. Churchill
O. W. Kochtitzky
W. T. Lammers

Forestry Relations Division, Fish and Game Branch

C. J. Chance

Division of Water Control Planning, Hydraulic Data Branch

James Smallshaw

For the U. S. PUBLIC HEALTH SERVICE, Division of Radiological Health
Robert A. Taft Sanitary Engineering Center

A. G. Friend D. B. Porcella
A. H. Story

For the TENNESSEE DEPARTMENT OF PUBLIC HEALTH
Stream Pollution Control Board

S. Leary Jones

For the TENNESSEE GAME AND FISH COMMISSION

John Conder
L. P. Wilkins

FEATURES OF THE OVER-ALL PROGRAM

This is the third of the series of status reports on the Clinch River Study which has been in progress since February 1960.[1,2] In the two previous reports the objectives and organization of the study were described, and the results available through April 1961 were summarized. This report is based on progress reports submitted to the Clinch River Study Steering Committee on October 27, 1961, for the period May to October 1961. It also includes data on some earlier work that were not available for inclusion in Status Report No. 1 or No. 2.

Portions of the Clinch and Tennessee Rivers pertinent to the study are shown in a list of locations and on three maps in Appendix A and Appendix B, respectively.

Steering Committee Actions

The Steering Committee held an open session and an executive meeting on October 27, 1961, and an executive meeting November 21, 1961. The agency representation and individual members of the committee are shown on page viii.

The open session October 27, 1961, was attended by thirty-four persons, including steering committee members, staff of the study, and visitors. Ten progress reports were presented and discussed: (1) "Report of Applied Health Physics Annual River Sediment Survey, 1961" by H. H. Abee (ORNL); (2) "Results of PHS Surveys in May and September 1960" by A. G. Friend et al. (USPHS), presented by D. B. Porcella; (3) "Progress Report No. 2, Subcommittee on Water

Sampling and Analysis" by M. A. Churchill, chairman (TVA); (4) "Progress Report No. 1, Subcommittee on Bottom Sediment Sampling and Analysis" by P. H. Carrigan, chairman (USGS); (5) "Progress in Surface Water Data Collection" by E. P. Mathews (USGS); (6) "Radiotracer Study in Clinch River, August 30-31, 1961" by B. J. Frederick (USGS); (7) "Density Gradient Separation of Plankton and Clay from River Water" by W. T. Lammers (TVA and Davidson College); (8) "Evidence of Pollution in East Tennessee Streams, Based on Mollusk Distribution" by H. van der Schalie and B. Dazo (U. of Mich.), presented by S. I. Auerbach (ORNL); (9) "Report on Fish Tagging in Clinch River," "Additional Data on Chemical Morphology of Clams," "Progress Report on Uptake of Co^{60} by Crayfish," and "Dissolved O_2 in Clinch River During Period of Stabilized Flow" by D. J. Nelson (ORNL); and (10) "Summary of Water Analyses at ORNL -- Stable Chemical and Radiochemical Analyses," "Clinch River Dilution Factors," and "Effect of Power Releases on Flow and Radioactivity Levels in Clinch River" by P. H. Carrigan (USGS). Copies of the above reports, submitted to the Steering Committee, have served as the principal basis for the present status report.

At the executive meeting, October 27, 1961, Leo Weaver, Chief of the Water Quality Section, U. S. Public Health Service (USPHS), discussed with the committee three additional water-sampling stations to be included as a part of the USPHS national water-quality network. The committee voted to cooperate with USPHS in the establishment and operation of the three proposed stations. The subcommittee on Water Sampling and Analysis was designated to work with the Water Quality Section of USPHS and to implement this

cooperation.*

The committee authorized release for publication of two papers by D. J. Nelson,[3,4] which were summarized in Status Report No. 2 under the titles: "Biogeochemistry of Strontium and Calcium in Clams" and "Estimated Radiation Dose Received by Diptera with Life Stages in Bottom Sediments." The committee also authorized release, for publication in the open literature, of a paper by W. T. Lammers on "Density Gradient Separation of Plankton and Clay from River Water" (see page 78).

A Subcommittee on Safety Evaluation was established to study available information and additional data that may be obtained and evaluate the potential hazards of discharges of radioactive wastes from Oak Ridge installations to the Clinch and Tennessee Rivers. The committee determined that the chairman of this subcommittee should be from the Tennessee Department of Public Health and that members should include representatives of the Tennessee Valley Authority, the U. S. Public Health Service, the U. S. Atomic Energy Commission, and the Oak Ridge National Laboratory. It was noted that this was the fourth subcommittee established by the Steering Committee.

---

*After subsequent discussion by the chief of the Water Quality Section of USPHS and the chairman of the Subcommittee on Water Sampling and Analysis for the Clinch River Study, it was agreed that the three national network stations would be (1) Clinch River near Clinton, Tennessee; (2) Clinch River at the ORGDP water plant intake; and (3) Tennessee River at the municipal water plant in Lenoir City, Tennessee. The ORGDP water plant intake also is used as a regular water sampling station in the Clinch River Study.

The Steering Committee held another executive meeting, November 21, 1961, primarily to meet with the new Subcommittee on Safety Evaluation and define the scope of work expected of this subcommittee. Actions at this meeting included the following:

(1) Current membership of the four subcommittees was reviewed. These include: Subcommittee on Water Sampling and Analysis - M. A. Churchill (TVA), chairman, J. S. Cragwall (USGS), A. G. Friend (USPHS), and S. L. Jones (TDPH); Subcommittee on Bottom Sediment Sampling and Analysis - P. H. Carrigan (USGS), chairman, R. W. Andrew (USPHS), James Smallshaw (TVA), and T. Tamura (ORNL); Subcommittee on Aquatic Biology - S. I. Auerbach (ORNL), chairman, C. J. Chance (TVA), D. B. Porcella (USPHS), and L. P. Wilkins (TGFC); and Subcommittee on Safety Evaluation - C. P. McCammon (TDPH), chairman, R. L. Hervin (AEC-ORO), O. W. Kochtitzky (TVA), W. S. Snyder (ORNL), and C. P. Straub (USPHS).

(2) As a check list of potential hazards to be considered by the Subcommittee on Safety Evaluation, a basic outline of "Exposure Pathways of Released Radioactive Wastes" was adopted. This outline was developed from a statement submitted by H. M. Parker at the 1959 Congressional Hearings on Industrial Radioactive Waste Disposal[5] with additions and revisions agreed to by the Steering Committee and the subcommittee.

(3) In joint discussion with the Subcommittee on Safety Evaluation, the scope of its assignment was outlined:

a. Evaluate safety in the rivers below White Oak Dam in relation to ORNL waste discharges with potential hazards to the

public as the primary consideration.

b. Consider potential hazards from H. M. Parker's outline of exposure pathways under Case 1; namely, "Radioactive Wastes in Rivers, Streams, Lakes, or Oceans" (omitting exposures through atmospheric dispersion and contaminated soil from ground disposal).

c. Consider processed (not raw) data from the Clinch River Study primarily and other pertinent data, if available.

d. Consider radiation protection guides of the Federal Radiation Council (FRC) as the basis for evaluating safety.

e. Consider safety of routine discharges only (not the potential hazards from major accidents).

(4) The committee reviewed the objectives of the Clinch River Study, as previously stated,[6] and adopted a fifth objective (see "e" below). These objectives are:

a. To determine the fate of radioactive materials currently being discharged to the Clinch River.

b. To determine and understand the mechanisms of dispersion of radionuclides released to the river.

c. To evaluate the direct and indirect hazards of current disposal practices in the river.

d. To evaluate the over-all usefulness of this river for radioactive waste disposal purposes.

e. To recommend long-term monitoring procedures.

(5) In other actions the preparation and publication of Status Report No. 3 was authorized. Also, the subcommittees were instructed to review and outline their functions and to indicate

allocations of responsibility to the various agencies participating. Systematic cross checking of analytical results and occasional analyses of duplicate samples in different laboratories to assure accuracy and comparability of analytical results were demanded by the Steering Committee.

Quarterly Surveys by U. S. Public Health Service

Under a contract with the Atomic Energy Commission, the Public Health Service (PHS) is carrying on a program of investigations of the "fate" of radionuclides discharged to fresh-water environments. These investigations include periodic field-sampling of streams in the vicinity of Knolls Atomic Power Laboratory in New York and of the Savannah River Plant in South Carolina. As a part of its participation in the Clinch River Study, PHS has included the Clinch and Tennessee Rivers in its survey program. The results of three surveys, in February, May, and September 1960, have been reported at Steering Committee meetings and were made available for this status report.[7,8,9] Detailed reports on these quarterly surveys are to be issued as publications of the PHS.

As described in the first status report,[10] the PHS surveys have included collection and analysis of samples of water, bottom muds, fish, miscellaneous aquatic fauna, and plankton, and of filter sand from a water plant which uses the Tennessee River as the source of raw water for a municipal supply. Also, the concentrations of radionuclides in various artificial media submerged in Clinch River were determined. Reaches of the rivers covered include the Clinch River from Norris Dam to Kingston and the Tennessee River

from Fort Loudon Dam downstream beyond Chattanooga. In the present report, portions of the PHS progress reports on surveys in May and September 1960 are summarized in the sections on water sampling and analysis (page 22), radioactivity in bottom sediments (page 67), and biological phases (page 81).

Agency Cooperation

The agencies and staff investigators who have participated in the Clinch River Study during this period are listed on page ix and x. The Steering Committee recognizes that this comprehensive study is of necessity a cooperative project in which essential parts of the work must be performed by various agencies that have the particular competency and experience required. Allocations of sampling and analysis in connection with the study were outlined in the appendix of the first status report.[1]

Several extraordinary contributions by the different agencies during the period covered by this report have been made. Participation by the U. S. Geological Survey has been increased in providing additional hydraulic measurements for different phases of the study, and in the assignment of personnel to supplement the study staff. P. H. Carrigan of USGS has served as group leader of the study while the ORNL group leader (F. L. Parker) was away on leave of absence. A tracer study using gold-198 injected into the Clinch River at the mouth of White Oak Creek was made by USGS in August 1961 to gain further information about dispersion in the river, times of flow, and other parameters (see page 88). Operation of gaging stations in the Oak Ridge area has been extended by USGS, and much additional

work has been done in developing rating curves for these stations (see pages 86-88).

Work of the various subcommittees constitutes a major contribution to the study by several agencies (see page 4).

During the summer of 1961, the staff of the study was augmented by the assignment of a temporary summer employee of the TVA -- W. T. Lammers, a biologist on the regular staff of Davidson College. His work for three months included studies on the density-gradient technique for separation of plankton and clay from river sediments, summarized in a later section of this report (see page 78).

WATER SAMPLING AND ANALYSIS

The data available for this section of the report are from three parts of the water sampling program (as explained in Status Report No. 2[11]): (1) Basic Sampling Network. -- water samples taken regularly at the six network stations and analyzed for radioactive constituents in Cincinnati and for stable chemicals in Nashville; (2) Supplementary Sampling on the Clinch River. -- portions of regular samples from the basic network stations at Oak Ridge Water Plant and above Centers Ferry on the Clinch River, and weekly samples from Clinch River at the water plant of the Oak Ridge Gaseous Diffusion Plant (ORGDP) at CRM 14.4, which were analyzed for selected stable chemicals at ORNL; and (3) radiological determinations on water samples collected as part of the PHS quarterly environmental surveys on the Clinch and Tennessee Rivers. Data from each part of the program will be summarized separately in the order mentioned above.

The basic sampling network has continued as described in Status Report No. 2.[11] It includes six water sampling stations as follows:

(1) Clinch River at Oak Ridge Water Plant (CRM 41.5).

(2) White Oak Creek at White Oak Dam.

(3) Clinch River above Centers Ferry (CRM 5.5).

(4) Tennessee River at Loudon, Tennessee (TRM 591.4).

(5) Tennessee River at Watts Bar Dam (TRM 529.9).

(6) Tennessee River at Chickamauga Dam (TRM 471.0).

In its progress report No. 2, presented to the Steering Committee on October 27, 1961, the Subcommittee on Water Sampling

and Analysis summarized data from the six basic network stations. Their primary purpose is to determine concentrations and total cumulative loads of important radionuclides in the Clinch and Tennessee Rivers at selected locations between Oak Ridge and Chattanooga. A secondary purpose is to determine the mineral (stable chemical) quality of the river waters at and downstream from Oak Ridge, with special reference to phosphates and nitrates.[12]

The procedures followed in water sampling at each of the basic network stations were described in Status Report No. 2.[11] The general plan is to composite into weekly samples (monthly for some stable-chemical analyses) daily subsamples of water whose individual volumes are proportional to the respective volumes of daily stream flow passing the particular sampling station. By this procedure the weekly mean concentration of each radionuclide is determined, and the total cumulative load of each constituent passing each station may be computed. The one exception to this plan of proportional sampling is the Tennessee River at Loudon where a nonproportional monthly composite sample is prepared from fixed-volume daily grab samples from the river. These monthly samples are used for radiological determinations and stable chemical analyses.

Sampling procedure at all basic network stations have remained the same as reported in Status Report No. 2, except that, beginning May 1, 1961, proportional samples for stable-chemical analyses have been composited on a monthly basis at three stations: (1) Oak Ridge Water Plant, (2) Watts Bar Dam, and (3) Chickamauga Dam. Compositing of nonproportional samples from the Tennessee River at Loudon has been on a monthly basis since November 1960 when the

basic sampling network was established.

In Status Report No. 2,[11] it was mentioned that the USPHS at Cincinnati was preparing a program for the analysis of gamma spectra on an electronic computer. This program was written and the previously-estimated concentrations of Cs^{137}, Co^{60}, and Ru^{106} given in Status Report No. 2 were computed and revised. Because of this revision of the radiochemical data, concentrations of each radionuclide are reported for all network samples, beginning in November 1960 and extending into June or July, 1961.[12] Results of the stable-chemical analyses made at ORNL, reported October 27, 1961, include later samples (into August or September 1961), as shown in the tables.

Based on suggestions of the Subcommittee on Water Sampling and Analysis, USGS has attempted to develop an improved method of sampling at the Centers Ferry station. More accurate stream-flow measurements are needed as a basis for proportioning samples and computing the total load of radionuclides passing the station. However, the USGS electromagnetic flowmeter, installed at this station, has not operated properly, apparently because of a 10-volt 60-cycle ground current which presumably originates at the Kingston Steam Plant. Further testing of the instrument is under-way, and efforts to improve sampling techniques at this station are being continued.

With the exception of two sampling stations, data on stream flows have been provided through cooperation of the district office of the USGS. Data on discharges at Watts Bar and Chickamauga Dams have been supplied by TVA.

Radiological Determinations

Basic Sampling Network

Determinations are made of concentrations and total loads of Sr^{90}, Cs^{137}, Co^{60}, and Ru^{106}, considered to be the radionuclides of primary importance in this study. Status Report No. 2 indicated that the 5-gal samples sent to USPHS were evaporated to dryness and the solids (including silt) transferred to 2-in. stainless steel planchets for gamma determinations.[11] Beginning with samples collected during the week ending April 29, 1961, or May 6 at certain stations, suspended solids in the samples have been separated from the water by use of a Servall Superspeed Centrifuge. For all samples prepared in this manner, gamma determinations (and radiochemical determinations for Sr^{90}) have been made separately on dissolved solids and on suspended solids.

Strontium-90. - Concentrations of Sr^{90} found in samples at all stations are shown in Table 1. Comments by the Subcommittee on Water Sampling and Analysis[12] regarding their findings are summarized below.

In Clinch River samples at the Oak Ridge Water Plant, Sr^{90} in detectable concentrations was found every week during the period, November 13, 1960, through June 3, 1961. From White Oak Creek at White Oak Dam samples showed widely variable Sr^{90} concentrations discharged to the Clinch River during the same period, with a minimum value of 75.6 μμc per liter and a maximum of 17,450 μμc per liter. At Centers Ferry, from November 13, 1960, through June 3, 1961, Sr^{90} concentrations varied from less than

Table 1. Concentrations (μμc per liter) of Sr^{90} in Water Samples

Date	Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River Above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
1960						
Nov. 1-12	---[a]	---	lost		---	---
13-19	1.2 ± 0.3	17,450 ± 450	21.6 ± 0.57		---	---
20-26	0.9 ± 0.2	75.6 ± 3.9	7.5 ± 0.2	---	25.8 ± 2.0	1.5 ± 0.08
27-Dec. 3	0.2 ± 0.1	640 ± 6.6	14.3 ± 0.4		4.8 ± 0.18	0.9 ± 0.02
Dec. 4-10	5.0 ± 0.4	4,770 ± 20	5.0 ± 0.33		6.7 ± 0.4	4.3 ± 0.14
11-17	3.1 ± 0.3	---	24.1 ± 0.5	35.4[c] ± 0.8	0.7 ± 0.04	0.7 ± 0.57
18-24	0.5 ± 0.1	6,280 ± 22	1.5 ± 0.1	for Dec.	2.1 ± 0.1	3.6 ± 0.25
25-31	0.6 ± 0.09	7,070 ± 74	42.6 ± 1.6		16.4 ± 1.3	1.4 ± 0.1
1961						
Jan. 1-7	2.0 ± 0.2	878 ± 8.8	13.3 ± 0.32		2.0 ± 0.01	1.7 ± 0.16
8-14	0.2 ± 0.03	15,900 ± 26.2	6.3 ± 0.2		4.8 ± 0.3	5.6 ± 0.9
15-21	1.9 ± 0.1	2,875 ± 13	4.6 ± 0.1	2.3 ± 0.1	12.0 ± 0.6	14.1 ± 0.4
22-28	0.5 ± 0.1	2,032 ± 14	3.9 ± 0.2	for Jan.	5.1 ± 0.24	2.4 ± 0.2
29-Feb. 4	0.3 ± 0.04	6,700 ± 62	9.9 ± 0.37		2.7 ± 0.2	3.7 ± 0.23
Feb. 5-11	0.8 ± 0.1	---	37.0 ± 0.6		lost	2.0 ± 0.25
12-18	0.3 ± 0.04	6,600 ± 53	3.0 ± 0.1	0.39 ± 0.07	0.3 ± 0.1	1.3 ± 0.1
19-25	0.6[c] ± 0.1	1,350 ± 10	0.4[c] ± 0.02	for Feb.	0.6 ± 0.1	1.7 ± 0.05
26-Mar. 4	11.9[c] ± 0.2	1,060 ± 8	4.1 ± 0.1		2.2 ± 0.2	2.8 ± 0.2
Mar. 5-11	0.3 ± 0.1	590 ± 7	2.9 ± 0.1	< 0.1 ± 0.01 SS[b]	1.0 ± 0.04	1.5 ± 0.1
12-18	0.3 ± 0.06	---	1.8 ± 0.1	0.3 ± 0.04 DS	0.9 ± 0.1	0.8 ± 0.1
19-25	0.3 ± 0.02	930 ± 80	2.5 ± 0.1	for Mar.	2.0 ± 0.2	1.0 ± 0.1
26-Apr. 1	0.2 ± 0.02	1,000 ± 80	2.3 ± 0.2		0.9 ± 0.1	0.3 ± 0.1
Apr. 2-8	0.6 ± 0.1	---	5.3 ± 0.1		0.7 ± 0.05	1.3 ± 0.1
9-15	0.3 ± 0.04	953 ± 128	2.7 ± 0.06		1.5 ± 0.2	1.5 ± 0.07
16-22	0.3 ± 0.02	1,208 ± 50	4.7 ± 0.08	0.05 ± 0.009 SS	1.2 ± 0.01	1.0 ± 0.07
23-29	< 0.1 ± 0.01 SS	59.8 ± 0.9 SS	0.1 ± 0.01 SS	0.4 ± 0.04 DS	1.3 ± 0.09	1.2 ± 0.06
	0.3 ± 0.03 DS	1,175 ± 126 DS	8.4 ± 0.1 DS	for Apr.		
30-May 6	< 0.1 ± 0.01 SS	110.5 ± 1.2 SS	0.1 ± 0.01 SS		< 0.1 ± 0.01 SS	< 0.1 ± 0.01 SS
	0.3 ± 0.03 DS	2,225 ± 130 DS	2.8 ± 0.07 DS		0.8 ± 0.04 DS	1.2 ± 0.1 DS
May 7-13	< 0.1 ± 0.01 SS	25.4 ± 0.8 SS	0.1 ± 0.01 SS		0.1 ± 0.01 SS	0.1 ± 0.01 SS
	0.3 ± 0.03 DS	1,462 ± 6 DS	0.6 ± 0.07 DS		1.4 ± 0.04 DS	0.5 ± 0.03 DS
14-20	0.1 ± 0.02 SS	18.8 ± 0.6 SS	0.1 ± 0.06 SS	< 0.1 ± 0.01 SS	0.1 ± 0.01 SS	< 0.1 ± 0.01 SS
	0.3 ± 0.02 DS	1,400 ± 100 DS	4.5 ± 0.1 DS	0.3 ± 0.03 DS	< 1.4 ± 0.03 DS	1.6 ± 0.07 DS
21-27	< 0.1 ± 0.01 SS	12.9 ± 0.5 SS	0.1 ± 0.01 SS	for May	< 0.1 ± 0.01 SS	< 0.1 ± 0.01 SS
	0.3 ± 0.02 DS	1,500 ± 100 DS	9.2 ± 0.1 DS		0.7 ± 0.04 DS	0.8 ± 0.04 DS
28-June 3	< 0.1 ± 0.01 SS	30.0 ± 0.08 SS	< 0.1 ± 0.01 SS		< 0.1 ± 0.01 SS	< 0.1 ± 0.01 SS
	0.5 ± 0.03 DS	2,000 ± 70 DS	4.0 ± 0.06 DS		1.4 ± 0.04 DS	0.8 ± 0.03 DS

[a] --- indicates data not available.

[b] SS - suspended solids; DS - dissolved solids.

[c] Considered to be questionable.

1 μμc per liter in February and May 1961 to a maximum of 42.6 μμc per liter late in December 1960. As noted in the table, based on examination of correlative data the values 11.9 μμc per liter at the Oak Ridge Water Plant for the week ending March 4, 1961, and 0.4 μμc per liter above Centers Ferry for the week ending February 25, 1961 are considered to be questionable, although no known source of error in analysis or in the handling of samples has been found.

In the Tennessee River at Loudon, Tennessee, Sr^{90} concentrations were determined on each of six monthly composite samples, including December 1960 to May 1961. The maximum monthly mean concentration during this period was 35.4 μμc per liter in December 1960, followed by 2.3 μμc per liter in January 1961, and less than 0.5 μμc per liter in February, March, April, and May 1961. As noted in the table, the value 35.4 μμc per liter for December 1960 is considered to be questionable. At Watts Bar Dam from November 20, 1960 through June 3, 1961, Sr^{90} was found in each weekly sample during the period, but less than 1.0 μμc per liter in 30 per cent of samples; and the two highest concentrations were 25.8 and 16.4 μμc per liter in samples for the weeks ending November 26 and December 31, 1960, respectively. At Chickamauga Dam from November 20, 1960, through June 3, 1961, detectable concentrations were found each week in the period, the two highest being 14.1 and 5.6 μμc per liter in samples for the weeks ending January 21 and January 14, 1961, respectively.

Cesium-137 - Concentrations of Cs^{137} found in all samples for the period of available record are shown in Table 2. Comments by

Table 2. Concentrations (μμc per liter) of Cs^{137} in Water Samples

Date	Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River Above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
1960						
Nov. 1-12	---[a]	---	10	---	---	---
13-19	0[b]	1,100	10	---	---	---
20-26	0	375	10	---	0	0
27-Dec. 3	0	4,200	0	---	0	0
Dec. 4-10	0	800	5		0	0
11-17	0	190	0	10	0	5
18-24	0	610	5	for Dec.	0	0
25-31	0	385	25		0	0
1961						
Jan. 1-7	0	700	10		0	0
8-14	0	690	0	0	0	0
15-21	0	1,400	5	for Jan.	0	0
22-28	0	180	5		0	0
29-Feb. 4	5	1,050	0		0	0
Feb. 5-11	0	3,000	0		---	0
12-18	0	825	10	35[d]	0	0
19-25	5	790	10	for Feb.	0	0
26-Mar. 4	5	530	5		0	0
Mar. 5-11	0	520	5	0 SS[c]	0	0
12-18	0	2,100	10	0 DS	0	0
19-25	5	2,700	5	for Mar.	5	0
26-Apr. 1	5	0	15		0	5
Apr. 2-8	0	330	5	0 SS	5	0
9-15	0	4,300	0	5 DS	0	0
16-22	0	460	0	for Apr.	0	0
23-29	0 SS	830 SS	5 SS		0	0 SS
	0 DS	740 DS	5 DS			0 DS
30-May 6	0 SS	670 SS	5 SS		0 SS	0 SS
	0 DS	45 DS	0 DS		0 DS	0 DS
May 7-13	0 SS	380 SS	0 SS		0 SS	0 SS
	0 DS	0 DS	0 DS		0 DS	0 DS
14-20	0 SS	185 SS	0 SS	0 SS	0 SS	0 SS
	0 DS	0 DS	0 DS	0 DS	0 DS	0 DS
21-27	0 SS	340 SS	5 SS	for May	0 SS	0 SS
	0 DS	40 DS	0 DS		0 DS	40[d] DS
28-June 3	0 SS	630 SS	5 SS		0 SS	0 SS
	0 DS	0 DS	0 DS		0 DS	0 DS
June 4-10	0 SS	950 SS	5 SS		0 SS	0 SS
	0 DS	0 DS	0 DS		0 DS	0 DS
11-17	0 SS	1,150 SS	5 SS	0 SS	0 SS	0 SS
	0 DS	150 DS	0 DS	0 DS	0 DS	0 DS
18-24	0 SS	750 SS	15 SS	for June	0 SS	0 SS
	0 DS	0 DS	0 DS		0 DS	0 DS
25-July 1	0 SS	4,400 SS	15 SS		0 SS	0 SS
	0 DS	425 DS	0 DS		0 DS	0 DS
July 2-8	5 SS	700 SS	0 SS	---	0 SS	0 SS
	0 DS	85 DS	0 DS	---	0 DS	0 DS
9-15	0 SS	970 SS	5 SS	---	0 SS	0 SS
	0 DS	5,400 DS	0 DS	---	0 DS	0 DS
16-22	0 SS	730 SS	5 SS	---	0 SS	0 SS
	0 DS	1,650 DS	0 DS	---	0 DS	0 DS

[a] --- indicates data not available.
[b] 0 indicates below detectability by gamma spectroscopy.
[c] SS - suspended solids; DS - dissolved solids.
[d] Considered to be questionable.

the Subcommittee on Water Sampling and Analysis[12] are summarized below.

In Clinch River samples at the Oak Ridge Water Plant during the period November 13, 1960 through July 22, 1961, Cs^{137} in detectable concentrations was found in six weekly composites. During all other weeks in this period concentrations were too low for detection by gamma spectrometry. In White Oak Creek at White Oak Dam, November 13, 1960, to July 22, 1961, weekly samples varied from concentrations too low for detection up to a maximum of 6370 μμc per liter for the week ending July 15, 1961. As would be expected most of the Cs^{137} was associated with the suspended sediments. At Centers Ferry the activity level of Cs^{137}, November 1, 1960, through July 22, 1961, varied from a minimum too low for detection to a maximum of 25 μμc per liter. The second highest concentration during the period was 15 μμc per liter in three samples.

In the Tennessee River at Loudon, Tennessee, seven monthly samples represented the period, December 4, 1960, to July 1, 1961. Concentrations of Cs^{137} were too low for detection in January, March, May, and June 1961. Mean concentrations of 10 μμc per liter in December 1960, 35 μμc per liter in February 1961, and 5 μμc per liter in April 1961 were found. At Watts Bar Dam, November 20, 1960, through July 22, 1961, detectable concentrations of Cs^{137} were found in only two of the weekly samples; namely, 5 μμc per liter for each of two weeks ending March 25 and April 8, 1961. In available weekly samples at Chickamauga Dam, November 20, 1960, through July 22, 1961, concentrations of Cs^{137} were detectable in only three samples; namely,

5 μμc per liter for the week ending December 17, 1960, 5 μμc per liter for the week ending April 1, 1961, and 40 μμc per liter for the week ending May 27, 1961. As noted in the table, based on examination of correlative data the concentrations of 35 μμc per liter at Loudon for the week ending February 18, 1961 and 40 μμc per liter in dissolved solids of the sample at Chickamauga Dam for the week ending May 27, 1961, are considered to be questionable, although no known source of error in analysis or handling of samples has been found.

Cobalt-60. - Concentrations of Co^{60} found in all samples for the period of available record are shown in Table 3. Comments by the Subcommittee on Water Sampling and Analysis[12] are summarized below.

In the Clinch River, samples at the Oak Ridge Water Plant, November 13, 1960, through July 22, 1961, showed Co^{60} concentrations of 15 and 55 μμc per liter for the weeks ending March 4 and May 20, 1961, respectively which, based on examination of correlative data, are considered to be questionable. However, no known source of error in analysis or in handling of samples has been found. During all other weeks in the period of record at this station, concentrations were too low for detection.

Samples from White Oak Creek at White Oak Dam covered the period, November 13, 1960, through July 22, 1961. The minimum concentration during this period was 350 μμc per liter in the sample for the week ending May 6, 1961, and the maximum was 5000 μμc per liter in the sample for the week ending November 26, 1960. As judged by the results from several samples on which determinations were made on both suspended and dissolved solids, most of the Co^{60} present was in

Table 3. Concentrations (μμc per liter) of Co^{60} in Water Samples

Date	Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River Above Centers Ferry	Tennessee River[a] Loudon, Tenn.
1960				
Nov. 1-12	---[b]	---	10	---
13-19	0[c]	3,600	10	---
20-26	0	5,000	10	---
27-Dec. 3	0	3,700	10	---
Dec. 4-10	0	2,500	5	
11-17	0	3,200	5	0
18-24	0	3,300	15	for Dec.
25-31	0	3,600	10	
1961				
Jan. 1-7	0	2,000	20	0
8-14	0	2,200	0	for Jan.
15-21	0	3,700	5	
22-28	0	2,500	5	
29-Feb. 4	0	3,800	0	
Feb. 5-11	0	3,800	35	
12-18	0	2,800	30	0
19-25	0	1,800	0	for Feb.
26-Mar. 4	15[d]	1,500	5	
Mar. 5-11	0	1,000	0	0 SS[e]
12-18	0	1,500	5	0 DS
19-25	0	1,900	0	for Mar.
26-Apr. 1	0	1,700	5	
Apr. 2-8	0	1,600	15	
9-15	0	1,600	5	0 SS
16-22	0	1,500	10	0 DS
23-29	0	160 SS[e]	0 SS[e]	for Apr.
		850 DS	10 DS	
30-May 6	0 SS[e]	250 SS	0 SS	
	0 DS	100 DS	0 DS	
May 7-13	0 SS	180 SS	0 SS	
	0 DS	1,600 DS	10 DS	
14-20	55[d] SS	10 SS	0 SS	0 SS
	0 DS	1,900 DS	5 DS	0 DS
21-27	0 SS	70 SS	0 SS	for May
	0 DS	1,300 DS	10 DS	
28-June 3	0 SS	145 SS	0 SS	
	0 DS	930 DS	0 DS	
June 4-10	0 SS	295 SS	0 SS	
	0 DS	1,900 DS	0 DS	
11-17	0 SS	325 SS	5 SS	0 SS
	0 DS	2,100 DS	50 DS	0 DS
18-24	0 SS	240 SS	5 SS	for June
	0 DS	1,900 DS	15 DS	
25-July 1	0 SS	200 SS	0 SS	
	0 DS	1,100 DS	5 DS	
July 2-8	0 SS	125 SS	0 SS	---
	0 DS	790 DS	0 DS	---
9-15	0 SS	210 SS	0 SS	---
	0 DS	2,100 DS	0 DS	---
16-22	0 SS	2,200 SS	5 SS	---
	0 DS	2,400 DS	5 DS	---

[a]Cobalt-60 not detected at Watts Bar or Chickamauga Dams.
[b]--- indicates data not available.
[c]0 indicates below detectability by gamma spectroscopy.
[d]Considered to be questionable.
[e]SS - suspended solids; DS - dissolved solids.

solution. In Clinch River at Centers Ferry, November 1, 1960, through July 22, 1961, the maximum concentration found was 55 μμc per liter for the week ending July 17, 1961; and on numerous occasions concentrations were too low for detection.

In the Tennessee River at Loudon, Tennessee, December 1, 1960, through June 30, 1961, Co^{60} could not be detected in any of the monthly samples. In weekly samples at Watts Bar Dam and Chickamauga Dam, Co^{60} was not detected in any sample.

Examination of data from the Clinch River and Tennessee River samples taken together indicates that practically all of the Co^{60} discharged from White Oak Creek arrives at Centers Ferry. Between Centers Ferry and Watts Bar Dam, the concentration of Co^{60} in the water is decreased by dilution, and perhaps also by removal of Co^{60} from the water, so as to be below detection limits at Watts Bar Dam and likewise at Chickamauga Dam farther downstream.

Ruthenium-106. - Concentrations of Ru^{106} found in all samples for the period of available record are shown in Table 4. Comments by the Subcommittee on Water Sampling and Analysis[12] are summarized below.

In the Clinch River at Oak Ridge Water Plant from November 13, 1960, through July 29, 1961, Ru^{106} was found in about two-thirds of all the weekly samples collected at this station. As noted in the table, based on examination of correlative data the value of 1200 μμc per liter for the week ending March 4, 1961, is considered to be questionable, although no known source of error in analysis or in the handling of samples has been found. In weekly samples from

Table 4. Concentrations (μμc per liter) of Ru^{106} in Water Samples

Date	Clinch River at Oak Ridge Water Plant	White Oak Creek at Dam	Clinch River Above Centers Ferry	Tennessee River at Loudon, Tenn.	Tennessee River at Watts Bar Dam	Tennessee River at Chickamauga Dam
1960						
Nov. 1-12	---	---	360	---	---	---
13-19	10	200,000	390	---	---	---
20-26	50	280,000	320	---	25	290
27-Dec. 3	0	230,000	750	---	65	35
Dec. 4-10	220	160,000	165		50	70
11-17	15	220,000	610	0	80	170
18-24	0	190,000	850	for Dec.	60	70
25-31	210	220,000	840		110	60
1961						
Jan. 1-7	5	130,000	1,500		95	85
8-14	0	160,000	130	0	160	65
15-21	0	280,000	390	for Jan.	160	160
22-28	0	180,000	365		95	125
29-Feb. 4	10	210,000	180		115	90
Feb. 5-11	0	180,000	2,400		lost	95
12-18	5	190,000	2,300	0	55	75
19-25	5	130,000	5[c]	for Feb.	120	35
26-Mar. 4	1,200[c]	88,000	350		170	130
Mar. 5-11	10	87,000	350	0 SS[d]	80	75
12-18	0	110,000	280	40 DS	60	55
19-25	0	140,000	310	for Mar.	70	35
26-Apr. 1	0	120,000	200		60	40
Apr. 2-8	10	99,000	1,100		50	50
9-15	10	89,000	510	0 SS	55	40
16-22	5	98,000	1,100	55 DS	100	35
23-29	0 SS[d]	7,600 SS[d]	100 SS[d]	for Apr.	115	50
	105 DS	96,000 DS	640 DS			
30-May 6	10 SS	12,000 SS	35 SS		0 SS[d]	0 SS[d]
	30 DS	14,000 DS	170 DS		75 DS	65 DS
May 7-13	0 SS	8,800 SS	50 SS		0 SS	0 SS
	15 DS	165,000 DS	630 DS		105 DS	25 DS
14-20	250 SS	2,600 SS	30 SS	0 SS	0 SS	5 SS
	20 DS	154,000 DS	360 DS	5 DS	75 DS	95 DS
21-27	0 SS	9,800 SS	100 SS	for May	0 SS	5 SS
	5 DS	68,000 DS	510 DS		65 DS	40 DS
28-June 3	0 SS	7,600 SS	80 SS		0 SS	0 SS
	25 DS	69,000 DS	200 DS		80 DS	110 DS
June 4-10	5 SS	9,100 SS	40 SS		5 SS	5 SS
	10 DS	145,000 DS	200 DS		85 DS	50 DS
11-17	5 SS	12,000 SS	205 SS	0 SS	0 SS	0 SS
	10 DS	133,000 DS	610 DS	15 DS	75 DS	55 DS
18-24	5 SS	4,500 SS	290 SS	for June	0 SS	0 SS
	29 DS	127,000 DS	1,100 DS		60 DS	55 DS
25-July 1	0 SS	3,200 SS	220 SS		0 SS	0 SS
	5 DS	58,000 DS	710 DS		50 DS	35 DS
July 2-8	25 SS	2,900 SS	5 SS		10 SS	5 SS
	55 DS	64,000 DS	5 DS		110 DS	75 DS
9-15	0 SS	2,900 SS	20 SS	--- SS	5 SS	5 SS
	5 DS	93,000 DS	55 DS	--- DS	90 DS	55 DS
16-22	0 SS	5,500 SS	45 SS	for July	0 SS	5 SS
	5 DS	131,000 DS	450 DS		60 DS	55 DS
23-29	0 SS	1,700 SS	25 SS		5 SS	0 SS
	170 DS	58,000 DS	190 DS		50 DS	30 DS

[a] --- indicates data not available.
[b] 0 indicates below detectability by gamma spectroscopy.
[c] Considered to be questionable.
[d] SS - suspended solids; DS - dissolved solids.

White Oak Creek at White Oak Dam, November 13, 1960, through July 29, 1961, concentrations of Ru^{106} varied from a minimum of 26,000 μμc per liter for the week ending May 6, 1961, to a maximum of 280,000 μμc per liter in samples collected for two weeks ending November 26, 1960 and January 21, 1961. Most of the Ru^{106} at this station was in solution as judged from the available results on dissolved and suspended solids. In most of the samples less than 10% and in half of the samples less than 5% of the Ru^{106} activity was associated with the suspended solids. At Centers Ferry concentrations of Ru^{106} in weekly samples, November 1, 1960, through July 29, 1961, varied from a low of 5 μμc per liter to a high of 2400 μμc per liter in samples for the weeks ending February 25, 1961, and February 11, 1961, respectively. At this station also the Ru^{106} is, for the most part, in solution; but, when the activity is low, it appears that relatively more of the total activity is associated with the suspended solids.

In seven monthly samples from the Tennessee River at Loudon, Tennessee, concentrations of Ru^{106} were not detectable in samples collected for the months of December 1960 and January and February 1961, but Ru^{106} was detectable in samples for the months of March, April, May, and June 1961. The maximum concentration, 55 μμc per liter, occurred in April 1961. At Watts Bar Dam concentrations of Ru^{106} varied from a low of 25 μμc per liter for the week ending November 26, 1960, to a maximum of 170 μμc per liter in the sample for the week ending March 4, 1961. At Chickamauga Dam concentrations of Ru^{106} varied from a low of 25 μμc per liter to a maximum of 290 μμc

per liter in samples for weeks ending May 13, 1961, and November 26, 1960, respectively. The data indicate that approximately 90% of the Ru^{106} is present in solution at Watts Bar Dam and also at Chickamauga Dam.

The Subcommittee on Water Sampling and Analysis prepared mass diagrams for Ru^{106} at the several sampling stations to indicate the cumulative total load passing each station. A careful analysis of the data was made, taking into account the sampling dates and time of water travel from station to station. It was found that all station loads at the several stations, accumulated through the end of May 1961, agreed with each other within less than 10%.

Samples Collected in Environmental Surveys by USPHS[8,9]

Radiological determinations were made by USPHS on water samples collected during quarterly surveys in May 1960 and in September 1960 (see page 6). Also, in May 1960, selected artificial media were submerged in the Clinch River at CRM 14.6 for a period of 10 days and analyzed for radionuclides accumulated by the media. The water samples and artificial media were analyzed for five radionuclides of major interest; namely, Ru^{106}, Cs^{137}, Zr^{95}- Nb^{95}, Co^{60}, and Sr^{90}.

Daily water samples were collected in May 1960 during a 9-day period, May 18 to 26, from White Oak Creek and from Clinch River stations at CRM 14.6 and CRM 4.5. These were processed as individual samples, but other samples, collected daily from stations at CRM 43.5, TRM 551.0, TRM 528.9, TRM 517.9, and TRM 468.2, were composited into large samples, one for each station.

After separation of suspended solids from the water using Millipore filters (Type HA, pore size, 0.45 μ), radionuclide concentrations in the two fractions were determined (Table 5).

The radioactivity associated with the suspended matter, that is, the particulate matter retained on the Millipore filter, was compared with the total activity (suspended plus dissolved) at White Oak Creek, CRM 14.6, and CRM 4.5. During this study the percentages of total activity associated with the suspended matter showed an increase with distance of flow downstream for Cs^{137} and Co^{60}, while for Ru^{106} and Zr^{95} - N^{95} the highest percentages were at CRM 14.6. Cesium is taken up by the clayey materials, and cobalt is probably associated more with the organic materials in the suspended solids than with the clayey materials. In the absence of drastic changes in the pH or other chemical factors in the system, these reactions are not reversed; and, consequently, once the radioactive atoms are associated with the suspended fraction, they tend to remain so.

Little is known about the manner of uptake of Ru^{106} and Zr^{95}- Nb^{95} by the suspended solids. It appears from the data in Table 5 that after dilution of White Oak Creek water in the Clinch River, the proportions of these radionuclides in the suspended solids were greatly increased, and that the proportions were variable, as indicated by the lower percentages of the total activity associated with the suspended solids at CRM 4.5 as compared with CRM 14.6

Similar comparisons were made, using data from the composited water samples collected at the Tennessee River stations; but the

Table 5. Average Radionuclide Concentrations in Daily Water Samples Collected from Stations on White Oak Creek, the Clinch River, and the Tennessee River, May 1960

Number of Samples	Sampling Location	Fraction	Activity μμc/liter									
			Ru^{106}		Cs^{137}		Zr^{95}-Nb^{95}		Co^{60}		Sr^{90}	
			Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
1	CRM 43.5[a]	S.S.[b]	9		4		1		0[c]		---[d]	---
		D.S.	15		5		2		0		---	---
9	White Oak Creek	S.S.	200	70-460	95	35-290	2	1-4	35	20-80	---	---
		D.S.	9400	1200-37,000	2004	30-16,000	30	6-65	410	100-1260	18.0	1.5-35
8	CRM 14.6	S.S.	35	9-90	8	0-20	7	1-30	0.5	0-1	---	---
		D.S.	100	35-220	70	0-360	8	1-10	3	0-15	0.7	0.4-1.5
9	CRM 4.5	S.S.	7	0-40	2	0-4	1.5	0-3	0.5	0-2	---	---
		D.S.	130	45-255	8	0-60	8.5	0-15	0.5	0-4	0.08	0.02-0.14
1	TRM 551[a]	S.S.	0		2		1		1		0.5	
		D.S.	185		3		2		0		3.2	
1	TRM 528.9[a]	S.S.	10		3		1		4		0.2	
		D.S.	95		100		0		15		3	
1	TRM 517.9[a]	S.S.	15		1		1		---		0.2	
		D.S.	150		4		3		2		2.5	
1	TRM 468.2[a]	S.S.	7		5		---		---		0.06	
		D.S.	40		50		5		1		0.15	

[a]Composited samples from 9 days of water collection, May 18-26, 1960.

[b]S.S. indicates suspended solids; D.S., dissolved solids.

[c]0 indicates that the concentration was below the level of detectability.

[d]--- indicates samples not analyzed.

percentages of the total activity in the suspended solids at the several stations were variable; and no consistent pattern of distribution was found for any of the radionuclides.

A summary of the data from the water samples taken in September 1960 is shown in Table 6. Although these samples were not separated into suspended and dissolved fractions, the data in Table 6 show the marked reduction in concentration of radionuclides by the dilution of White Oak Creek water in Clinch River. Also it appears that Ru^{106} and Sr^{90} have not localized appreciably in the bottom sediments or biota, but are still in the water, 123 miles downstream at the Chattanooga Water Plant (TRM 465.5). It should be noted that the results of analyses of water samples from the basic sampling network of the Clinch River Study have led to the same conclusions.

During May 1960 selected artificial media were placed in the Clinch River at CRM 14.6 and removed after 10 day's contact with the river water. The specimens were analyzed for their radionuclide content and the concentration factors relative to the river water were calculated on an actual weight basis (see Table 7). All exposed media except nylon sponge were analyzed for Sr^{90} but, as noted in the table, concentration factors for Sr^{90} could not be determined. These media concentrated the radionuclides from the river water; and, though the data are qualitative and the time required to reach equilibrium has not been assessed, the materials showed a selectivity in the amount of each radionuclide accumulated. The most notable selectivity was found in comparing the concentrations

Table 6. Radionuclide Concentrations in Composite Water Samples Collected from Stations on the Clinch and Tennessee Rivers[a] September 1960

Sampling Location	Activity (μμc/liter)				
	Ru^{106}	Cs^{137}	Zr^{95}-Nb^{95}	Co^{60}	Sr^{90}
CRM 41.5	0[b]	370	0	0	2.6
White Oak Creek	460,000	14,000	2,000	13,000	200
CRM 14.6	100	5	0	5	3
CRM 4.5	170	0	5	5	7.1
TRM 529.9	100	0	0	0	18.0
TRM 517.3	0	0	0	0	2.4
TRM 465.5[c]	10	0	0	0	1.2
TRM 465.5[d]	5	0	0	0	---[e]

[a]Total activity in solution and in suspended solids.

[b]0 indicates that the concentration was below the level of detectability.

[c]Chattanooga water treatment plant before treatment.

[d]Chattanooga water treatment plant after treatment.

[e]--- indicates sample not analyzed.

Table 7. Concentration of Radionuclides from Clinch River Water by Artificial Media at CRM 14.6, May 1960

Medium	Concentration Factors[a]				
	Ru^{106}	Cs^{137}	Zr^{95}-Nb^{95}	Co^{60}	Sr^{90}[b]
Fine Charcoal	29	57	29	180	---
Algae	27	48	26	125	---
Charcoal Briquets	26	36	9	140	---
Nylon Sponge	21	26	18	90	---
Peat Moss	15	12	8	10	---
Tea	9	10	16	52	---

[a]Concentration factors, from original counting data, are ratios of activity per gram of artificial medium after exposure to activity per gram of river water, calculated for each radionuclide as accumulated in each medium.

[b]No concentration factors calculated for Sr^{90} because water data were insufficient.

in charcoal and in peat moss. The charcoal had relatively the highest concentration for Ru^{106}, Cs^{137}, Zr^{95}- Nb^{95}, and Co^{60}, but the lowest for Sr^{90} (not shown in Table 7). In peat moss, however, the accumulation of Sr^{90} was greater than of any of the other four radionuclides by factors ranging from about 3 to 25. Future work with artificial media will include time required to reach equilibrium, rate of uptake, and further definition of concentration factors for the different media and specific radionuclides.

Stable-Chemical Analyses

Basic Sampling Network

The stable-chemical analyses of basic network samples have been made in Nashville in the laboratory of the Tennessee Department of Public Health. The results were included in the progress report submitted by the Subcommittee on Water Sampling and Analysis on October 27, 1961.[12] As indicated previously (page 10), sampling periods at various stations have been changed so that stable-chemical analyses are now made on weekly composites from the station at Centers Ferry on Clinch River and on monthly composites from the Clinch River at the Oak Ridge Water Plant and the Tennessee River at Loudon, Watts Bar Dam, and Chickamauga Dam. The stable-chemical analyses of basic network samples have not included samples from White Oak Creek at White Oak Dam. Stable-chemical determinations on White Oak Creek samples are now being made at ORNL, but the results are not available for inclusion in this status report. Also, stable chemical analyses of Clinch River water samples have been made to supplement the results from the basic sampling network (see below,

and Status Report No. 2[2]).

The results of stable-chemical analyses of samples from the Clinch River at the Oak Ridge Water Plant and at Centers Ferry are given in Tables 8 and 9, respectively. The data in these tables indicate no major increase in the various forms of nitrogen and no increase in phosphates between the upper and lower Clinch River stations.

The results of stable-chemical analyses of samples from the three network stations on the Tennessee River are shown in Table 10.

Samples Analyzed at ORNL[13]

Stable-chemical analyses were made of filtered water samples collected at three stations on the Clinch River. Weekly proportional composite samples from the stations at Oak Ridge Water Plant and Centers Ferry were analyzed for stable cesium, strontium, cobalt, and ruthenium concentrations. Samples from weekly composites of once-daily constant-volume collections at the water plant of Oak Ridge Gaseous Diffusion Plant (ORGDP) were analyzed for concentrations of many constituents. Determinations of some constituents in the ORGDP samples were made every week; other determinations were made, on the average, every third week.

The results of analyses of weekly samples for these three stations are summarized below. At the Oak Ridge Water Plant and Centers Ferry the period of sampling was March 19 to September 3, 1961. Because the concentrations of the four constituents analyzed for at these two stations were very low, practically uniform, and often below the limits of detection, the results are not tabulated,

Table 8. Results of Stable-Chemical Analyses*, Clinch River at Oak Ridge Water Plant - CRM 41.5

Determination	Concentration in Parts Per Million**		
	Week Ending April 8, 1961	May 1961	June 1961
Turbidity	20	15	10
Apparent Color	134	120	84
Centrifuged Color	34	10	27
pH	8.5	7.8	7.1
M.O. Alk. as $CaCO_3$	92	96	90
Phth. Alk. as $CaCO_3$	6		
Acidity as $CaCO_3$		4	10
Hardness as $CaCO_3$	86	85	78
Calcium as $CaCO_3$	60	44	57
Magnesium as $CaCO_3$	26	41	21
Chlorides as Cl	5	4	5
Sulfates as SO_4	18	14	12
Nitrates as NO_3	1.6	0.4	0.5
Kjeldahl Nitrogen as N	0.6	0.5	1.1
Iron as Fe	2.1	2.1	5.2
Phosphates as PO_4	0.4	0.1	0.2
Potassium as K	1.4	1.1	1.4
Sodium as Na	3.6	1.7	5.2
Silica as SiO_2	6.4	6.8	7.7
Manganese as Mn	0.2	0.1	0.2
Fluorides as F	0.0	0.0	0.0
Specific Resistance	4027	5293	5409
Suspended Solids	167	90	274
Total Solids	315	222	341
Dissolved Solids	148	132	67

*Daily grab samples composited for weekly or monthly periods indicated.

**Specific resistance is in ohms at 20° C; pH is dimensionless.

Table 9. Results of Stable-Chemical Analyses*, Clinch River Above Centers Ferry - CRM 5.5

Determinations	Concentration in Parts Per Million**															
	1961 Weekly Periods, Ending on Dates Given															
	Mar. 18	Mar. 25	Apr. 1	Apr. 8	Apr. 15	Apr. 22	Apr. 29	May 6	May 13	May 20	May 27	June 3	June 10	June 17	June 24	July 1
Turbidity	17	6	12	13	16	11	12	15	10	6	17	15	16	40	50	20
Apparent Color	110	47	95	118	127	88	91	104	84	49	101	98	95	243	439	102
Centrifuged Color	20	10	12	44	37	30	15	7	7	8	10	10	5	8	37	18
pH	7.9	8.0	8.0	8.5	7.9	7.3	7.7	8.2	8.3	8.2	7.6	7.6	7.8	7.2	7.4	7.4
M.O. Alk. as $CaCO_3$	100	96	94	86	88	80	98	86	84	86	98	98	86	86	84	90
Phth. Alk. as $CaCO_3$		0	0	6				0	0	0						
Acidity as $CaCO_3$	5	0	0		14	13	9	0	0	0	4	6	2	4	4	6
Hardness as $CaCO_3$	93	87	102	80	87	75	89	75	73	73	84	82	73	85	82	78
Calcium as $CaCO_3$	58	46	56	60	56	51	62	56	54	52	52	45	52	63	57	56
Magnesium as $CaCO_3$	35	41	46	20	31	24	27	19	19	21	32	37	21	22	25	22
Chlorides as Cl	3	3	2	2	4	3	3	3	3	3	3	4	3	4	4	3
Sulfates as SO_4	11	12	10	16	13	6	7	15	14	9	14	9	10	18	4	23
Nitrates as NO_3	1.2	1.1	1.9	1.8	1.4	0.4	0.7	0.9	1.6	0.7	2.0	1.6	1.8	1.6	1.3	0.0
Kjeldahl Nitrogen as N	0.5	0.4	0.6	0.5	0.5	0.7	0.5	0.6	0.4	0.8	0.5	0.5	0.5	0.6	1.0	0.7
Iron as Fe	2.1	0.5	1.8	1.7	0.6	2.0	2.0	1.4	1.0	0.5	1.5	1.9	1.0	2.2	2.7	4.3
Phosphates as PO_4	0.1	0.2	0.4	0.4	0.3	0.2	0.2	0.1	0.2	0.1	0.2	0.2	0.1	0.2	0.3	0.1
Potassium as K	1.5	1.3	1.4	2.0	1.7	1.6	1.1	1.9	0.9	1.4	1.6	1.1	1.5	1.7	2.4	1.4
Sodium as Na	2.5	2.7	2.6	2.8	2.7	2.0	3.5	2.2	1.7	2.9	2.2	1.7	2.2	2.4	2.6	5.3
Silica as SiO_2	6.5	6.4	6.0	6.8	7.1	5.8	7.0	7.6	6.4	6.7	6.2	6.2	6.8	6.0	9.4	7.7
Manganese as Mn	0.0	0.1	0.2	0.1	0.0	0.1	0.1	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.2	0.2
Fluorides as F	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Specific Resistance	4584	4702	5216	4603	4603	5555	4861	5555	4346	4968	5063	5293	5431	6489	5799	5409
Suspended Solids	75	29	54	87	35	49	62	41	25	17	49	86	36	115	124	79
Total Solids	203	148	194	112	147	158	181	172	139	139	173	187	142	230	300	202
Dissolved Solids	128	119	140	25	112	109	119	131	114	122	124	101	106	115	176	123

*Daily grab samples composited for weekly periods indicated.

**Specific resistance is in ohms at 20° C; pH is dimensionless.

Table 10. Results of Stable-Chemical Analyses*, Tennessee River at Loudon (TRM 591.8), Tennessee River at Watts Bar Dam (TRM 529.9), and Tennessee River at Chickamauga Dam (TRM 471.0), March Through June 1961

Determinations	Concentration in Parts Per Million**									
	Loudon				Watts Bar Dam			Chickamauga Dam		
	March	April	May	June	Week Ending April 8	May	June	Week Ending April 8	May	June
Turbidity	38	13	8	7	7	1	1	20	1	2
Apparent Color	272	108	67	62	73	25	18	160	30	18
Centrifuged Color	95	39	10	15	32	12	8	42	12	8
pH	7.8	7.8	7.9	7.8	7.6	7.6	7.5	7.8	7.9	7.6
M.O. Alk. as $CaCO_3$	48	50	51	49	54	51	59	54	47	53
Phth. Alk. as $CaCO_3$										
Acidity as $CaCO_3$	4	6	2	2	4	2	4	4	2	4
Hardness as $CaCO_3$	56	49	78	49	55	47	78	56	44	64
Calcium as $CaCO_3$	36	33	35	35	38	35	45	40	31	40
Magnesium as $CaCO_3$	20	16	43	14	17	12	33	16	13	24
Chlorides as Cl	11	9	13	15	12	6	9	11	6	8
Sulfates as SO_4	5	1	8	13	11	8	9	10	9	10
Nitrates as NO_3	1.7	1.0	0.7	1.1	1.0	1.0	1.1	0.9	0.9	0.9
Kjeldahl Nitrogen as N					0.5	0.5	0.8	0.5	0.6	0.6
Iron as Fe	3.4	1.5	0.6	1.3	0.4	0.2	0.2	1.6	0.2	0.2
Phosphates as PO_4	0.6	0.2	0.2	0.1	0.2	0.2	0.0	0.2	0.1	0.1
Potassium as K	1.6	1.5	0.9	0.9	1.5	1.1	1.2	1.3	0.8	1.2
Sodium as Na	5.8	5.8	3.9	8.9	5.8	2.9	5.5	5.2	4.7	5.2
Silica As SiO_2	10.0	5.2	5.4	7.7	8.0	7.1	6.4	8.0	7.1	5.5
Manganese as Mn	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0
Fluorides as F	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Specific Resistance	6520	8194	7405	6812	6520	5713	6812	6520	5216	7318
Suspended Solids	65	28	18	19	6	3	5	11	6	5
Total Solids	163	109	129	117	103	107	122	125	93	108
Dissolved Solids	98	81	111	98	97	104	117	114	87	103

*Daily grab samples composited for weekly or monthly periods indicated.

**Specific resistance is in ohms at 20° C; pH is dimensionless.

but are summarized in the narrative below. Results from samples collected at the ORGDP Water Plant are discussed and given in tables and charts as explained later.

Oak Ridge Water Plant. - Strontium was found in all weekly samples, and the average concentration was 0.07 ppm. The variation in concentrations from week to week was small, maximum and minimum concentrations being 0.08 and 0.06 ppm, respectively. The standard deviation was 0.006 ppm.

Concentrations of cesium and ruthenium were below limits of detection (cesium, 0.01 ppm; ruthenium, 0.1 ppm). Concentrations of cobalt were below limits of detection, with the exception of two weekly samples, both of which were reported as 0.02 ppm. In seven samples analyzed for hexavalent chromium, this element was not detected (generally less than 0.01 ppm).

Centers Ferry. - Strontium was found in all samples with average, maximum, and minimum concentrations of 0.07, 0.08, and 0.05 ppm, respectively. The standard deviation was 0.007 ppm.

Concentrations of cesium and ruthenium were below limits of detection in all samples. Cobalt was detected in two weekly samples, the concentration being 0.02 ppm in the same weeks that this constituent was detected in the samples from Oak Ridge Water Plant; namely, June 4 to 10 and July 2 to 8, 1961. Hexavalent chromium was detected in three of seven samples analyzed for chromium, the concentrations being 0.01 and 0.02 in March 1961 and 0.013 for the week of July 9 to 15, 1961.

ORGDP Water Plant. - The period of sampling reported for this station is November 2, 1960, to September 10, 1961. The average, maximum, and minimum concentrations and the standard deviation for each constituent detected in weekly samples from this station are listed in Table 11. The subheadings in the table indicate the period represented. In Table 12 results of triweekly analyses of the weekly samples, i.e., made every third week, are summarized.

The standard deviation from the average concentration exceeds 30% for nitrates, suspended solids, loss on ignition of solids, chlorides, phosphates, and sulfates. The standard deviation is less than 15% for calcium, potassium, total solids, bicarbonates, pH, conductivity, and strontium.

Cesium, cobalt, and ruthenium were not detected in any sample analyzed. In a few infrequent analyses, bromides, iodides, and hexavalent chromium were not detected. The concentration of lithium was found to be 0.005 ppm in one sample.

The results of triweekly analyses indicate that copper, zinc, aluminum, iron, silicon, titanium, zirconium, and fluorides are commonly present in Clinch River waters. Rubidium, barium, manganese, and nickel were not detected in the samples.

The variation in concentration with time at the ORGDP Water Plant from November 1960 to September 1961 for several constituents is shown in Figs. 1, 2, and 3. For calcium the concentrations were higher and more variable from November to February than in the remainder of the period. For magnesium the concentrations were lower and more variable from November to January than in the remainder

Table 11. A Summary of Stable-Chemical Analyses of Water Samples from ORGDP Water Plant, CRM 14.4 - Weekly Analyses

Constituent	Concentrations in ppm[a]			
	Average	Standard Deviation	Maximum	Minimum
	Nov. 2, 1960, to Sept. 10, 1961			
Ca	21.3	3.0	30	17
Mg	6.97	2.33	10	< 2.0
Na	2.46	0.54	4.7	1.8
K	1.37	0.15	2.3	1.1
NO_3	6.01	---[b]	40	0.59
Suspended Solids	23.5	19.9	104	0.75
Total Solids	154	23	231	127
Loss on Ignition	28.7	18.0	95	10.5
	Nov. 28, 1960, to Sept. 10, 1961			
Cl	1.65	0.54	4.51	1.1
SO_4	10.9	4.5	27	0.8
PO_4	0.238	0.174	< 1	< 0.003
HCO_3	112	12	134	87
pH	7.67	0.35	8.4	6.5
Conductivity	215	14	282	190
	Feb. 6, 1961, to Sept. 10, 1961			
Cs	< 0.01	---	---	---
Sr	0.068	0.0094	0.08	0.04
Co	< 0.02	---	---	---
Ru	< 0.1	---	---	---

[a]Conductivity is in μ mho/cm; pH is dimensionless.

[b]--- indicates no data available.

Table 12. A Summary of Stable-Chemical Analyses of Water Samples from ORGDP Water Plant, CRM 14.4 - Triweekly Analyses

Constituent	Concentrations in ppm		
	Average	Maximum	Minimum
	Feb. 6, 1961, to Sept. 10, 1961		
Cu	0.028	0.10	< 0.01
Rb	< 0.005	---[a]	---
NH_4	---	1	0.02
Zn	0.139[b]	19	0.059
Ba	< 0.3 - < 0.05	---	---
Al	0.117	0.34	0.01
Fe	0.081	0.37	0.003
Mn	< 0.01	---	---
Si	1.73	2.4	0.24
Ti	0.030	0.06	0.01
Zr	0.032	0.06	0.01
Ni	< 0.01	---	---
F	0.20	0.33	0.05

[a]--- indicates no data available.

[b]Maximum observed concentration is questionable and was not included in computing the average of nine observations.

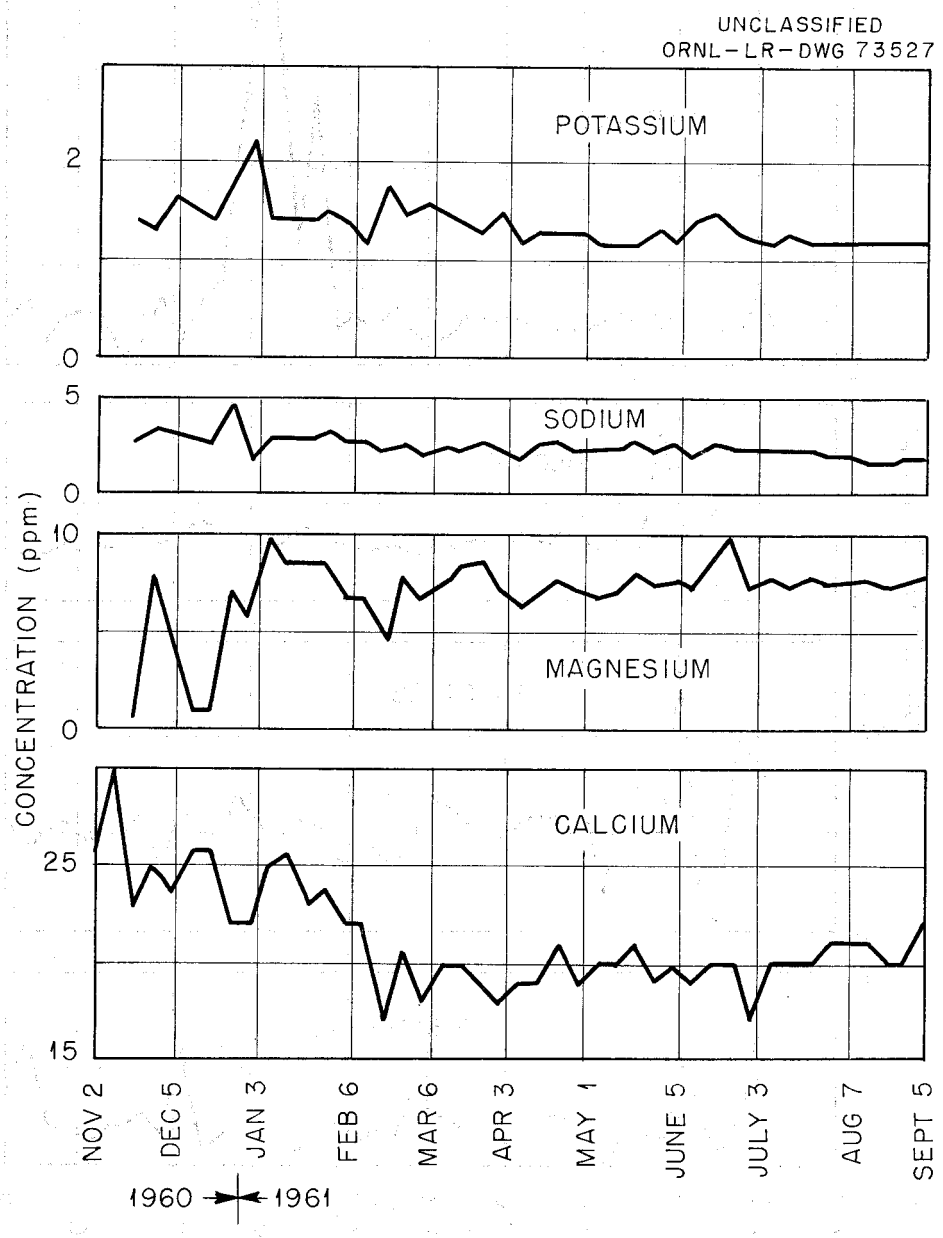

Fig. 1. Variation in weekly concentration of major cations in Clinch River water at ORGDP Water Plant.

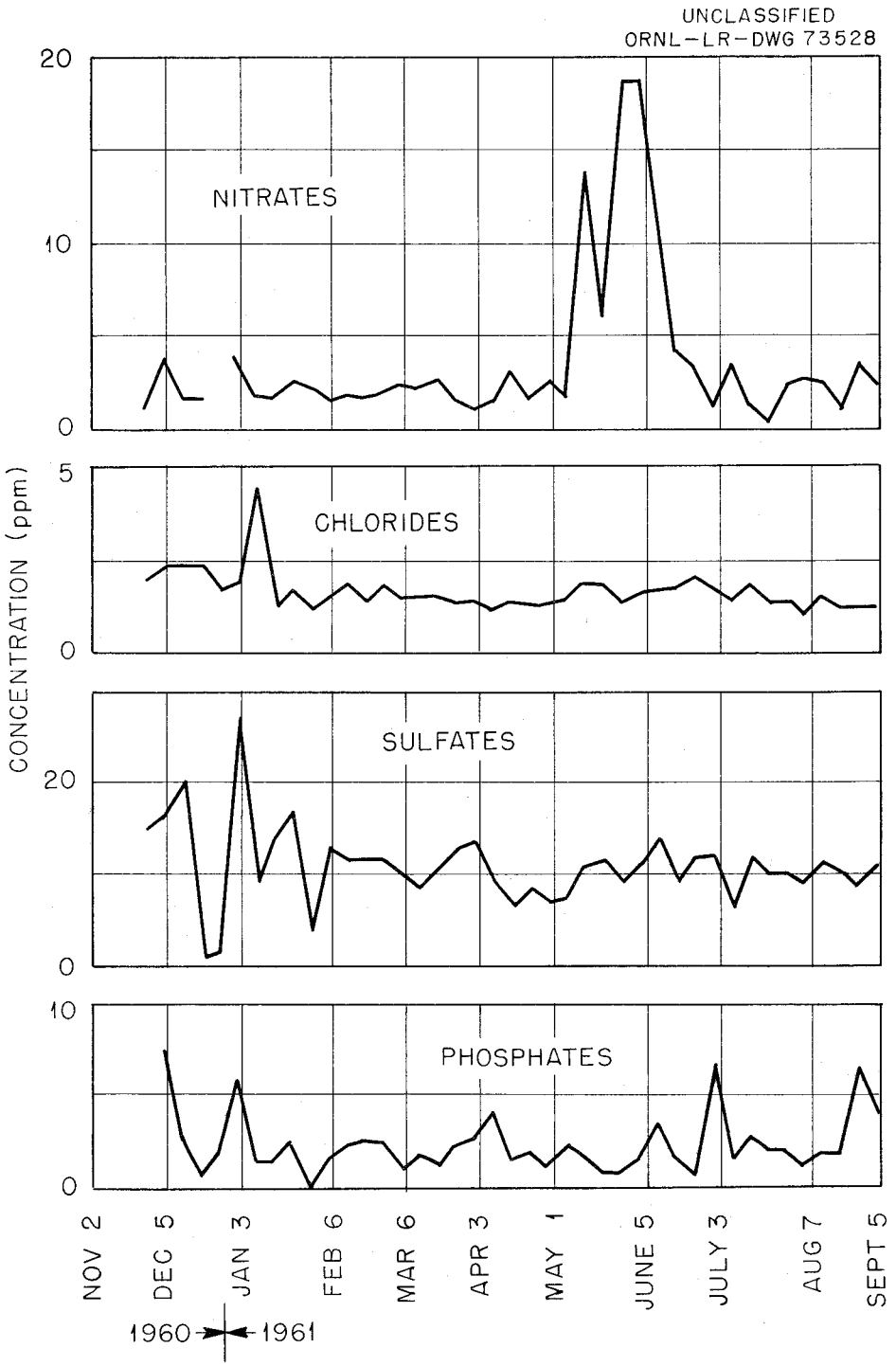

Fig. 2. Variation in weekly concentration of major anions in Clinch River water at ORGDP Water Plant.

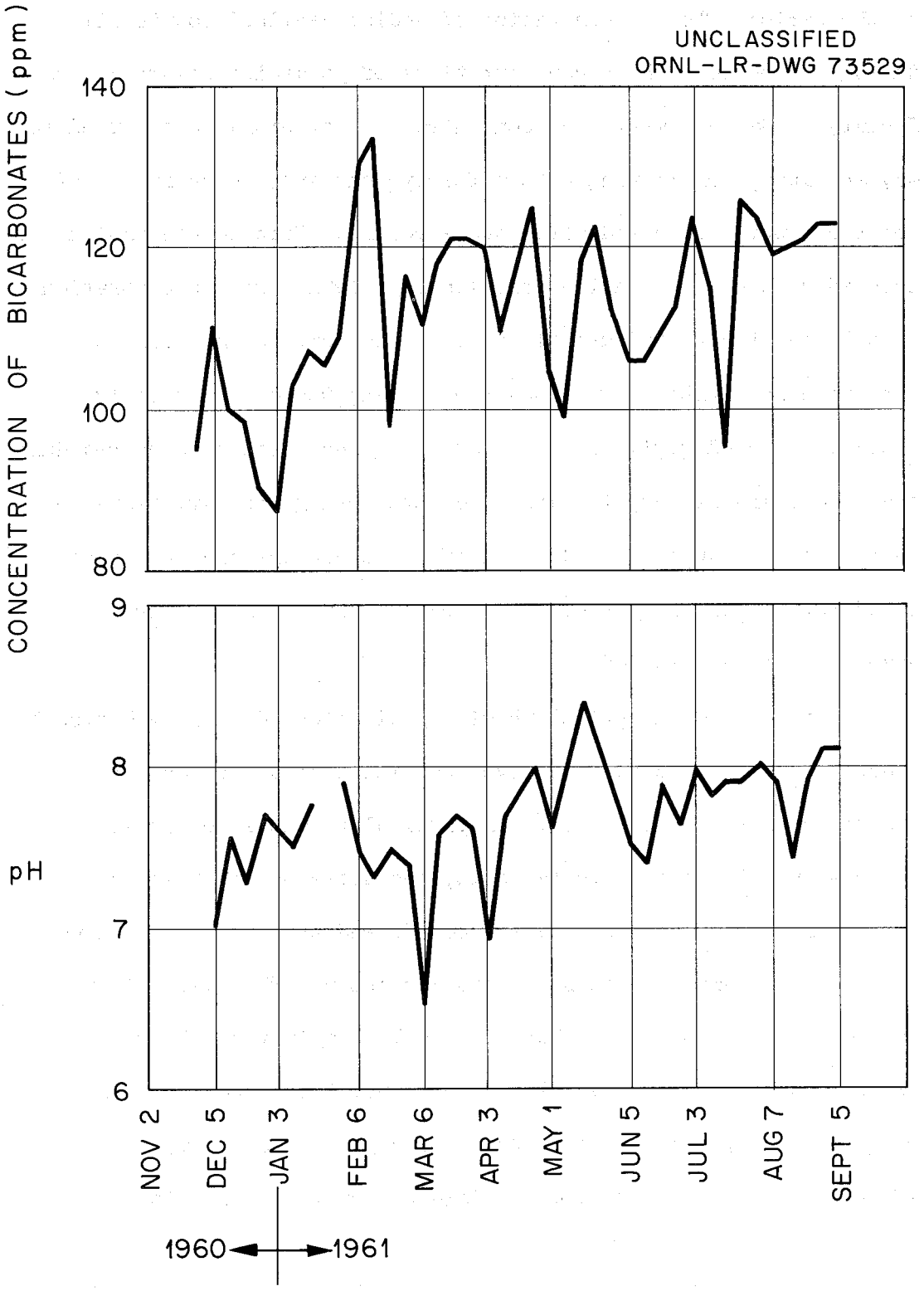

Fig. 3. Variation in pH and concentration of bicarbonates in weekly samples of Clinch River water at ORGDP Water Plant.

of the period. The concentration of sodium declined continually during the period. High concentrations of potassium occurred from January to March. Very high concentrations of nitrates occurred in May and June, contrasting with a fairly constant concentration of about 2.5 ppm before and after these months. Peak concentrations of chlorides were observed in early January, 1961. The concentration of sulfates fluctuated greatly during December; the maximum and minimum concentrations were observed during December and early January. Marked variations in phosphate concentration occurred during the summer and winter; in early and late spring the variations were much less. An upward trend in bicarbonate content and pH may be noted for the entire period. The reasons for the above variations have not been determined.

Work by the Analytical Chemistry Division, Oak Ridge National Laboratory, has succeeded in lowering limits of detection for cesium, cobalt, and ruthenium, in particular, and also for several other stable isotopes. In Table 13, the dates on which some detection limits were lowered are noted, and the approximate lower limits for a number of constituents are shown. The exact limits are not known at present. For the weekly sample from the ORGDP Water Plant, collected July 10 to 16, 1961, the concentrations of cobalt, cesium, and ruthenium were 0.002 ppm, 0.0006 ppm, and 0.001 ppm, respectively as determined by neutron activation analysis.

The concentration of iron was determined in the filtered and unfiltered portions of the weekly sample collected June 11 to 17, 1961; the respective results were 0.06 and 1.3 ppm.

Table 13. Dates of Change in Lower Limits of Detection and the Limits for Some Constituents

Lowering of Detection Limits		Limits of Detection	
Constituent	Date - 1961	Constituent	Limit (ppm)
Sr	Aug. 6	Cu	0.01
Co	Aug. 14	Rb	0.005
Ba	July 10	Cs	0.01
NH_4	Sept. 4	NH_4	0.003
		Ba	0.05
		Al	0.01
		Mn	0.01
		Co	0.01
		Ni	0.01
		Br	1
		I	2
		Ru	0.1
		Sr	0.001

The week-by-week results of all determinations on samples from the ORGDP Water Plant, representing weekly periods from April 10 to September 10, 1961, are shown in Table 14.* Analyses were made of one monthly sample collected in April at the Loudon station on Tennessee River. The concentration of strontium was 0.05 ppm; cesium ruthenium, and cobalt were below the limits of detection.

*Results of similar determinations from November 28, 1960, to April 9, 1961, were given in Status Report No. 2, Tables 12 and 13.[2]

Table 14. Results of Stable-Chemical Analyses of Filtered Water Samples from ORGDP Water Plant, CRM 14.4

Sample No.	Weekly Period		Na	K	Cu	Rb	Cs	NH_4	Ca	Mg	Zn	Sr	Ba	Al	Fe	Mn	Si	Ti	Zr	Co	Ni	F	Cl	Br	I	Ru	NO_3	SO_4	PO_4	HCO_3	pH	Li	Cr^{+6}	Specific conductivity at 25°C μmhos/cm	Suspended solids ppm	Total solids 102°C ppm	Total solids Loss on ignition at 500°C ppm
			ppm																													ppm					
	1961																																				
42	Apr. 10	Apr. 16	1.9	1.2	0.02		<0.01		19	6.2		0.07					1.7			<0.02		<0.2	1.2	<1	<2	<0.1	1.7	9.3	0.42	109	7.7			218	50.4	141	
43	Apr. 17	Apr. 23	2.6	1.3			<0.01		19	6.9		0.06	<0.3		0.06	<0.01			0.04	<0.02			1.4			<0.1	3.1	6.4	0.15	118	7.8			211	30.7	143	10.5
44	Apr. 24	Apr. 30	2.9	1.3		<0.005	<0.01	<1	21	7.6	0.059	0.07		<0.02				0.01		<0.02	<0.01		1.3			<0.1	1.8	8.3	0.18	126	8.0			225	17.8	140	22.4
45	May 1	May 8	2.2	1.3	0.016		<0.01		19	7.0		0.08					2.0			<0.02		0.21	1.3	<1	<2	<0.1	2.7	7.1	0.10	105	7.6			197	15.1	128	14.0
46	May 9	May 14	2.2	1.2			<0.01		20	6.8		0.06	<0.3		0.10	<0.01			0.02	<0.02			1.5			<0.1	1.9	7.4	0.23	99	8.0			205	17.8	129	19.2
47	May 15	May 21	2.2	1.2		<0.005	<0.01		20	7.0	0.16	0.07		<0.01				0.02		<0.02	<0.01		1.9			<0.1	14	11	0.14	118	8.4	0.005		205		159	26.5
48	May 22	May 30	2.8	1.2	<0.01		<0.01		21	8.0		0.07					1.8			<0.02		0.20	1.8	<1	<2	<0.1	5.9	11.9	0.07	123	8.1	0.004		218	17.7	141	22.2
49	May 31	June 4	2.2	1.3			<0.01		19	7.3		0.08	<0.3		0.07	<0.01			0.01	<0.02			1.4			<0.1	19	9.2	0.09	112	7.8			207	10.6	184	70.5
50	June 5	June 10	2.6	1.2			<0.01		20	7.4		0.08	<0.3		0.09	<0.01			0.01	<0.02			1.6			<0.1	19	11.0	0.14	106	7.5			201	14.5	135	20.2
51	June 11	June 17	2.0	1.4			<0.01		19	7.1		0.07	<0.3		0.06	<0.01			0.04	<0.02			1.7			<0.1	12.0	14.0	0.38	106	7.4			199	51.8	174	36.3
															1.3*																						
52	June 18	June 24	2.5	1.5			<0.01		20	8.5		0.06	<0.3		0.05	<0.01			0.06	<0.02			1.8			<0.1	4.2	9.8	0.16	109	7.9			209	32.2	159	35.1
53	June 25	July 2	2.2	1.3		<0.005	<0.01	0.11	20	10	0.20	0.08		<0.01				0.02		<0.02	<0.01		2.0			<0.1	3.4	12	0.06	113	7.6			190	18.4	142	54.6
54	July 3	July 9	2.2	1.2	0.07		<0.01		17	7.2		0.07					0.24			<0.02		<0.05	1.57			<0.1	1.5	12	0.69	124	8.0			207	12.4	147	58.0
55	July 10	July 16	2.1	1.2			<0.01		20	7.5		0.08	<0.05		0.003	<0.01			0.02	<0.02			1.4			<0.1	3.7	6.2	0.15	115	7.8			205	17.4	142	34.1
56	July 17	July 23	2.1	1.3		<0.005	<0.01	0.11	20	7.3	0.07	0.07		<0.01						<0.02	0.01		1.8			<0.1	1.4	12	0.27	95.2	7.9			209	41.2	160	20.6
57	July 24	July 30	2.2	1.2	0.01		<0.01		20	7.7		0.08					1.6			<0.02		0.33	1.4			<0.1	0.59	10	0.20	126	7.9			209	27.9	154	17.3
58	July 31	Aug. 6	2.0	1.2			<0.01		21	7.4		0.08	<0.05		0.02	<0.01			0.05	<0.02			1.4			<0.1	2.4	9.8	0.20	124	8.0			207	13.1	133	15.4
59	Aug. 7	Aug. 13	2.0	1.2		<0.005	<0.01	<0.02	21	7.3	19	0.08		0.14				0.06		<0.02	<0.01		1.0			<0.1	2.8	9.1	0.12	119	7.9		<0.01	203	12.9	132	14.0
60	Aug. 14	Aug. 20	1.9	1.2	0.02		<0.01		21	7.6		0.08					2.4			<0.01		0.27	1.5			<0.1	2.5	11	0.19	120	7.4			211	9.7	165	54.3
61	Aug. 21	Aug. 27	1.8	1.2			<0.01		20	7.4		0.061	<0.05		0.07	<0.01			0.02	<0.01			1.3			<0.1	1.0	10	0.18	121	7.9			209	9.4	135	17.4
62	Aug. 28	Sept. 4	1.9	1.2		<0.005	<0.01	<0.03	20	7.4	0.09	0.072		0.03				<0.01		<0.01	<0.01		1.2			<0.1	3.6	8.4	0.64	123	8.1		<0.01	218	12.4	143	19.0
63	Sept. 5	Sept. 10	1.9	1.2	0.01		<0.01		22	7.8		0.070					2.2			<0.01		0.23	1.1			<0.1	2.6	11	0.47	123	8.1		<0.01	220	11.2	141	20.4
64	Sept. 11	Sept. 17																																			
65	Sept. 18	Sept. 24																																			

*Determination on unfiltered sample.

RADIOACTIVITY IN BOTTOM SEDIMENTS

The data summarized in this section of the report are from three sources: (1) Progress Report No. 1 of the Subcommittee on Bottom Sediment Sampling and Analysis,[14] (2) the 1961 annual survey of the Clinch and Tennessee Rivers by the ORNL Applied Health Physics Section, and (3) analyses of sediment samples collected by USPHS in connection with their quarterly surveys in May and September 1960.[8,9] Because of differences in techniques of collection and analysis, the results reported from these three sources are not strictly comparable and, therefore, will be summarized separately below.

Report of Subcommittee on Bottom Sediment Sampling and Analysis

This subcommittee (see page 4) was requested by the Clinch River Study Steering Committee to review previous investigations of radioactivity in bottom sediments of Clinch River, to define the purpose of future work, and to outline the program of investigations. The subcommittee held two meetings at ORNL, May 24, 1961 and October 12, 1961, during which the above assignment was considered in detail. The conclusions reached by the subcommittee and accomplishments to date are summarized below.

Objectives

The objectives in the investigations of radioactivity in bottom sediment were outlined as follows:

(1) Preliminary assessment of selected radionuclides in the bottom sediments of Clinch River has indicated that relatively

small proportions of the activity released to the river are retained in the bottom sediments. Immediate work should be directed toward improving the reliability of estimates of radioactivity in the bottom sediments.

(2) The major emphasis in future work should be directed toward investigating the factors which determine the distribution of radioactivity in bottom sediments, including those factors which affect deposition and movement of sediments and those which will indicate the ultimate capacity of the sediments to accept and retain radioactivity.

(3) Improved methods of monitoring the radioactivity in the bottom sediments should be developed.

Methods of Estimating Radioactivity in Sediments

Based on a review of the previous investigations of radioactivity in the bottom sediments of Clinch River, methods of improving the estimate of the selected radionuclides in sediments of the study reach were suggested: (1) an adequate sampler should be sought; (2) the number of sections required to accurately estimate the volume of sediments should be determined; and (3) the influence of bends on the distribution of activity should be assessed.

Fourteen different soil-sampling tools were evaluated in field tests to determine the one that had the best cutting action, penetration, and retention characteristics. A split-tube sampler with basket shoe was found to be the most suitable for use in sediment core collection in Clinch River. The amount of compaction

of cores was investigated in the field tests. Essentially no compaction was observed with tubes having diameters greater than 3 in. About 4 in. of compaction in 2 ft of penetration was observed with 2-in.-dia tubes. Severe compaction was observed with 1-in.-dia tubes--3-in. compaction in 1 ft of penetration and 11-3/8-in. compaction in 2 ft of penetration.

Sediment Volumes

In May 1961, personnel of the Hydraulic Data Branch, TVA, made a silt range survey in Clinch River. In addition to measurements at the standard silt ranges - CRM 4.3, 7.6, 11.9, and 19.2 (Ranges 31, 32, 33, and 34, respectively) - four other sections were included: CRM 4.7, 9.0, 14.0, and 16.9. At sections intermediate to the four silt ranges, the area of sediment and area of water was to be determined. Comparison of the results of computing water volumes by using the cross-sectional area of water (a) at the silt ranges and (b) at all of the sections showed a difference of less than 1%. The volume of water was 29,000 acre-ft. Comparison of the silt volumes computed for the 1956 and 1961 surveys indicates a net decrease in volume in the reach upstream from Mile 11.9, while downstream from Mile 11.9 the sediment volume has increased. In general, the bed material was too hard to probe; therefore, the depth of sediment at sections intermediate to the silt ranges was not measured.

From the results of the TVA silt range survey in 1961, it was concluded that accurate determination of sediment volume may be based on as few as four sections - the four standard silt ranges.

Influence of Bends on Sediment Deposits

Fifteen bends in the Clinch River between CRM 4.7 and CRM 18.8 have been defined as shown in Table 15. The relative curvature of a bend is defined as the ratio of the inside radius of the bend (r) to the width of channel (b), i.e., r/b. In Table 15 this value varies from 1.08 to 25.2. The included angle of the bends varies from 0.59 to 2.82 radians (34° to 161°).

Work by Ralph A. Bagnold indicates that bends with relative curvature greater than 3.5 offer no greater resistance to flow than a straight channel.[15] From his study, it might be assumed that in bends with relative curvature greater than 3.5, the distribution of sediment deposits is not different from straight channels. There are seven bends in the study reach of Clinch River for which the relative curvature is greater than 3.5.

The distribution of sediment deposits and of gross gamma counts *in situ* were studied in one of the sharpest bends of Clinch River ($\frac{r}{b}$ = 1.95), CRM 5.4 to CRM 5.9 (Table 15 and Fig. 4). A comparison of the variations found in water depth, probed depth of sediment, and gross gamma activity measured at the surface of the sediment in the six sections is shown in Fig. 5. It should be noted that the channel is relatively straight at the three upstream sections (CRM 6.3, 6.1, and 5.9), while the three downstream sections (CRM 5.7, 5.6, and 5.4) are within the sharp bend.

The results of the study are summarized in Table 16. The sediment area increases almost linearly from CRM 5.4 to CRM 6.3 (Fig. 6). The mean depth of water varies within narrow limits from

Table 15. Properties of Channel Bends of Clinch River

Bend		Relative Curvature (r/b)[a]	Included Angle	
Begins (CRM)	Ends (CRM)		Radians	Degrees
4.71	5.00	1.08	1.69	97
5.43	5.86	1.95	1.59	91
6.12	6.90	2.73	1.98	113
7.24	7.87	3.29	1.22	70
8.58	9.21	3.45	1.26	72
9.41	10.23	4.20	1.00	57
10.38	10.74	5.53	0.59	34
11.06	12.17	4.61	2.82	161
12.36	12.71	3.00	1.47	84
12.77	13.37	12.4	0.73	42
13.64	15.41	11.3	1.83	105
15.47	16.36	5.73	1.57	90
16.85	17.43	3.21	1.96	112
18.06	18.60	2.86	1.78	102
18.82	19.76	25.2	0.63	36

[a]Ratio of the radius of the inside of the bend to the width of the channel. It should be noted that relative curvature does not depend upon the length of the bend.

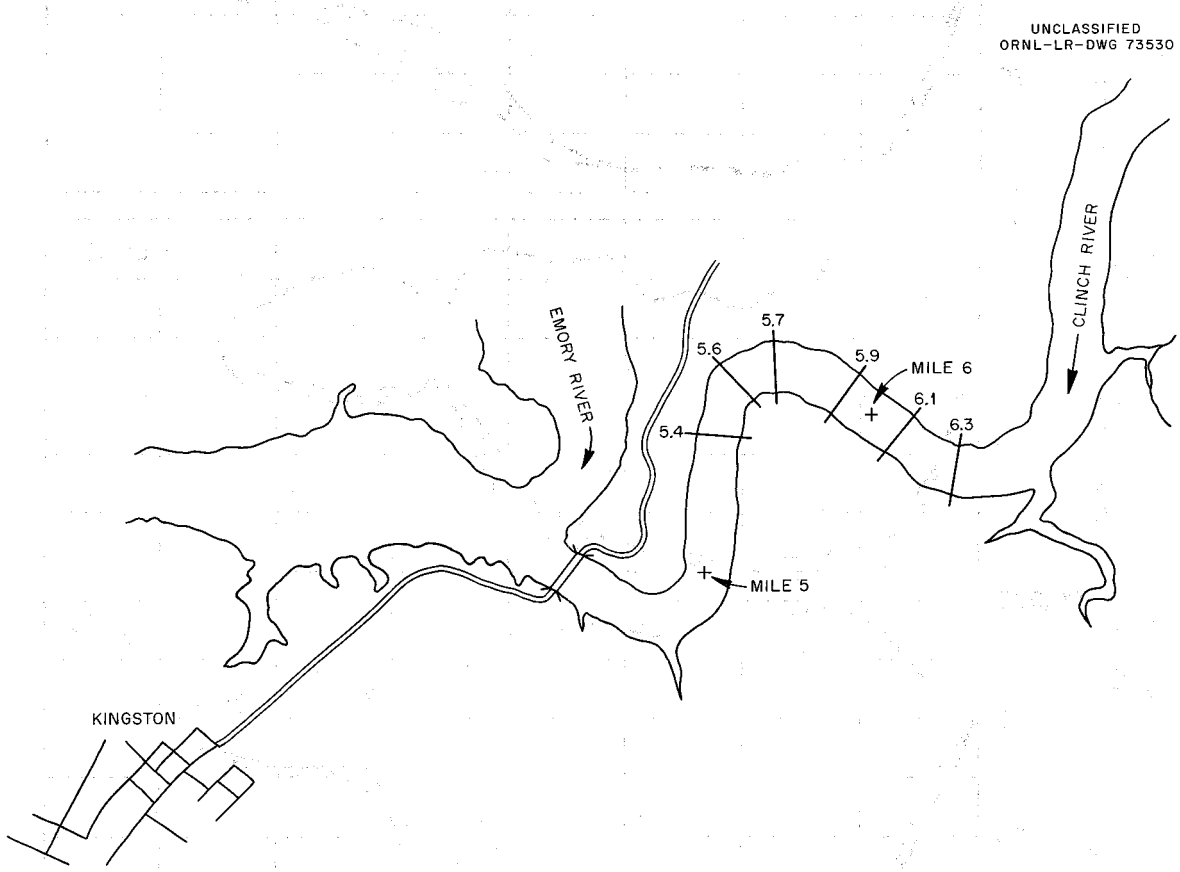

Fig. 4. Map of Clinch River bend showing sections of bottom sediments.

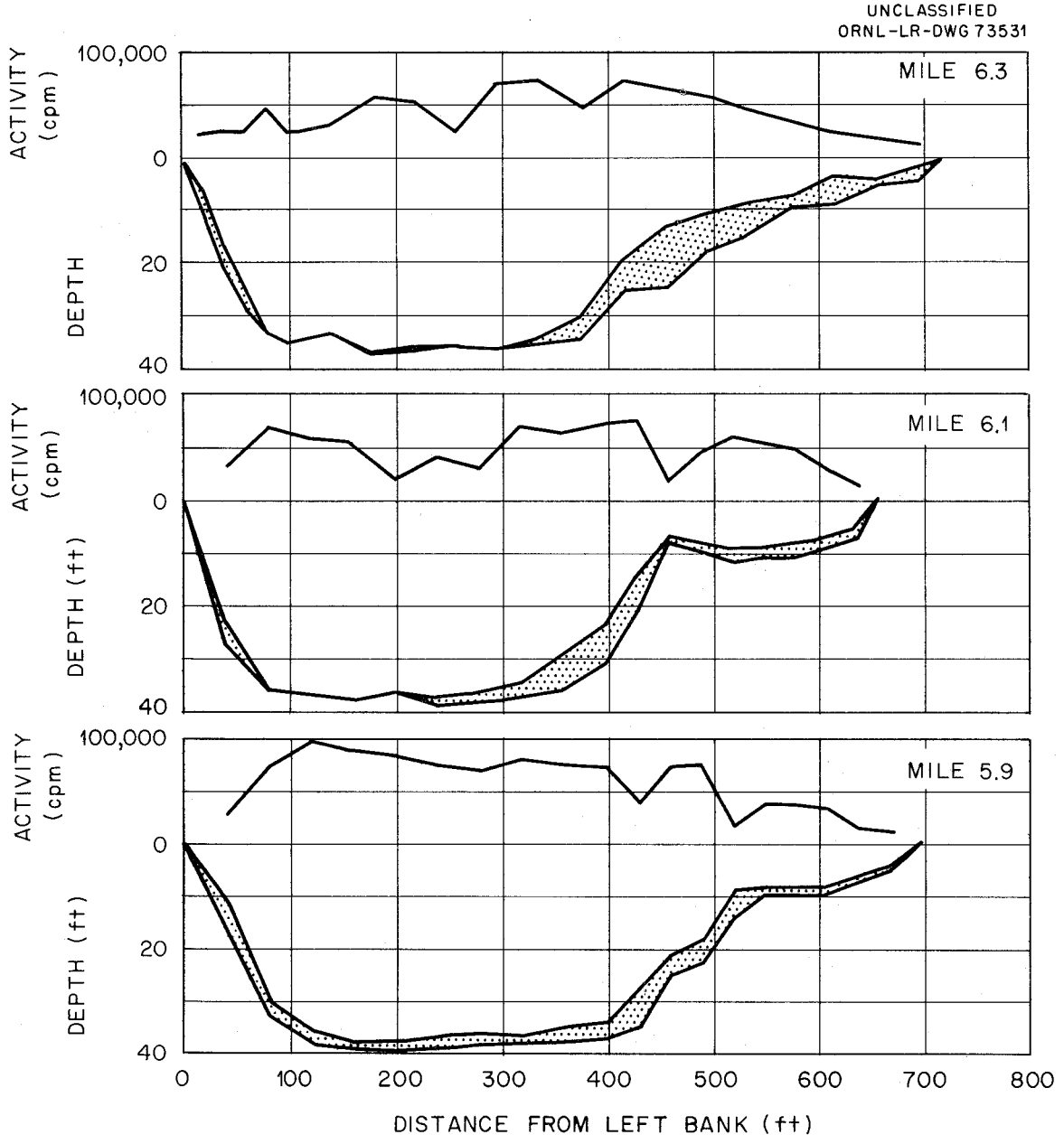

Fig. 5. Variation of water depth, probed depth of bottom sediment, and gross gamma activity detected at surface of bottom sediment in cross-sections at Clinch River Miles 5.4, 5.6, 5.7, 5.9, 6.1, and 6.3.

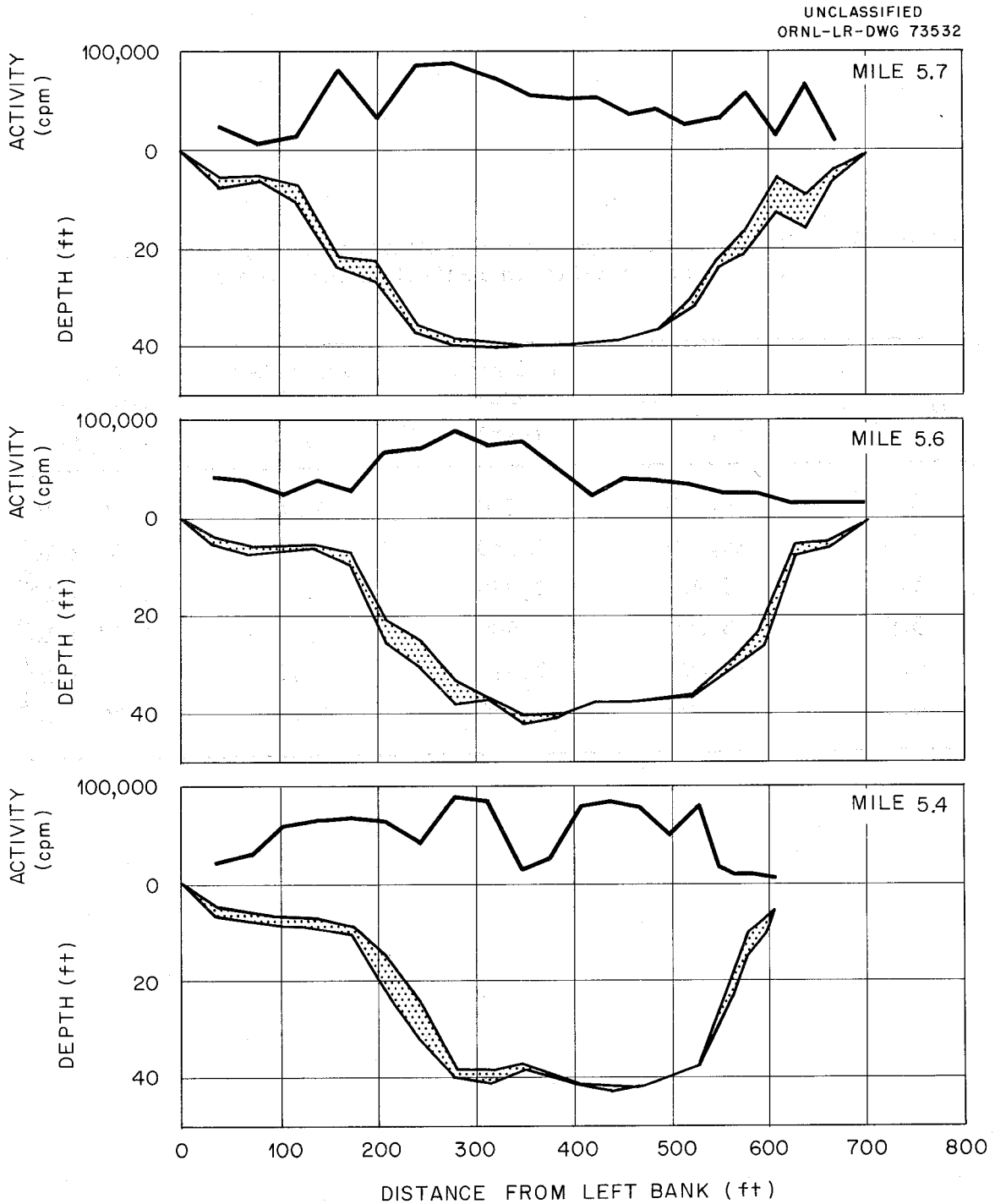

Fig. 5 (continued)

Table 16. Distribution of Water Area, Sediment Area, Mean Water Depth, and Gamma Activity in Bend of Clinch River

Location (CRM)	Water Area (ft^2)	Sediment Area (ft^2)	Mean Water Depth (ft)	Gamma Activity (cpm/ft^2)
5.4	14,600	970	22.8	3.29×10^4
5.6	15,500	1,230	21.8	2.33×10^4
5.7	15,900	1,470	22.6	2.12×10^4
5.9	16,600	1,900	23.7	2.07×10^4
6.1	15,200	1,470	23.0	2.05×10^4
6.3	14,900	2,430	20.5	1.32×10^4

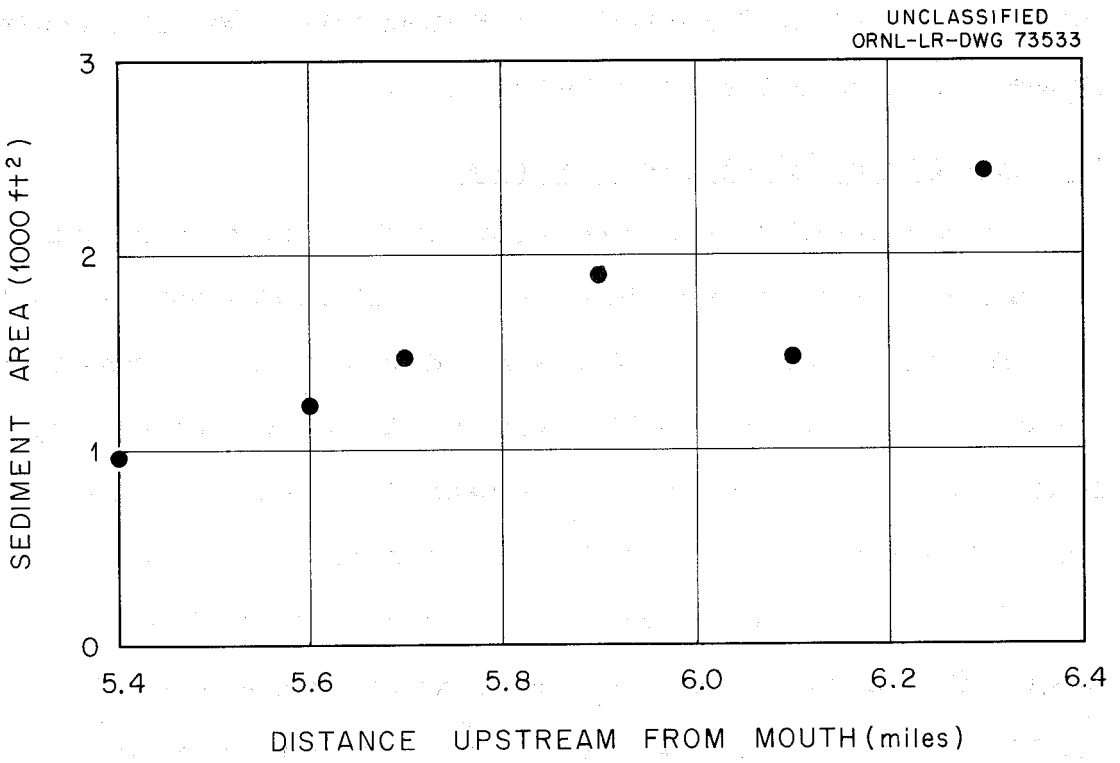

Fig. 6. Distribution of bottom sediment cross-sectional area in bend of Clinch River.

20.5 ft to 23.7 ft. The ratio of the total gross gamma count to cross-sectional area of the sediment is fairly constant within the bend, but the ratio increases sharply at the downstream end of the bend and decreases at the upstream end (Fig. 7). Some relationship between gross gamma count and water depth was noted, but not defined. Before firm conclusions can be drawn about the influence of bends on distribution of radioactivity, the distribution of particle sizes in bends must be investigated.

Investigations of Clinch River Sediments

Using a scintillation detector, a survey of gamma activity at the surface of the bottom sediments was made at quarter-mile intervals from CRM 10.0 to CRM 13.0. Three counts were made in each section at the quarter points. The results indicate that the maximum activity in the river, downstream from the vicinity of the mouth of White Oak Creek, occurs at about CRM 12.0 (near TVA Silt Range 33).

Ten core samples were collected at each of three TVA Silt Ranges (CRM 7.6, 11.9, and 19.2) and in two sections at CRM 4.7 and 15.3. The ten cores collected in each section were composited and split into several aliquots for analyses to determine particle-size distribution, mineralogy, and exchange capacity. Only the particle-size analyses are available for this report.

The results of analyses for particle-size distribution at these five sections are shown in Table 17. By definition sediments are classified according to ranges of particle size as follows: sand, 62 microns or larger; silt, 62 to 2 microns; clay 2 microns or smaller. These analyses indicate that the sediments

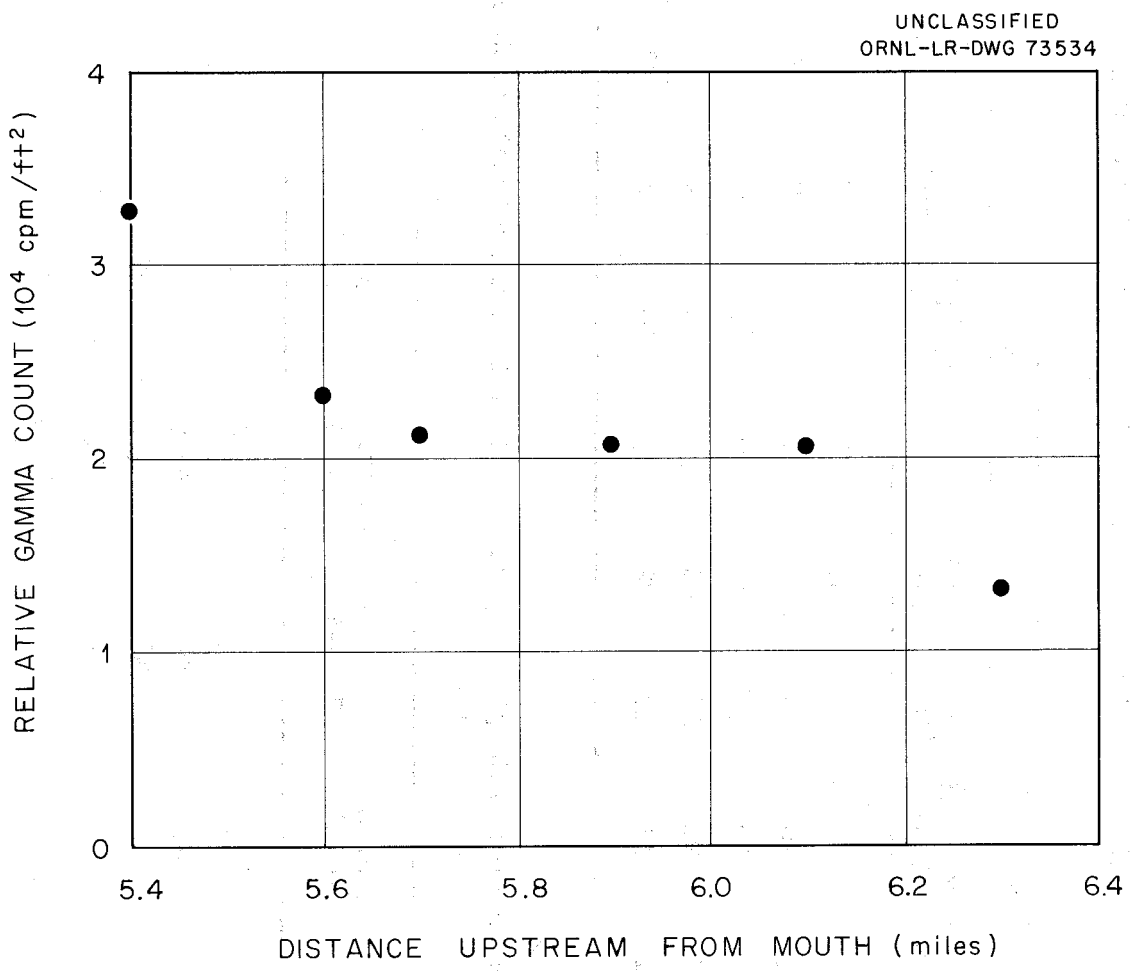

Fig. 7. Distribution of total gross gamma count relative to cross-sectional area of bottom sediments in bend of Clinch River.

Table 17. Results of Particle-Size Analysis of Clinch River Bottom Sediments

Location (CRM)	Specific Gravity	% Finer than Indicated Size									
		0.002 (mm)	0.004 (mm)	0.008 (mm)	0.016 (mm)	0.031 (mm)	0.062 (mm)	0.125 (mm)	0.250 (mm)	0.500 (mm)	1.000 (mm)
4.7	2.73	12	15	26	39	55	70	82	91	94	96
7.6	2.64	13	18	28	42	58	67	87	96	99	100
11.9	2.58	14	19	31	45	60	69	89	98	100	--
15.3	2.66	16	21	28	40	50	62	74	92	100	--
19.2	2.49	12	17	22	32	45	60	78	93	99	100

Table 18. Variation of Cesium Sorption by Clinch River Bottom Sediments with Distance

Location (CRM)	% Sorbed	Location (CRM)	% Sorbed
4.7	91	11.0	92
6.9	94	12.0	93
8.0	96	13.0	95
9.0	93	14.6	92
10.0	91	16.0	91

are a well-graded silty loam with fairly constant clay content throughout the reach (Fig. 8). The sand content decreased in the downstream direction. Figure 9 shows the variation of median particle size with distance. The minimum median particle size (at CRM 11.9) was 20 microns. The median size was greatest at the upstream end of the study reach, decreased downstream to the minimum at CRM 11.9, and increased downstream from CRM 11.9.

In laboratory studies of sediments collected from the river, the sorption capacity of the sediments was relatively constant throughout the study reach. For example, the percentages of cesium sorbed by bottom sediments from various sections, as found in these experiments, are listed in Table 18.

Future Work

The subcommittee discussed and outlined plans for collection and analysis of another series of core samples. According to these plans the depth of sediment will be determined by probing, and depth of sampler penetration and length of core retained will be carefully compared to the probed depths. It is planned that the sections to be sampled will include the TVA silt ranges and sections at which maximum and minimum activities have been determined previously. The number and spacing of cores to be collected at each section are to be based on the results of reliability studies which are being made by USPHS.

The wet and dry mass specific weights of the cores will be determined. Each full length core will be mixed thoroughly, and composites of these cores for each section will be prepared for

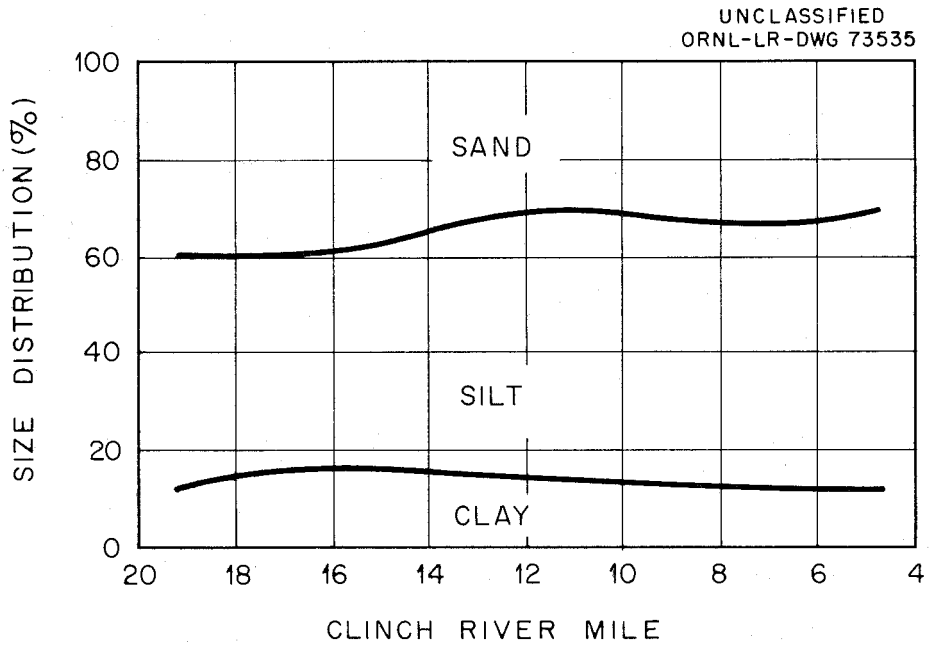

Fig. 8. Variation of particle size distribution in bottom sediments of Clinch River.

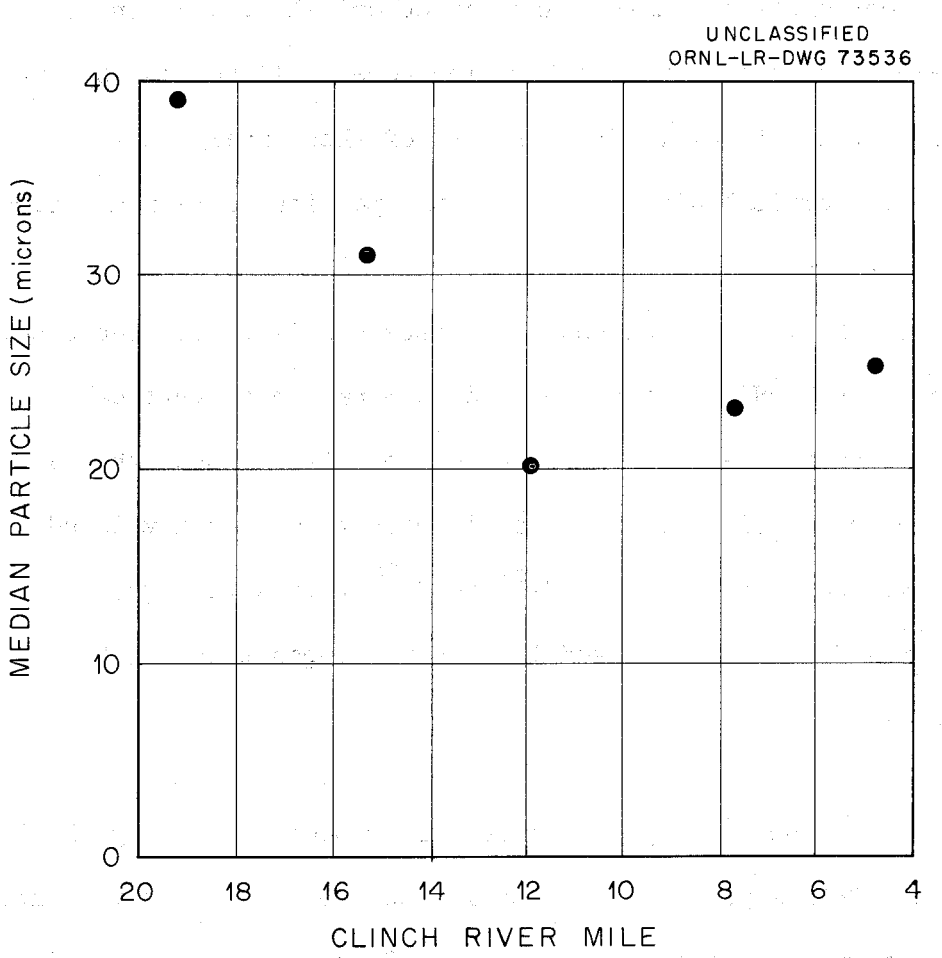

Fig. 9. Variation of median particle size in bottom sediments of Clinch River.

radiochemical analyses.

It is planned that three extra cores will be collected at the quarter points of each section. Gross gamma or beta counts will be made on ten equally-spaced 1-in. segments of each of these cores. Gamma spectrometric analyses and radiochemical separations of the 1-in. segments of the center-line cores will be made by USPHS and ORNL, respectively. The purposes of these analyses will be:

(1) Vertical distribution of the particular radionuclides will be examined.

(2) From a combination of surface sampling techniques being developed by USPHS and the simple determination of vertical distribution at one point in each section, it is hoped that a reliable method of estimating total activity may be developed.

(3) Comparison of the Sr^{89} to Sr^{90} ratios throughout the depth of sediment may be used to date the deposition of the sediments.

Applied Health Physics Annual River Sediment Survey, 1961

The ORNL Applied Health Physics Section conducted the annual survey of radioactivity in silt of the Clinch and Tennessee Rivers during the summer of 1961. At the request of the Clinch River study group, seven additional traverses in the Clinch and Emory Rivers were made during both the 1960 and 1961 surveys. In addition, four traverses were made in the Clinch River upstream from the Melton Hill Dam site; and the survey of the Tennessee River was extended downstream to TRM 24.6, approximately 2 miles upstream

from Kentucky Dam. The techniques and procedures used were those described in ORNL-2847.[16]

The tabulation of the gamma monitoring data from the 1961 survey was completed and made available for this report (Figs. 10, 11, 12). Assay of the 1960 and 1961 silt samples was completed since the last report, and the data for both 1960 and 1961 are included herein (Fig. 13).

Figures 10 and 11 show the gamma-count rate using the "flounder" instrument at the surface of the Clinch and Tennessee River silt versus river mile for the 2-year period, 1960 and 1961. In the Clinch River the 1961 gamma-count rate was down considerably from the 1960 levels at all points measured (Fig. 10). The same was true in the Tennessee River from the entry of Clinch River (TRM 567.7) to Guntersville Dam (TRM 349.0); the 1961 levels were well below the levels shown by the 1960 survey (Fig. 11). For the reaches of the Tennessee River downstream from Guntersville Dam no data from surveys in recent years prior to 1961 are available for comparison (see Fig. 11). The 1952 data in Figs. 10 and 11 are from earlier surveys by J. M. Garner *et al.*[17] The average gamma-count rate versus time for both the Clinch River and for the Tennessee River downstream to Guntersville Dam is shown in Fig. 12 for the period, 1951 to 1961.

An examination of the wastes discharged to the Clinch River prior to each of the surveys suggests a possible explanation for the over-all decrease in the gamma-count rate in 1961. Past experience has shown that the gamma count in the sediment follows the same trend as the total amount of wastes discharged during the 12-month period just prior to the survey. Although the total

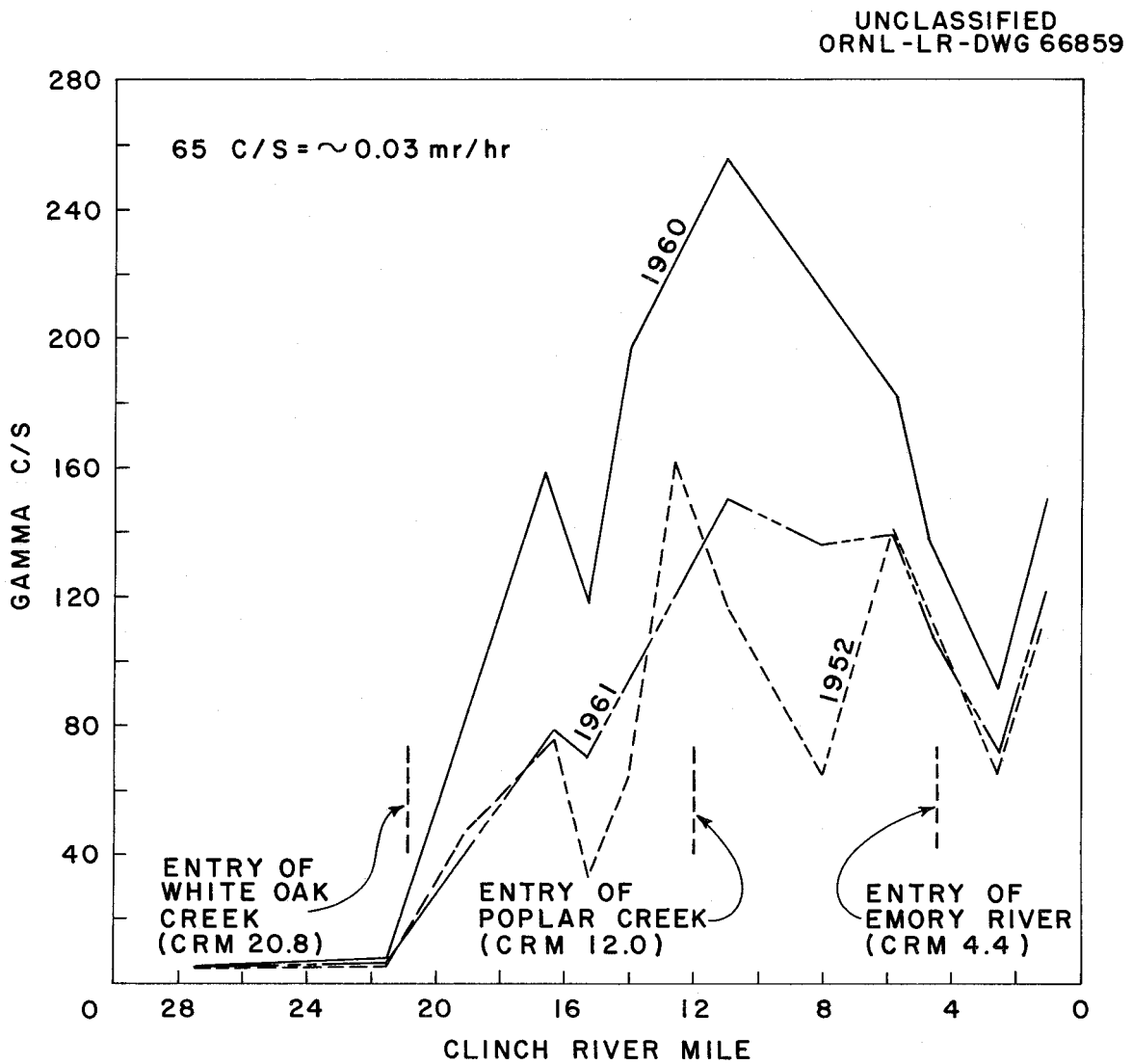

Fig. 10. Gamma count at surface of Clinch River silt.

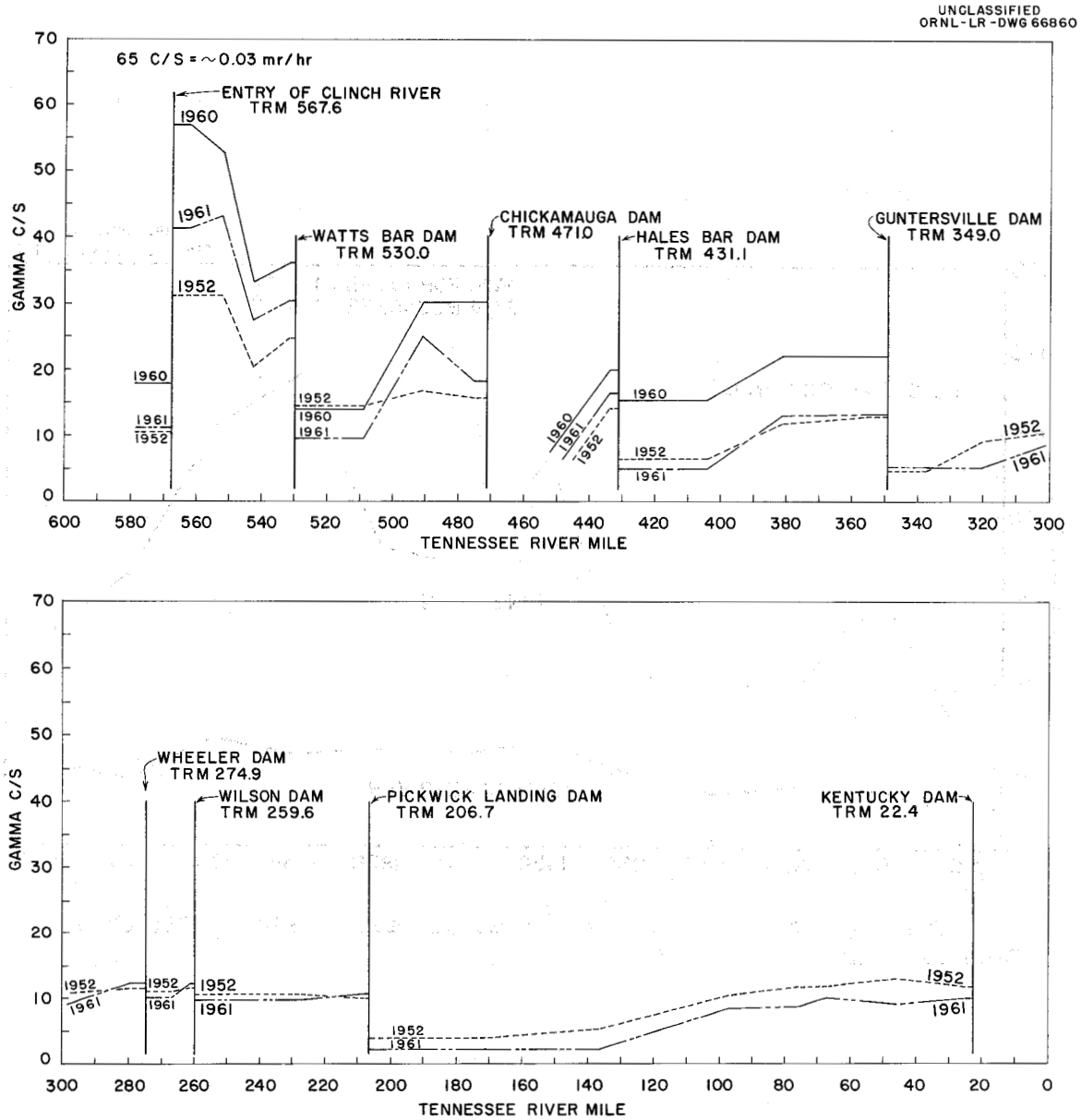

Fig. 11. Gamma count at surface of Tennessee River silt.

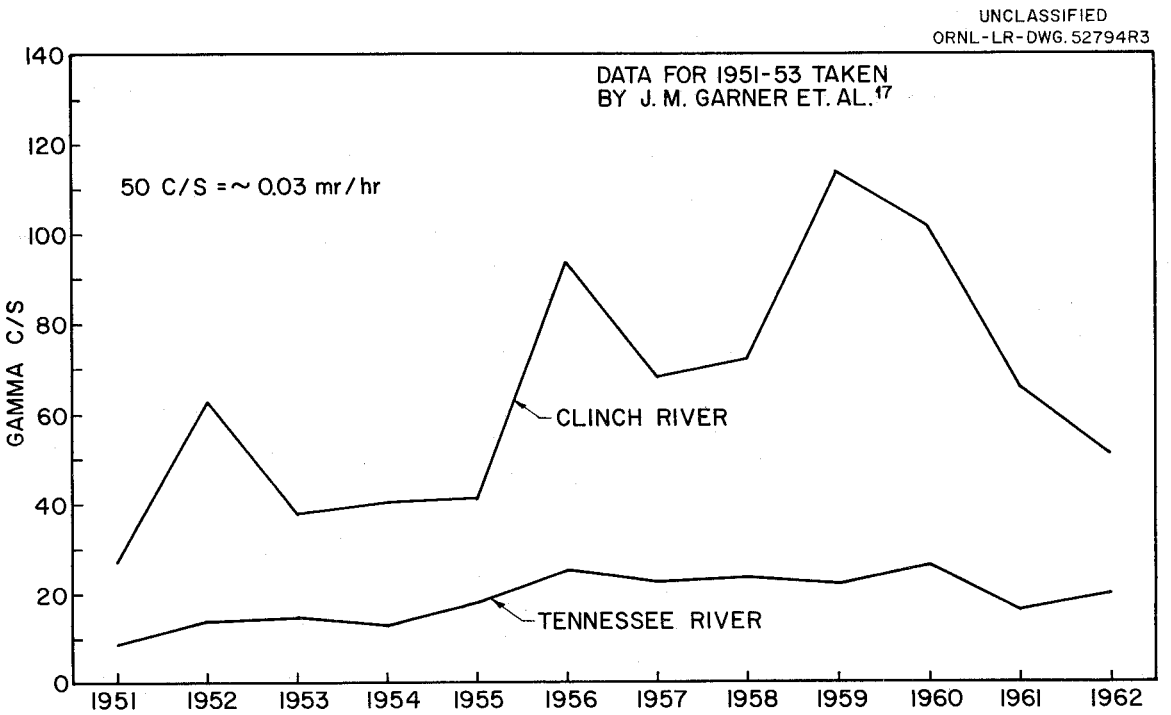

Fig. 12. Average gamma count at surface of silt — Clinch and Tennessee Rivers, 1951-61.

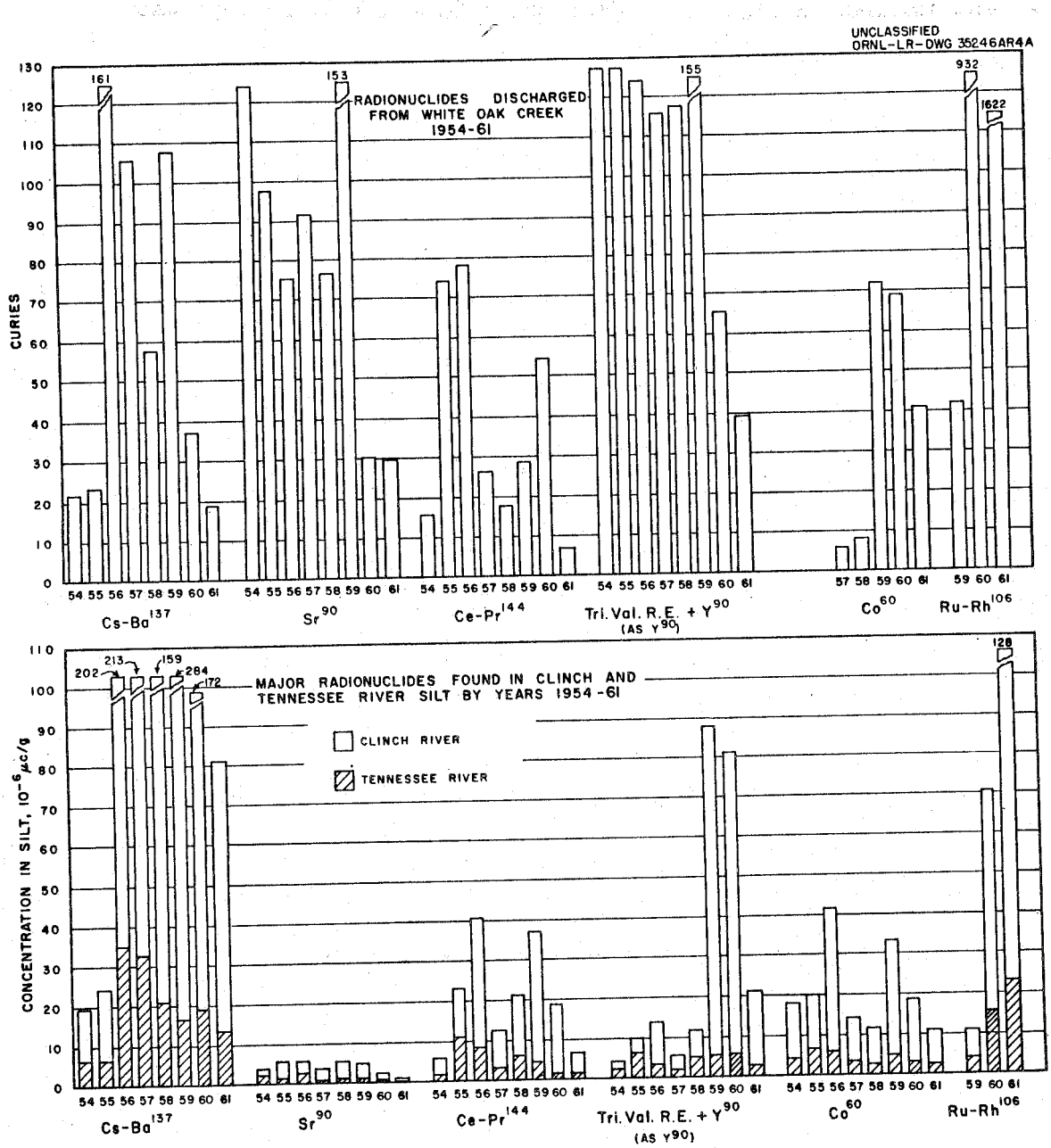

Fig. 13. Major radionuclides discharged and concentrations found in Clinch and Tennessee River silt, 1954-61.

number of curies of radioactivity discharged to the river during each of the 12-month periods preceding the 1960 and 1961 surveys was approximately the same, the isotopic composition of the wastes changed considerably. Beginning in the latter part of 1959, Ru^{106} comprised the major portion of all the wastes discharged to the river. The per cent of the total comprised by Ru^{106} increased from 47% during the latter half of 1959 to 82% during the first half of 1960 and from 71% for the latter half of 1960 to 90% for the first 6 months of 1961. Since Ru^{106} is a pure beta emitter and its daughter, Rh^{106}, emits gammas with only about 40% of its disintegrations, it would not be detected as efficiently by the flounder instrument, based on the number of curies present, as would some of the other radionuclides; for example, Cs^{137} whose decay results in emission of gamma rays with essentially 100% of its disintegrations.

The number of curies of wastes, other than ruthenium, discharged during the two periods decreased from 476 to 343. The ratio of these two values is 0.72. The ratios of the average gamma-count rate in the Clinch and Tennessee Rivers in 1960 and 1961 are 0.64 and 0.72, respectively. Considering the complex nature of the problem of discharge and detection of radioactive wastes in surface streams, the correlation of the gamma count detected in 1961 with the amount of wastes discharged appears to be good, and the values obtained during the 1961 survey seem reasonable.

Figure 13 shows a comparison of the curies of each of the principal radionuclides discharged to the Clinch River with the average microcuries per gram of these radionuclides found in the

Clinch and Tennessee River silt during the period of 1954 to 1961.

Sediment Samples Collected and Analyzed by USPHS

Sediment samples were included in the USPHS environmental surveys in May and September 1960 (see page 6). The results of analyses of these sediments are summarized here and are covered in detail in the USPHS reports.[7,8,9]

The sampling of sediments from the Clinch and Tennessee Rivers was designed to indicate radionuclide distribution in the beds of the streams in both transverse and longitudinal directions. Samples were collected at a number of cross sections in the Clinch River from Norris Dam (CRM 79.8) to the river mouth (CRM 0.0 and TRM 567.7) and in the Tennessee River from TRM 562.3, approximately 5 miles downstream from the mouth of Clinch River, to (TRM 496.6), near the mouth of Hiwassee River. The general procedure was to divide the transverse section of the river at each sampling station into a number of equal parts and to collect bottom-sediment samples at each division point across the river with an Eckman or Petersen dredge. Each dredge sample was thoroughly mixed, and about 500 g were packaged and returned to the laboratory for radionuclide analyses. As in the water samples, it was found that the predominant radionuclides were Sr^{90}, Cs^{137}, Ru^{106}, and Co^{60}; but the analyses also included Zr^{95}- Nb^{95}.

The location of the sampling stations and the average radionuclide concentrations in the bottom-sediment samples from each station for the May and September 1960 surveys are shown in Tables 19 and 20, respectively. The lower activity levels in the

Table 19. Average Radionuclide Concentration in Bottom Sediment Samples from the Clinch and Tennessee Rivers, May 1960

Station	Number of Samples Averaged	Activity, μμc/kg				
		Ru^{106}	Cs^{137}	Zr^{95}-Nb^{95}	Co^{60}	Sr^{90}
CRM 79.8	2	11,500	4,200	600	550	110
White Oak Creek below Dam	1	640,000	480,000	0[ab]	71,000	2,200
Mouth of White Oak Creek	1	1,420,000	7,150,000	0[b]	680,000	0[b]
CRM 20.0	8	42,000	70,000	400	8,200	600
CRM 19.0	1	68,000	150,000	5,400	12,000	1,800
CRM 18.0	1	260,000	390,000	4,700	37,000	920
CRM 17.0	1	160,000	120,000	9,300	24,000	2,300
CRM 16.0	1	130,000	120,000	150	15,000	1,500
CRM 15.0	1	220,000	360,000	0	34,000	4,000
Poplar Creek at CRM 12.0 500 ft upstream	5	73,000	41,000	4,600	5,400	810
CRM 11.0	12	200,000	220,000	11,000	22,000	2,800
CRM 5.4	8	160,000	110,000	6,600	17,000	1,500
Emory River (ERM 1.0)	2	44,000	16,000	1,600	2,500	550
Emory River (ERM 2.5)	1	3,400	940	300	270	200
CRM 4.1	8	240,000	140,000	7,300	17,000	1,400
TRM 562.2	9	20,000	29,000	1,400	4,000	460
TRM 537.8	10	21,000	9,700	890	2,100	210
TRM 517.9	10	12,000	1,800	340	770	170
TRM 496.6	10	24,000	11,000	750	2,000	230

[a]0 indicates value below limits of detectability.

[b]The three zero values are considered to be questionable in view of correlative data.

Table 20. Average Radionuclide Concentration in Bottom Sediment Samples from the Clinch and Tennessee Rivers, September 1960

Station	Number of Samples Averaged	Activity, μμc/kg				
		Ru^{106}	Cs^{137}	Zr^{95}-Nb^{95}	Co^{60}	Sr^{90}
CRM 79.8	1	3,800	1,300	480	600	0[a]
CRM 19.2	8	27,000	59,000	1,900	6,500	1,200
CRM 11.9	8	130,000	160,000	5,800	18,000	3,300
CRM 7.6	9	100,000	140,000	730	16,000	3,800
CRM 1.3	9	130,000	120,000	2,100	15,000	1,900
TRM 562.3	10	26,000	23,000	340	3,400	480
TRM 557.2	10	24,000	20,000	700	3,100	670
TRM 538.6	10	34,000	25,000	2,200	4,100	590
TRM 537.7	10	12,000	6,000	290	1,500	250
TRM 496.6	10	33,000	11,000	600	2,200	540

[a]0 indicates value below limits of detectability.

Clinch River sediments immediately downstream from the mouth of White Oak Creek as compared with those at lower stations presumably reflect higher velocities of flow in the river and incomplete mixing of White Oak Creek water with Clinch River water. Downstream from CRM 20.0 there was a consistent increase of activity in the bottom sediments, which reached a peak at about CRM 12.0. Thereafter, there was a decline in activity farther downstream.

Examination of the data from analyses of individual cross-sectional samples showed an unequal distribution of radionuclides in sediments across the river. Good correlation between radionuclide concentrations and depth of water was found at some cross-sections. For example, at CRM 4.1 correlation coefficients between activity and depth were 0.86 for Ru^{106}, 0.81 for Cs^{137}, 0.71 for Co^{60}, and 0.63 for Sr^{90}. Similar correlation coefficients were found at CRM 5.4. However, good correlations of activity levels and water depths were not found at certain other cross-sections. The USPHS workers who have studied these data and the results of similar surveys are convinced that irregularity of the bottom cross-section is a major factor, causing higher levels of activity to be accumulated in depressions of the river bottom. If confirmed when more adequate data are available, this conclusion may help to clarify the relationship between sediment activity and water depth.

In the Clinch River and the Tennessee River the ratio of Cs^{137} to Ru^{106} in bottom sediments gradually decreased with distance downstream. This is attributed to the fact, reported by Sorathesn _et al_ and cited in Status Report No. 1,[1] that sorption of cesium by

Clinch River mineral sediments in suspension is quite rapid and nearly irreversible. Cobalt-60 appears to be associated with the suspended organic matter, and higher concentrations of this radionuclide were found in mud samples that contained larger amounts of organic debris.

The effect of river hydraulics upon the localization of high levels of radioactivity can be seen in the contrast between the activity levels at TRM 538.6 and at TRM 537.7 as shown in Table 20. Between these points there is a great change in the river hydraulics. The river cross section at the downstream station (TRM 537.7) is reduced to about one-third the area of that at the upstream station (TRM 538.6) with a corresponding increase in the velocity of flow. The amount of silt deposition over a 10-year period, as measured by the Tennessee Valley Authority at TRM 537.7, was about one-third of that deposited at TRM 538.6; and the concentration of activity from all five radionuclides at TRM 537.7 was lower than at the upstream cross section.

BIOLOGICAL PHASES

Current investigations reported here include (1) results of fish-tagging studies to determine movements of fish, and (2) the data on oxygen concentrations in river water during a 24-hr period. Biological studies are continuing on strontium deposition in clams and the effects of radiation on Chironomus. These results will be included in a future report.

Fish-Tagging Studies

Fish-tagging was conducted on the Clinch River in the vicinity of White Oak Creek to determine the movement of fish caught in this portion of the Clinch-Tennessee River system. Fish were caught in hoop nets, marked with numbered tags, and released at the point of capture. Except for gizzard shad, all fish captured were tagged routinely. Tagging operations were conducted from July 6 through September 21, 1960, and from April 12 through July 13, 1961. Tagging was halted on the latter date because of poor fishing success in 1961. Construction activities, particularly blasting, associated with the Melton Hill Dam project may have been responsible for the poor fishing success during the summer of 1961.

There have been 226 (4.31%) recoveries from 5244 fish tagged (Table 21). Most of these recoveries were from white bass and white crappie. Particularly striking is the recovery of 142 (17.5%) tags from 812 marked white bass. Apparently, the white bass were originally captured as they made an upstream spawning run in the Clinch during April and May and then were recaptured by fishermen after they returned to Watts Bar reservoir. The distance between

Table 21. Species and Numbers of Fish Tagged and Numbers of Fish-Tag Returns

Species	Number Tagged	Tag Returns	% Returns
Longnose Gar, *Lepisosteus osseus*	3	-	-
Skipjack Herring, *Alosa chrysochloris*	30	2	6.67
Gizzard Shad, *Dorosoma cepedianum*	577	2	0.35
Mooneye, *Hiodon tergisus*	12	-	-
Carp, *Cyprinus carpio*	978	6	0.61
River Carpsucker, *Carpiodes carpio*	183	11	6.01
Quillback, *Carpiodes cyprinus*	11	-	-
Smallmouth Buffalo, *Ictiobus bubalus*	639	11	1.72
Bigmouth Buffalo, *Ictiobus cyprinellus*	1	-	-
Black Buffalo, *Ictiobus niger*	6	-	-
River Redhorse, *Moxostoma carinatum*	2	-	-
Black Redhorse, *Moxostoma duquesnei*	1	-	-
Golden Redhorse, *Moxostoma erythrurum*	94	3	3.19
Blue Catfish, *Ictalurus furcatus*	24	1	4.17
Yellow Bullhead, *Ictalurus natalis*	2	-	-
Channel Catfish, *Ictalurus punctatus*	151	13	8.61
Flathead Catfish, *Pylodictis olivaris*	10	-	-
White Bass, *Roccus chrysops*	812	142	17.49
Rock Bass, *Ambloplites rupestris*	6	-	-
Bluegill, *Lepomis macrochirus*	149	-	-
Longear Sunfish, *Lepomis megalotis*	2	-	-
Smallmouth Bass, *Micropterus dolomieui*	2	-	-
Spotted Bass, *Micropterus punctulatus*	2	1	50.00
Largemouth Bass, *Micropterus salmoides*	5	-	-
White Crappie, *Pomoxis annularis*	1027	26	2.53
Black Crappie, *Pomoxis nigromaculatus*	9	1	11.11
Walleye, *Stizostedion v. vitreum*	1	1	100.00
Sauger, *Stizostedion canadense*	42	6	14.29
Freshwater Drum, *Aplodinotus grunniens*	463	-	-
	5244	226	4.31

the points of tagging and recovery for white bass ranged from 14.2 to 60.1 river miles, and the average distance was 38 miles. The average time between tagging and recovery was 50 days. On the other hand, the white crappie appears to be more restricted in its movements. While individuals were recovered a distance of 0 to 60 miles from the point of tagging, the average distance of recovery was only 10 river miles, and the average time between tagging and recovery was 89 days.

The value of the fish-tagging studies will increase as more tags are recovered. It is already evident that fish which have been in the Clinch River in the vicinity of White Oak Creek move considerable distances in the Tennessee River system. While most tag recoveries indicate that the fish go downstream in the Tennessee River after leaving the Clinch, several fish have gone upstream. Two sauger have been caught 55 and 100 miles from the point of tagging and upstream on the Tennessee River. A skipjack herring followed the same pathway and was caught about 50 miles from the point of release.

The white crappie is being used to study the metabolism of strontium and cesium. The specific activity (radioactive atoms per total atoms of the element) of these fission-product elements is being determined in fish collected from the river. Concurrent laboratory investigations of the biological half lives of cesium and strontium in the flesh of white crappie will be used to relate uptake of these elements by the fish to low-level waste releases.

Diel Oxygen Determinations*

Diel changes in the dissolved oxygen concentration of flowing water are used as a quantitative measure of photosynthetic productivity

*The term "diel" refers to a 24-hr cycle with adjoining daytime and nighttime periods.

by aquatic plants. The dissolved oxygen concentration in Clinch River water was measured at hourly intervals at the time of a continuous steady release from Norris Dam. At CRM 20.8 a steady discharge of 7990 cfs, and a constant surface elevation of 740.6 ± 0.2 ft in Watts Bar Lake were maintained during the 24 hours of dissolved oxygen measurements and for a considerable time before and after the sampling period (see page 88). Hourly samples were obtained at CRM 20.8 and CRM 19.1 during the 24-hr period (2100 hr, August 29, to 2000 hr, August 30, 1961). Three replicate samples were taken from just below the surface at both locations. Similar samples were taken of the bottom water at CRM 19.1 about one-half of the time to determine whether there was a homogeneous distribution of oxygen through the water column. Downstream movement and dispersion of White Oak Creek water in Clinch River water was studied at the same time by following Au^{198} released in the mouth of White Oak Creek (see page 89).

In a typical, unpolluted stream the photosynthetic and respiratory activity of organisms in water produces a maximum oxygen concentration during mid-day and a minimum during the night. The diel sampling method assumes that the oxygen concentration pulsates in the same manner at all points on the river. The water is not always 100% saturated with oxygen; consequently, diffusion of oxygen into or out of the water will occur. When primary production is estimated, it is necessary to make corrections for diffusion based on approximations of the gas transfer coefficient, depending upon the conditions existing in the river.

The oxygen curve derived from the observations shows a mid-day

minimum (Fig. 14), which is exactly opposite from what was expected. Thus, estimates of primary production are not advisable. Oxygen concentrations in surface and bottom samples were similar, indicating vertical mixing of the water column. These results show that the concentration of dissolved oxygen in the river upstream from White Oak Creek was not uniform. Reasons for the particular shape of the oxygen curve may be explained by examining the river conditions at the time of the study.

Water released from Norris Reservoir is drawn from below the thermocline and during the late summer is deficient in oxygen. For several miles downstream from Norris Dam the Clinch River is relatively shallow, and the rocky bottom is covered with a thick growth of algae, moss, and higher aquatic plants. Water flowing through this reach of the river in daylight hours obtains oxygen through photosynthesis and diffusion from the atmosphere. During the nighttime, diffusion into the water occurs, but, also, respiration of the bottom vegetation uses oxygen. Consequently, water leaving the reach of the river immediately downstream from Norris Dam during the day has more oxygen in it than the water flowing at night.

The unusual oxygen curve in the vicinity of White Oak Creek is believed to be a consequence of these conditions. The range of differences between maximum and minimum dissolved oxygen was relatively small (82% to 77% saturation), and the conditions of discharge and water elevations were steady during the sampling period. Norris Dam is located on Clinch River at CRM 79.8, about 60 miles upstream from the sampling sites. If it is assumed that the nighttime flow of water

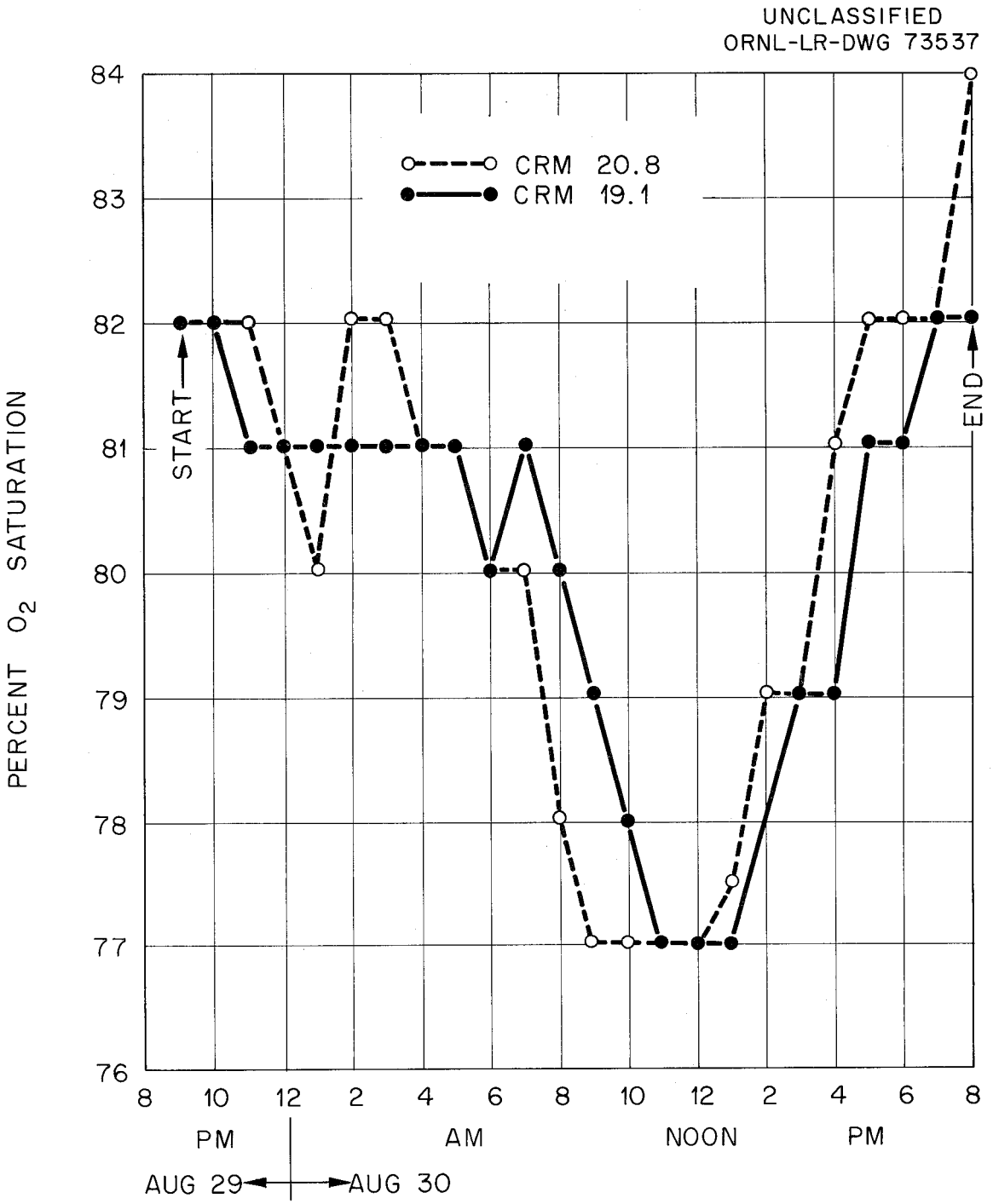

Fig. 14. Diel changes in oxygen saturation of Clinch River water, August 29-30, 1961.

from Norris Dam resulted in the mid-day minimum oxygen concentration at White Oak Creek, the flow time for this 60-mile reach of river would have been approximately 12 hr plus 24 hourly increments. A 36-hr flow time suggests an average current velocity of 1 2/3 mph, and a 60-hr flow time means a current velocity of about 1 mph. The separate oxygen curves obtained at CRM 20.8 and 19.1 indicate current velocities of between 1 and 2 mph. By personal communication with the Hydraulic Data Division of TVA it was learned that the steady discharge conditions began at 7:00 a.m. on August 27; and that a reasonable estimate of the time of travel of the power wave was 17 to 18 hours, and of the water mass about twice that or 34 to 36 hours. Therefore, the 36-hr flow time from Norris Dam to White Oak Creek was accepted as the better estimate.

The fact that Clinch River water masses are apparently "tagged" by oxygen may prove useful in future controlled studies. With more frequent and simultaneous sampling at a number of locations, it should be possible to determine flow rates, as well as longitudinal mixing of water masses.

Separation of Plankton and Clay from River Water

In order to obtain quantitative and qualitative information about the distribution of radionuclides or other contaminants within the various fractions of river water, the fractions must be removed from the water, isolated from each other, and then analyzed. A survey of previous work indicated that no satisfactory method was available for fractionating a water sample so as to represent the quantitative

uptake of radionuclides by organic materials and the distribution of radionuclides in the several fractions.

During the summer of 1961 a study was initiated to separate and isolate the major groups of organic and inorganic matter found suspended in the Clinch River and to investigate their behavior with respect to radionuclides being released by the Oak Ridge National Laboratory (ORNL) from White Oak Creek. This work was done by a biologist, W. T. Lammers, a summer employee of the Tennessee Valley Authority (TVA), assigned to the Clinch River Study. During the study a method was developed by which lake or river water can be fractionated into particulate organic matter, particulate inorganic matter, colloids, and solutes. These insolated fractions may then be analyzed for radionuclide accumulation, both qualitatively and quantitatively. A report, describing the details of the study and of the method of separation which was developed, has been prepared and authorized for publication in the open literature.[18]

Water samples, proportional to stream flow, were taken on an 8-day sampling schedule from three sites on the Clinch River and from White Oak Creek at White Oak Dam. Samples were taken from the Clinch River at CRM 21.6, CRM 9.3, CRM 5.6, and in the spillway of White Oak Dam. The water samples were iced and shielded from the sun as soon as collected and kept cold from collection time until the preparation of the separated fractions was completed. In the laboratory the water sample was initially separated into two fractions in a high-speed constant-flow centrifuge. The fractions were the supernatant water with the solutes and colloidal particles (smaller

than 0.5 μ) and the fraction containing the noncolloidal particulates - organic and inorganic matter.

The noncolloidal fraction was homogenized in a tissue homogenizer and put into a sucrose density gradient made in a 250-ml centrifuge tube in which the density gradient ranged from a top of about 50% down to a bottom layer of about 80% sucrose. Separation of the organic and inorganic matter was effected by aspirating off the top fraction from the density gradient after centrifugation and by repeated dilution with distilled water and recentrifugation at a suitable gravity force until the volume of the samples had been reduced to 10 ml. The samples were then subjected to a gamma-spectrum scan for Co^{60}, Cs^{137}, and Ru^{106} activity in a spectrometer, and later a strontium extraction was made and analyzed radiochemically for Sr^{90} activity. Microscopic particle counts were made in a counting chamber with medium dark-field phase microscopy.

The particulate material was examined and the number of particles per counting square determined before the material was put into the density gradient and after removal from it. The results of microscopy and the corresponding charts of data indicated that micro-organisms - diatoms, protozoa, bacteria, and algae - remained intact and apparently viable, and that a distinct density zone of separation (74% sucrose) could be chosen. The plotted data indicated that 99.7% of the organic particles remained in the density zone of less than 74% sucrose, while 98.4% of the inorganic particles were in the zone of more than 74%. Microscopic examination of the supernatant water indicated that 100% of all particles larger than 0.5 μ were removed from the water by the methods used, thus leaving the colloids in the

supernatant water from the initial centrifugation, along with the solutes, and available for separate analysis. Microscopic examination of the supernatant water from subsequent centrifugations indicated that no noncolloidal particles were lost in these steps.

It was concluded that the methods and materials used disrupted few, if any, of the organisms and should not have disturbed their surface charges. Therefore, there should be little danger that subsequent radionuclide assay of the various fractions would be misleading because of cell rupture or loss of surface-sorbed materials. These are questions that require further investigation. The report includes a technical discussion of the choice of a density gradient, which was the major technical problem of the investigation, and summarizes characteristics of an ideal density gradient material for use with river water samples.

Radionuclides in Fish Collected and Analyzed by USPHS

Environmental surveys by USPHS in May and September 1960 included collection and analysis of a variety of fish from the Clinch and Tennessee Rivers.[8,9] The study reaches extended from Norris Dam (CRM 79.8) downstream to the mouth of Clinch River at TRM 567.7, and from this point to Chickamauga Dam on the Tennessee River at TRM 471.0. In portions of these reaches the rivers are used extensively by both sport and commercial fishermen, and, therefore, considerable effort was expended in sampling and analyzing fish.

For purposes of study and interpretation of the analytical data, the various species of fish collected were classified into three categories: (1) bottom-feeding fish - carp, suckers, buffalo, redhorse,

carpsuckers, quillback, channel catfish, and flathead catfish; (2) sight-feeding fish - walleye, sauger, crappie, sunfish, skipjack herring, blue catfish, bullhead, white bass, smallmouth bass, fresh water drum, and longnose gar; and (3) plankton-feeding fish - of which gizzard shad and juvenile fish of other species are typical. Specimens of all the types of fish mentioned above were obtained and analyzed in one or both of the surveys in May and September 1960.

Radionuclide concentrations in bottom-feeding fish collected in May and September 1960 are summarized in Table 22. The highest concentrations of Ru^{106}, Cs^{137}, and Sr^{90} were found in the flesh and bone of fish taken at CRM 19.6, about 1.2 miles below the mouth of White Oak Creek. The maximum concentration of Co^{60} in flesh, however, occurred in the samples collected at CRM 14.6 about 6.2 miles downstream from White Oak Creek; and, although no single maximum value was found for Co^{60} in the bone, it also centered around CRM 14.6. In whole fish the maximum concentrations for Ru^{106}, Cs^{137}, and Co^{60} were found at CRM 14.6.

Since these types of fish are bottom feeders, they ingest some bottom-deposited silts along with organic matter. Analyses of bottom sediments have shown that the concentration of radionuclides in Clinch River sediments at CRM 14.6 is about a factor of 4 higher than at CRM 19.6. It is probable that the activity associated with the silt in the digestive tract of the whole-fish sample caused the shift of the maximum values to CRM 14.6. In the analyses of flesh and bone samples, no contents of the digestive tract were included, as was the case in analyses of whole fish.

Table 22. Average Radionuclide Concentrations in the Flesh, Bone, and Whole Organism of Bottom-Feeding Fish from Clinch and Tennessee Rivers, 1960
(Activity, μμc/kg, live weight)

River Mile	Number of Fish Collected		Ru^{106}		Cs^{137}		Co^{60}		Sr^{90}	
	May	Sept.	May	Sept.	May	Sept.	May	Sept.	May	Sept.
					Flesh					
CRM 79.8	5	---[a]	20	---	40	---	0[b]	---	125	---
CRM 19.6	6	4	200	5	2,100	570	165	80	350	1,400
CRM 14.6	8	9	150	60	1,100	860	225	110	90	2,000
CRM 4.5	7	3	125	65	425	490	80	95	40	1,500
TRM 562.7	7	---	30	---	75	---	80	---	150	---
TRM 517.9	2	---	15	---	65	---	275	---	140	---
TRM 417.0	---	2	---	35	---	30	---	40	---	175
					Bone					
CRM 79.8	5	---	275	---	5	---	25	---	150	---
CRM 19.6	6	4	1,900	65	1,200	240	150	260	52,000	3,900
CRM 14.6	8	9	525	160	350	300	150	260	29,000	4,200
CRM 4.5	7	3	0	160	250	300	150	75	35,000	12,000
TRM 562.7	7	---	0	---	15	---	35	---	3,000	---
TRM 517.9	2	---	0	---	0	---	225	---	5,100	---
TRM 417.0	---	2	---	175	---	35	---	35	---	875
					Whole Fish					
CRM 79.8	5	---	125	---	425	---	40	---		
CRM 19.6	6	4	725	160	1,400	660	250	170		
CRM 14.6	8	9	1,675	890	2,550	1,500	375	270	Not analyzed for Sr^{90}	
CRM 4.5	7	3	725	500	1,000	750	200	140		
TRM 562.7	7	---	300	---	450	---	80	---		
TRM 517.9	2	---	200	---	400	---	100	---		
TRM 471.0	---	2	---	140	---	45	---	45		

[a]--- indicates data not available.
[b]0 indicates values below limits of detectability.

The differences in concentrations and some apparent anomalies of the data in Table 22 are of interest and raise a number of questions which cannot be answered definitely from present information. For example, in the May 1960 survey, maximum concentrations of Ru^{106} and Cs^{137} occurred in flesh and bone at CRM 19.6, although concentrations in the sediment were higher at CRM 14.6. It may be that the Ru^{106} and Cs^{137}, associated with the clayey fraction of the silt, are not available to the fish, even when ingested, nor to the benthic organisms upon which they feed, to the same extent that radionuclides associated with organic matter are available. Likewise, maximum concentrations of Co^{60} in the flesh and bone were found in fish collected at CRM 14.6. It may be that Co^{60}, associated with the organic fraction of the bottom sediments, is more readily available in the food of bottom-feeding fish; and, therefore, the higher concentrations of Co^{60} in the bottom sediments at CRM 14.6 were reflected in the greater accumulation of Co^{60} in the fish.

There are seasonal differences between the results from the sampling locations in the Clinch River; but, due to the contrasts in samples and possible seasonal movement of fish, it is difficult to say what is responsible for the differences. For example, concentrations of Sr^{90} in the flesh of bottom-feeding fish were considerably higher in the September survey than in the May survey, while the bone concentrations of Sr^{90} were very much higher in the survey in May than in September.

In the category of sight-feeding fish numerous samples and types of fish were collected and analyzed in both the May and

September 1960 surveys. From analyses of the tabulated data, however, no correlation appears to exist between activity levels found in sight-feeding fish and the locations from which they were taken. In general, the average concentrations of activity were about an order of magnitude lower than the concentrations in the bottom-feeding fish taken from the same areas.

In the plankton-feeding category one or two or, at most, a very few fish were collected at the several sampling stations. Because of the small number of gizzard shad and juvenile fish sampled, no conclusive mathematical analysis or correlation was possible. However, based on the few samples taken, the gizzard shad concentrates radionuclides to a greater degree than any other fish. The data from analyses of sight-feeding and plankton-feeding fish collected during the two surveys in 1960 are voluminous and not amenable to definitive interpretation and, therefore the results are not tabulated in this report. The quantitative data will be made available in the more detailed reports by USPHS.

HYDROLOGIC MEASUREMENTS AND ANALYSES

Activities during this period relative to surface-water hydrology have included establishment and operation of gaging stations and provision of stream-flow data as part of the cooperative program of USGS. Also several studies were made jointly by ORNL and USGS personnel in efforts to define specific factors which are important in the Clinch River study. Programmatic cooperation by USGS and two special studies are summarized below.

Cooperation by the U. S. Geological Survey

With the organization of the Clinch River Study Steering Committee in 1960, a program was formulated to provide the stream-flow data necessary to serve the needs of the Clinch River study. The system of gaging stations, provided before and during 1960, was summarized in Status Report No. 2.[19] This system included five regular gaging stations on the Clinch River and in the White Oak Creek drainage area, three regular gaging stations in the Poplar Creek basin, and a station for recording stage only on the Clinch River at CRM 19.1. Also included were staff gages installed at fourteen sites on the Clinch River and Emory River as reference marks for sampling, temperature, and velocity studies.

A network of 24 partial-record, low-flow and crest-stage stations was established on principal and selected streams within and adjacent to the ORNL area during July and August 1961. Data collected at these stations, supplementing those gathered at the regular gaging-station network, are necessary to ultimately appraise the over-all water movement within and adjacent to the Oak Ridge reservation.

Cooperative activities by personnel of the Knoxville office of the Surface Water Branch, USGS during the period May 4, 1961 through October 1961 are summarized below.

Provisional mean daily gage heights and discharges have been furnished on a monthly basis to ORNL. These data were from the five stations in the Clinch River basin: namely, Clinch River near Scarboro, White Oak Creek below ORNL, White Oak Creek at White Oak Dam, Melton Branch, and the ORNL Settling Basin effluent. Also operation of the station for recording stage only on the Clinch River at CRM 19.1 has been continued.

Operation of the gaging stations of Bear Creek, East Fork of Poplar Creek, and Poplar Creek near Oak Ridge has been continued. These stations are well-rated throughout the range in stage that has been observed since they were established. Also momentary discharge figures for these stations have been furnished to personnel in the Y-12 area as requested.

Assistance has been provided by USGS in the river-sampling program of ORNL personnel, including determination of velocities and temperature profiles at Clinch River Miles (CRM) 5.5, 9.3, 12.0, 14.0, 19.1, and 21.6. Measurements were made at selected sites on streams in the ORNL area to assist the program of studies of the White Oak Creek drainage basin.[20,21] Assistance was provided in an around-the-clock observation of discharge and temperature at CRM 5.4 on August 17 to 18, 1961. The purpose was to aid a special study of the effect of power releases on river flow and radioactivity levels. Assistance was also provided in connection with the radio-tracer study on August 30 to 31, 1961, in which Au^{198} was injected at

the mouth of White Oak Creek and traced down the Clinch River (see below).

A round of low-flow discharge measurements was made, and water samples for chemical and spectrographic analysis were collected at the 24 newly established partial-record stations in the Oak Ridge area.

The Subcommittee on Water Sampling and Analysis was assisted by the provision of weekly discharge data during the period, March 26 to August 5, 1961, for White Oak Creek at White Oak Dam, Clinch River at Scarboro, and Clinch River at Centers Ferry. The results of velocity and temperature profiles made at many points on the Clinch River during the past several years were furnished to USPHS.

In addition to continued operation of the regular gaging-station network and hydrologic assistance on the Clinch River Study, it is expected that USGS will extend its operation of the 24 partial-record stations, established during July and August 1961, in the area. This will include making high- and low-water measurements and collecting water samples for chemical and sediment analyses in quality-of-water investigations. The results from these partial-record stations will be correlated with records from nearby regular gaging stations to provide data on high- and low-flow frequencies in the area.

Radiotracer Study, August 30-31, 1961

The effectiveness of the Clinch River in diluting and dispersing radioactive materials which might enter the river from the Oak Ridge National Laboratory is of great importance, and several reports are available which treat phases of this question.[17,22,23,24] In general, work previous to the current study has considered continuous releases

of radioactivity over a relatively long period of time - an hour or more - and has been designed to determine the effect of such releases in the Clinch River.

The current study was made by USGS at the request of the chairman of the Clinch River Study Steering Committee with concurrence of the several agencies comprising the committee. The purpose was to investigate the effectiveness of the Clinch River in diluting and dispersing a "slug" of radioactive materials discharged to the river from White Oak Creek. Such a discharge might conceivably result from an accidental spill at ORNL or a flood wave down White Oak Creek.

Conditions and Methods of Study

A steady discharge of 7990 cfs in Clinch River and a constant elevation of 740.6 ± 0.2 ft in Watts Bar Lake were maintained throughout the study period. In fact, this Clinch River discharge was steady for a considerable period before and after the study, and the variation in the elevation of Watts Bar Lake was quite small for the same period as shown in Fig. 15.

At 12:53 p.m. on August 30, 1961, a tracer solution, containing 7.5 curies of Au^{198}, was injected into White Oak Creek about 50 ft upstream from its mouth (CRM 20.8). The tracer solution was in the form of gold chloride dissolved in a solution of hydrochloric and nitric acids. The injection was made into White Oak Creek from a boat by releasing the tracer through a tube just below the water surface as the boat was moved across the stream. The injection period was 67 sec, and the discharge of White Oak Creek at the time of the injection was 6.7 cfs.

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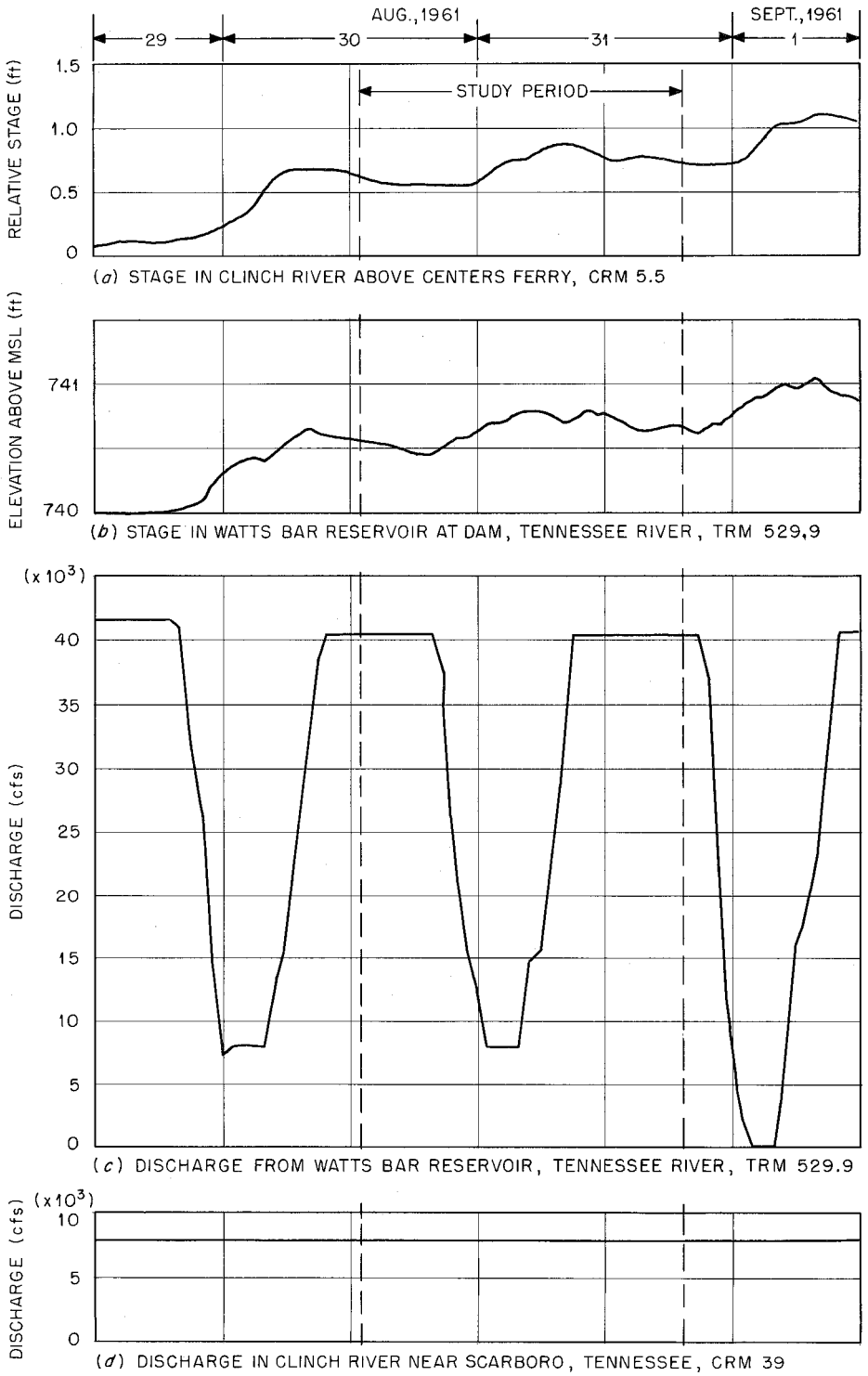

Fig. 15. Discharge and stage hydrographs, August 29 to September 1, 1961.

Observations of radioactivity in the river water were made from boats with scintillation detectors at a number of sections downstream from CRM 20.8. A map of this reach of the Clinch River, including the locations of the observation sections, is shown in Fig. 16.

Specific Objectives

The primary objectives of the study were:

1. To determine the areal extent of lateral dispersion of the radiotracer (as opposed to specific evaluation of the concentration of radioactivity at many points).

2. To find the point of relatively uniform stream-wide distribution of the tracer activity.

3. To determine the rate of reduction of the maximum concentration of activity as the tracer moved downstream.

4. To investigate time of travel of the main body of activity to various points along the stream, particularly to the intake of the ORGDP Water Plant, just downstream from Gallaher bridge (CRM 14.5) and at Centers Ferry (CRM 4.5) just above the mouth of Emory River.

Observations and Results

In the reach between CRM 20.8 and CRM 14.5 only the observations necessary to furnish the above data were made. It is regrettable that variation of the concentration of activity with depth was not investigated. It was believed, however, that, if an attempt were made to collect data covering so many different facets of the dispersion pattern, the observations necessary to fulfill the primary requirements might be missed. With the limited number of observing parties available at the time of the study and the rapid

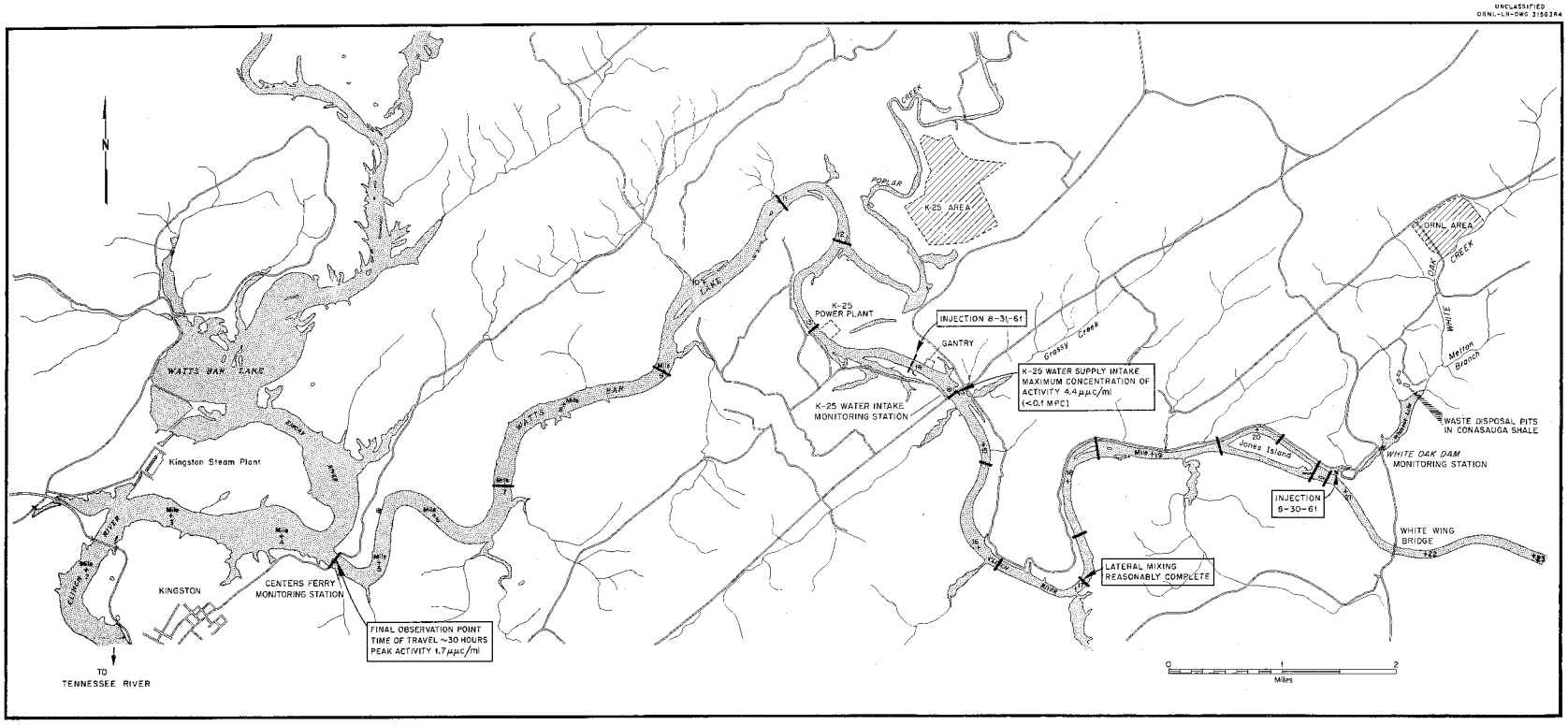

Fig. 16. Map of Clinch River showing location of observation sections, tracer study of August 30-31, 1961.

passage of the tracer cloud in the most upstream reaches (above CRM 19.6), this was a very real possibility. Consequently, in the reach of river above Gallaher bridge (CRM 14.5) detectors were located 5 ft below the surface, since this was the approximate location of maximum concentration of activity observed during the tracer study of July 1958.[22]

Below CRM 14.5 variation of the concentration of activity with depth was observed, but lateral variation was not observed, since observations at several points downstream from CRM 17.5 indicated that cross-stream distribution was reasonably uniform.

Maximum concentrations of activity, travel time, and velocity are listed in Table 23. To obtain a reliable value of maximum concentration at the points being studied, it was necessary to observe the passage of the tracer cloud by the point. Consequently, concentration-time curves for those points could be drawn. Several of these curves are included with this report (Figs. 17-23).

Classically, concentration-distance curves are desirable, for such curves do not include a velocity component and consequently are symmetrical and easier to analyze. However, it would have been necessary that the maximum downstream spacing between cross-sections be about 500 feet to collect enough data to prepare realistic concentration-distance curves, and, with the limited number of detecting units available, it was felt that more valuable information for this study would be obtained by increasing the distance between sections, investigating cross-stream distribution at those sections, and plotting concentration-time curves. It should be noted that,

Table 23. Radioactivity Levels, Travel Times, and Velocities of Downstream Movement of Peak-Tracer Study in Clinch River, August 30-31, 1961

Location of Section (CRM)	Distance from Right Bank (ft)	Depth Below Water Surface (ft)	Maximum Activity* (μμc/ml)	Travel Time from Injection Point (hr)	Average Velocity of Peak to Section (ft/sec)	Remarks (See page 95)
20.8	30	5	2000	~ 0.1	~ 0.4	a, b
20.6	20	5	400			c
	80	5	44	0.3	1.0	
20.2	20	5	100	1.0	0.9	d
	40	5	110			
	60	5	~10			
19.6	50	5	36	1.6	1.1	
	150	5	15			
	200	5	6.1			
18.5	150	5	16	2.5	1.3	
	250	5	12			
17.5	100	5	9.9	3.7	1.3	
	200	5	6.1			
17.1	125	5	6.6	4.2	1.3	
	250	5	6.4			
16.2	150	5	7.0	5.3	1.3	e
	300	5	6.0			
15.2	100	5	5.2	6.8	1.2	
	250	5	5.0			
14.4	125	5	4.4	7.9	1.2	f
	250	5	3.9			
13.0	Main		4.3**	10.0	1.1	g
	Stream	5	(4.3)***			
		10	(3.9)			
		15	(2.6)			
		20	(2.6)			
12.0	do.		3.9**	11.3	1.1	
		5	(3.5)***			
		10	(3.5)			
		15	(3.9)			
		20	(3.9)			
		25	(3.9)			
11.0	do.		3.5**	12.9	1.1	
		5	(3.2)***			
		10	(3.5)			
		15	(3.5)			
		20	(3.5)			
9.0	do.		2.9**	17.1	1.0	h
		5	(2.9)***			
		10	(2.9)			
		15	(2.9)			
		20	(2.9)			
7.0	do.	20	2.6	23.4	0.9	
4.4	do.	5	1.4	30.2	0.8	i
		10	1.7			
		15	1.2			
		20	1.0			

* Corrected for radioactive decay.
** Estimated on basis of August 30 injection at White Oak Creek.
***Values in parentheses based on August 31 injection at CRM 14 (See remark g).

Table 23. (contd)

Remarks (Column 7)

a. Tracer solution (7.5 c Au^{198}) injected in line across White Oak Creek about 50 feet upstream from mouth at 12:53 p.m. August 30, 1961. Average concentration of activity in White Oak Creek was 5.9×10^{-1} μc/ml, based on White Oak Creek discharge of 6.7 cfs.

b. Concentration of activity in Clinch River 60 feet from right bank was 1/4 of that at 30 feet, and at 80 feet it was 1/15 of that at 30 feet. Left edge of tracer cloud 100-120 feet from right bank.

c. Ratemeter for detector 20 feet from right bank went off scale during passage of peak. Concentration of activity 200 feet from right bank about 1/10 of that at 20 feet.

d. Traces of activity observed all across channel to right of Jones Island. No activity detected in left channel.

e. Cross-stream and depth dispersion assumed complete at this point. Area under dispersion curve shows activity of about 6 curies, or 80% of total injected.

f. ORGDP water plant intake (near Gallaher Bridge). Maximum concentration of activity 8-9% of MPC for release to unrestricted areas.

g. Injected 3.8 curies of Au^{198} in line across Clinch River at CRM 14 at 10:20 a.m. August 31, 1961. Travel time to downstream sections based on observations of this injection. Maximum activity figures estimated on basis of August 30 injection at White Oak Creek; activity figures at various depths based on estimated maximum activity and observations of August 31 injection.

h. Injected 3.1 curies of Au^{198} in line across Clinch River at CRM 9 at 11:22 a.m. August 31, 1961. Detector in use at CRM 8 and CRM 6 was apparently not functioning properly. Injection of August 30 was observed at CRM 7 and CRM 4.4. Therefore, data from the <u>injection at</u> CRM 9, even though it was observed at CRM 7 and CRM 4.4 was <u>not used</u>.

i. Centers Ferry, terminal point of study.

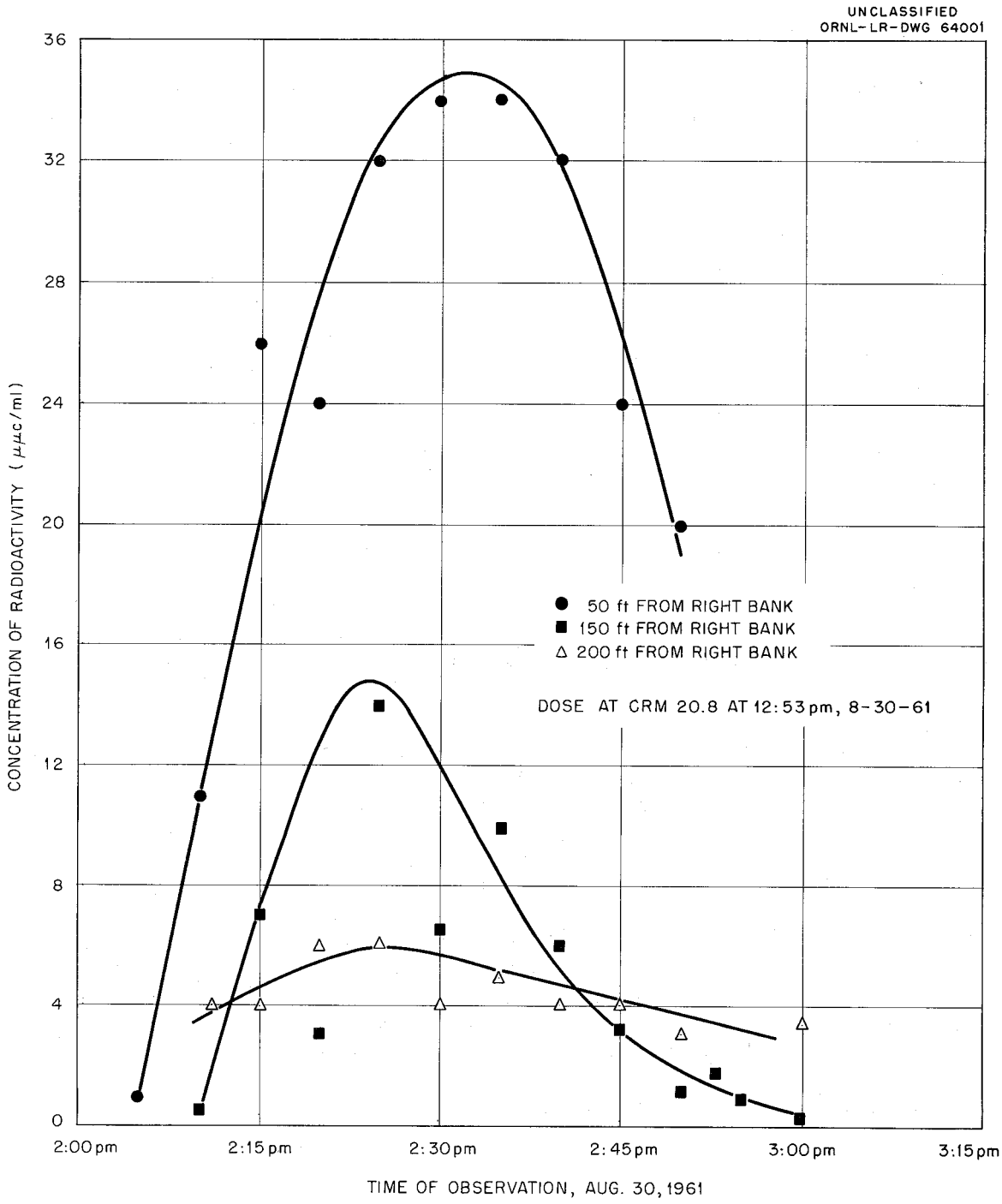

Fig. 17. Variation of radioactivity of gold-198 with time, tracer study of August 30-31, 1961, at Clinch River Mile 19.6.

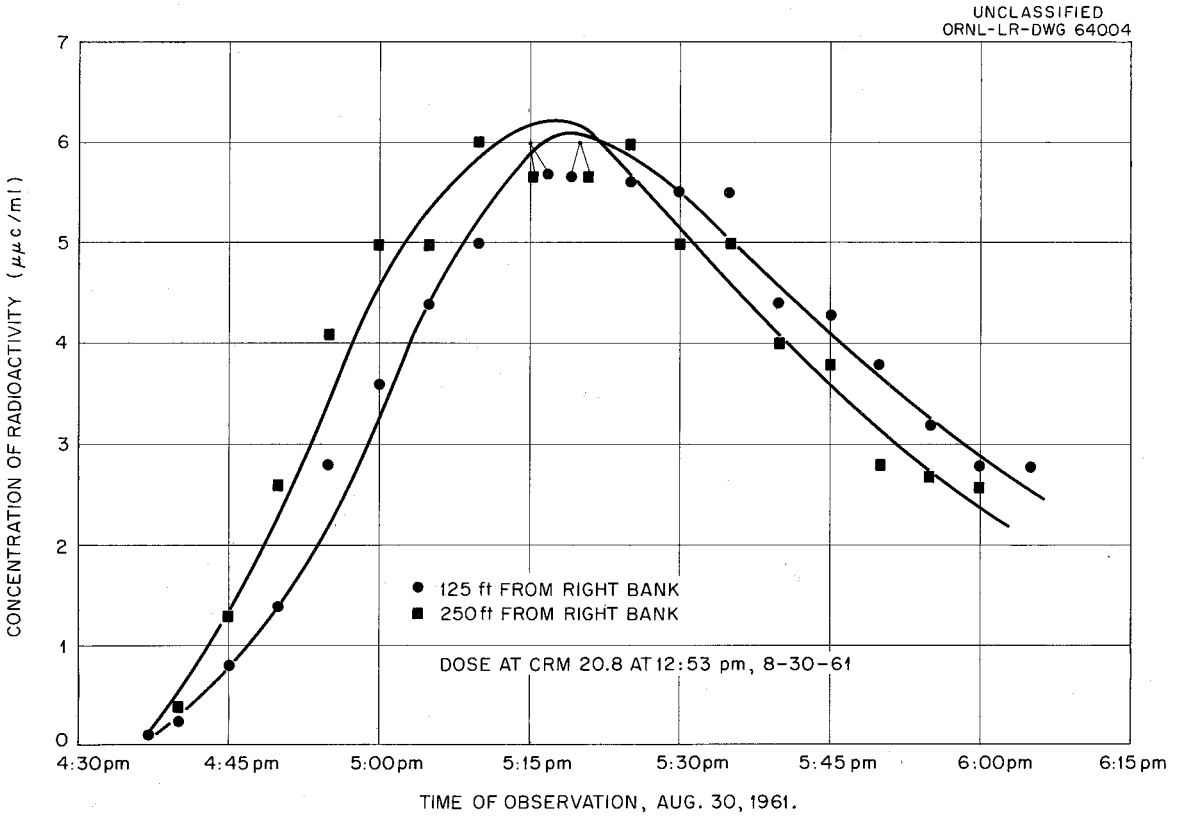

Fig. 18. Variation of radioactivity of gold-198 with time, tracer study of August 30-31, 1961, at Clinch River Mile 17.1.

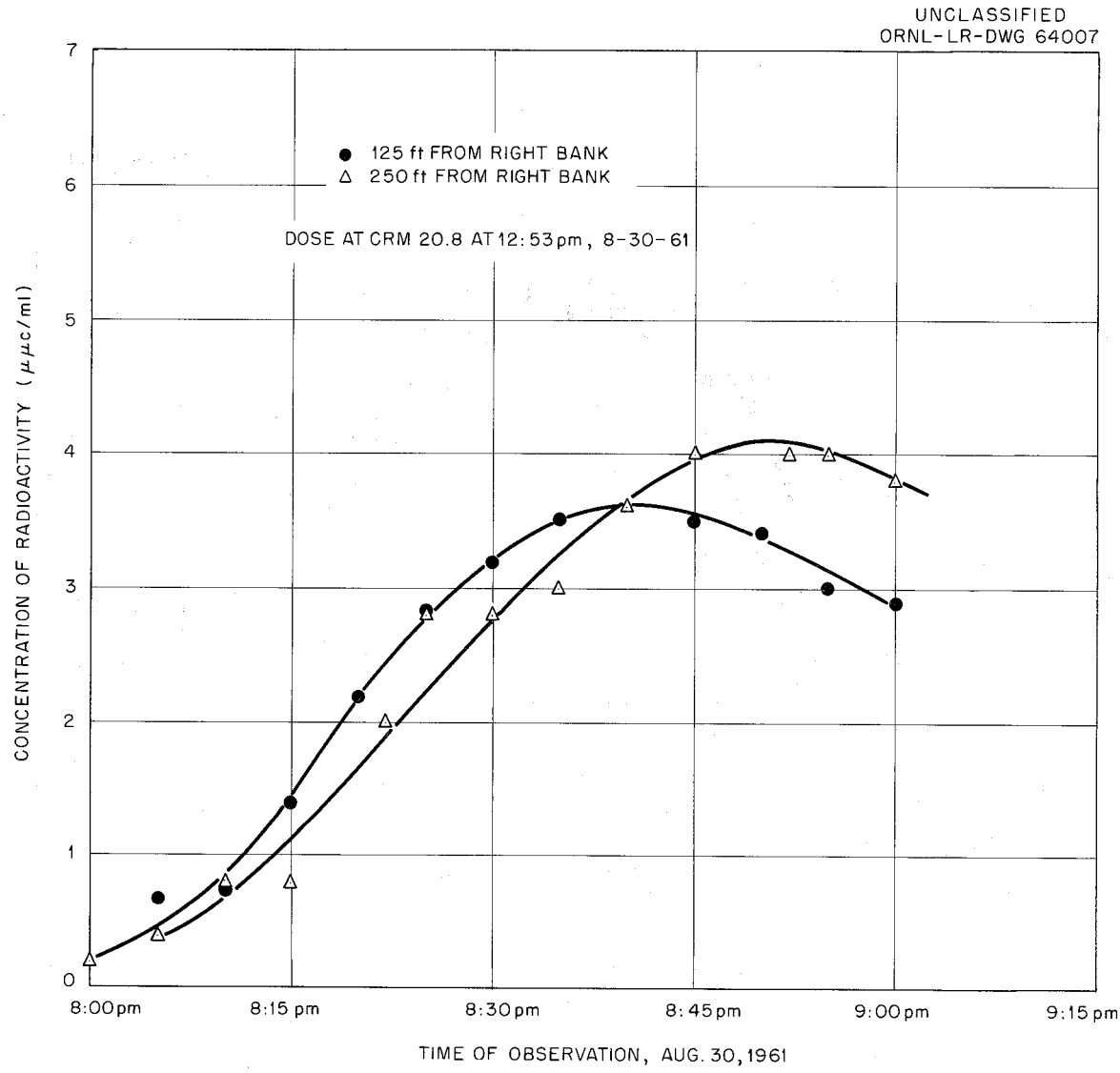

Fig. 19. Variation of radioactivity of gold-198 with time, tracer study of August 30-31, 1961, at Clinch River Mile 14.5 (Gallaher Bridge).

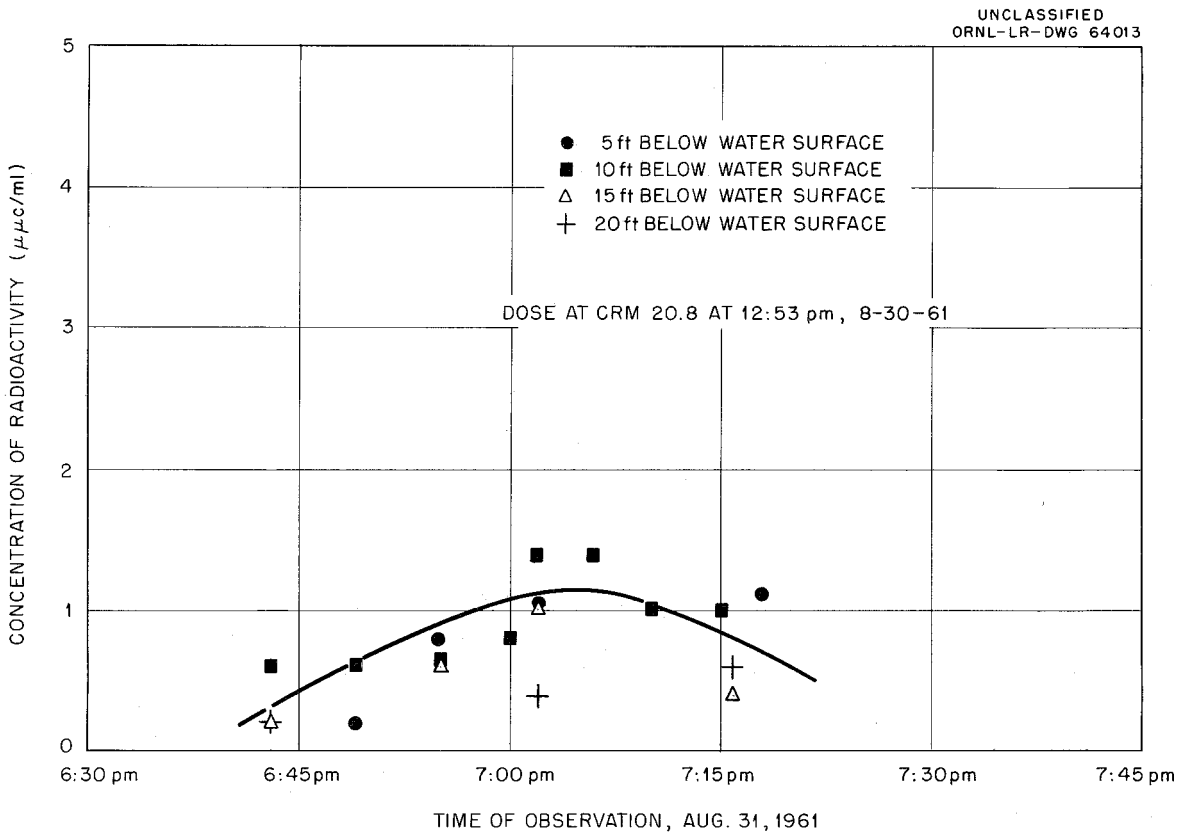

Fig. 20. Variation of radioactivity of gold-198 with time, tracer study of August 30-31, 1961, at Clinch River Mile 4.4 (Centers Ferry).

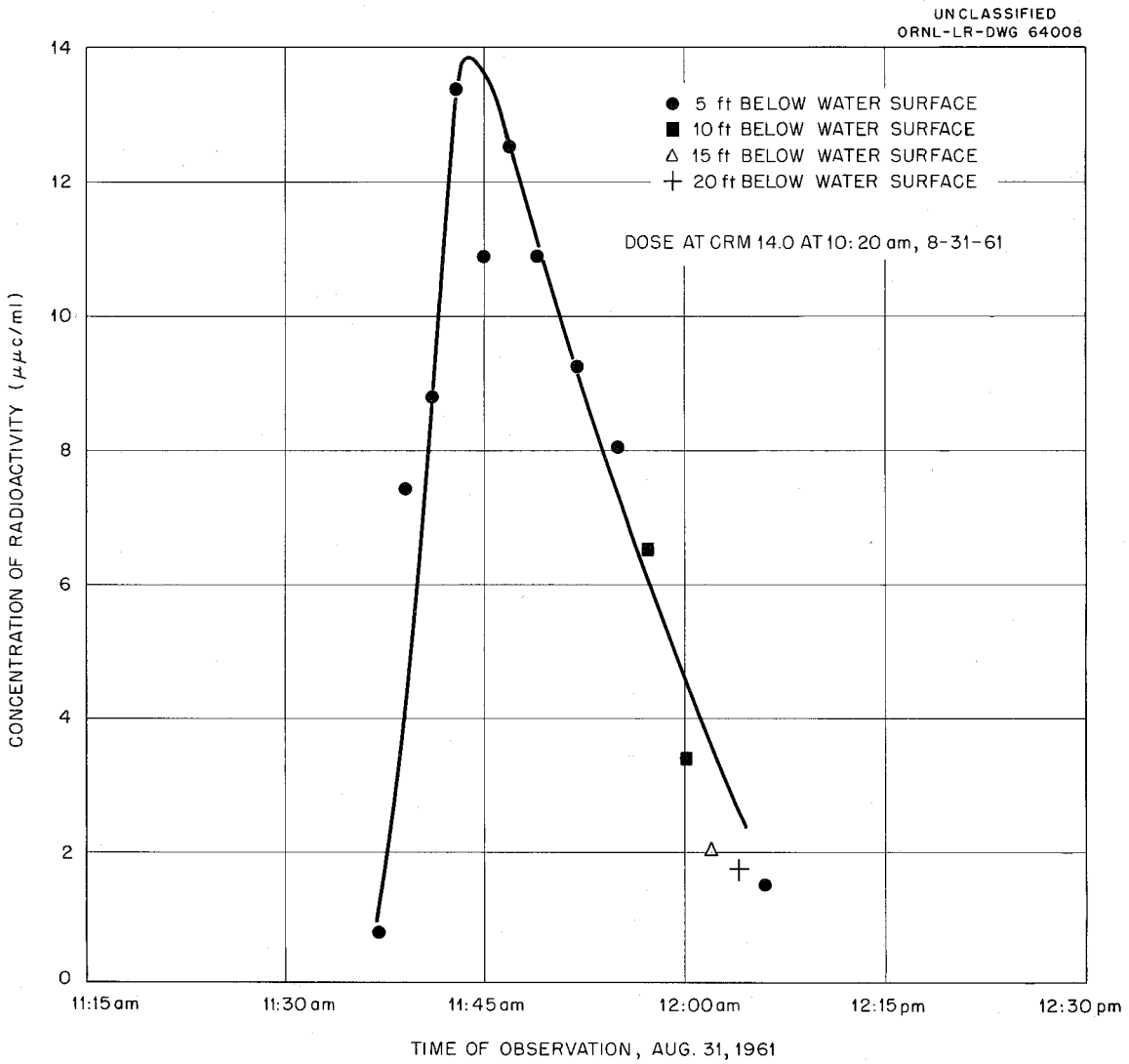

Fig. 21. Variation of radioactivity of gold-198 with time, tracer study of August 30-31, 1961, at Clinch River Mile 13.0.

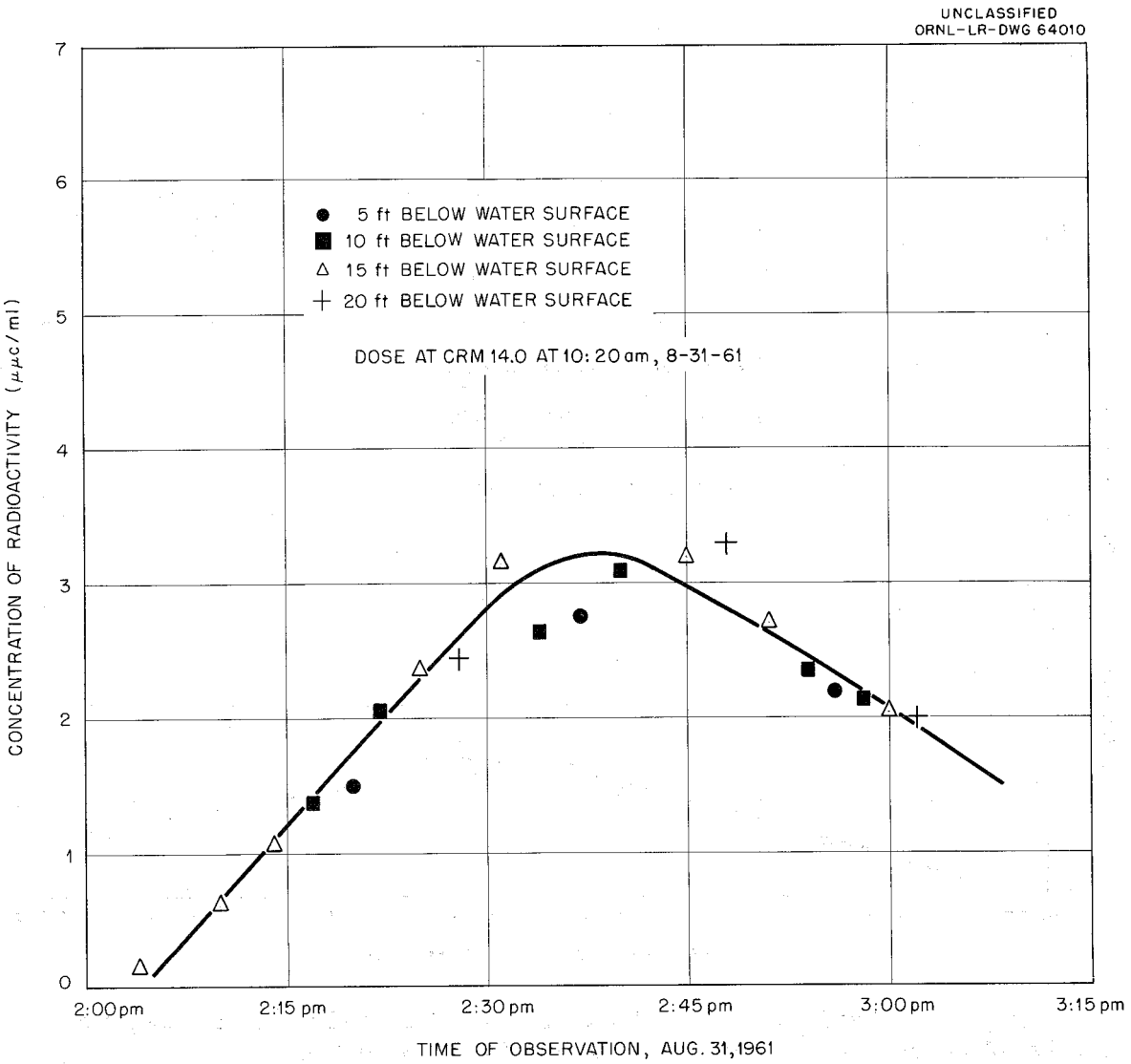

Fig. 22. Variation of radioactivity of gold-198 with time, tracer study of August 30-31, 1961, at Clinch River Mile 11.0.

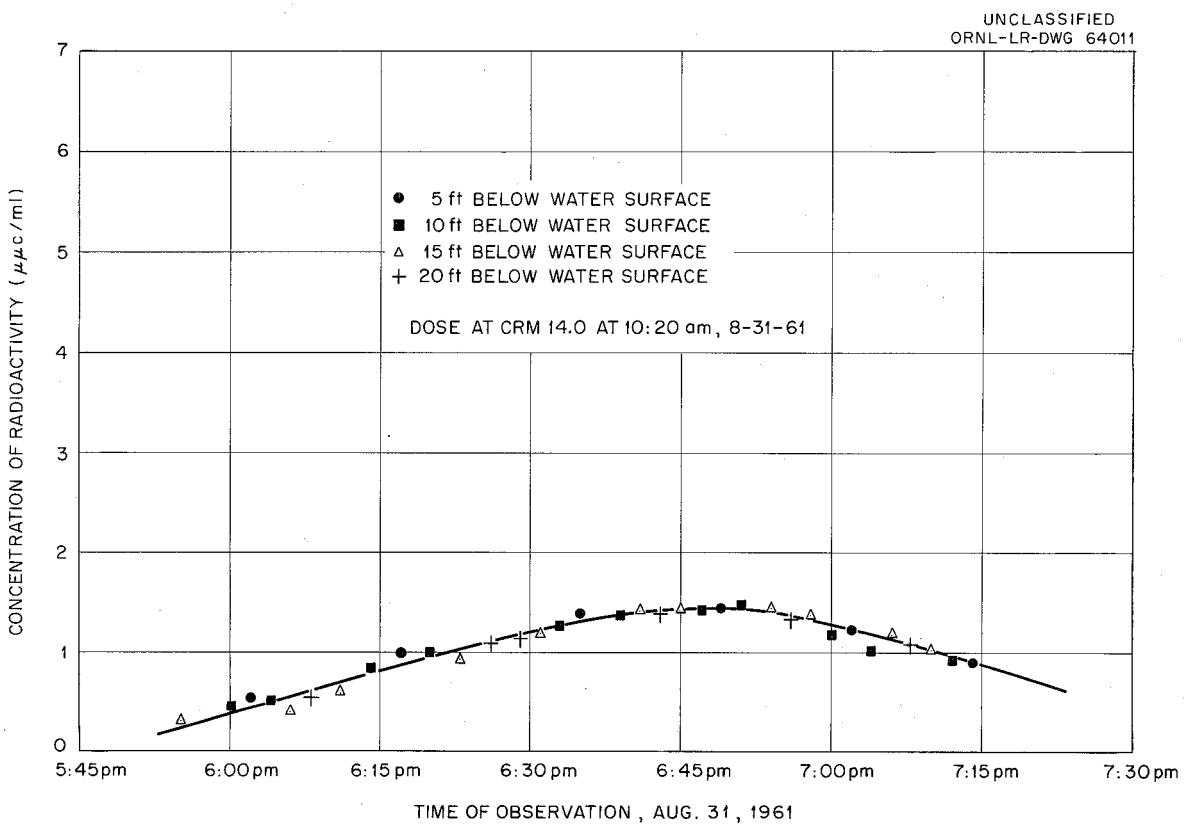

Fig. 23. Variation of radioactivity of gold-198 with time, tracer study of August 30-31, 1961, at Clinch River Mile 9.0.

regardless of which type curve is plotted, the magnitude of the maximum concentration is substantially the same, and the total activity indicated by the area under the curve is the same.

With reference to the primary objectives of the study, as stated earlier, and for the river conditions in effect at the time of the study, it may be concluded that:

1. A slug of activity entering Clinch River from White Oak Creek was dispersed rather slowly across the Clinch River, little or no activity entering the stream channel to the left (south) of Jones Island and practically negligible amounts reaching the left bank above CRM 19.6.

2. Relatively uniform stream-wide distribution was evident at about CRM 17.0.

3. Maximum concentration of activity was very rapidly reduced in the reach between the injection point and the point of uniform cross-stream distribution (see Fig. 24).

4. The time of travel of the peak concentration of the tracer from CRM 20.8 to the intake of the ORGDP Water Plant (CRM 14.5) was about 8 hr, and to Centers Ferry (CRM 4.4) was about 30 hr. It should be noted that the time of travel figures observed in this study are in good agreement with earlier estimates of time of water travel, under similar conditions, prepared by the Tennessee Valley Authority, Division of Water Control Planning, Hydraulic Data Branch, in November 1952.

Future studies are contemplated at extreme conditions of Clinch River discharge and Watts Bar reservoir elevation to obtain a more complete picture of the dispersal and dilution pattern in the Clinch River.

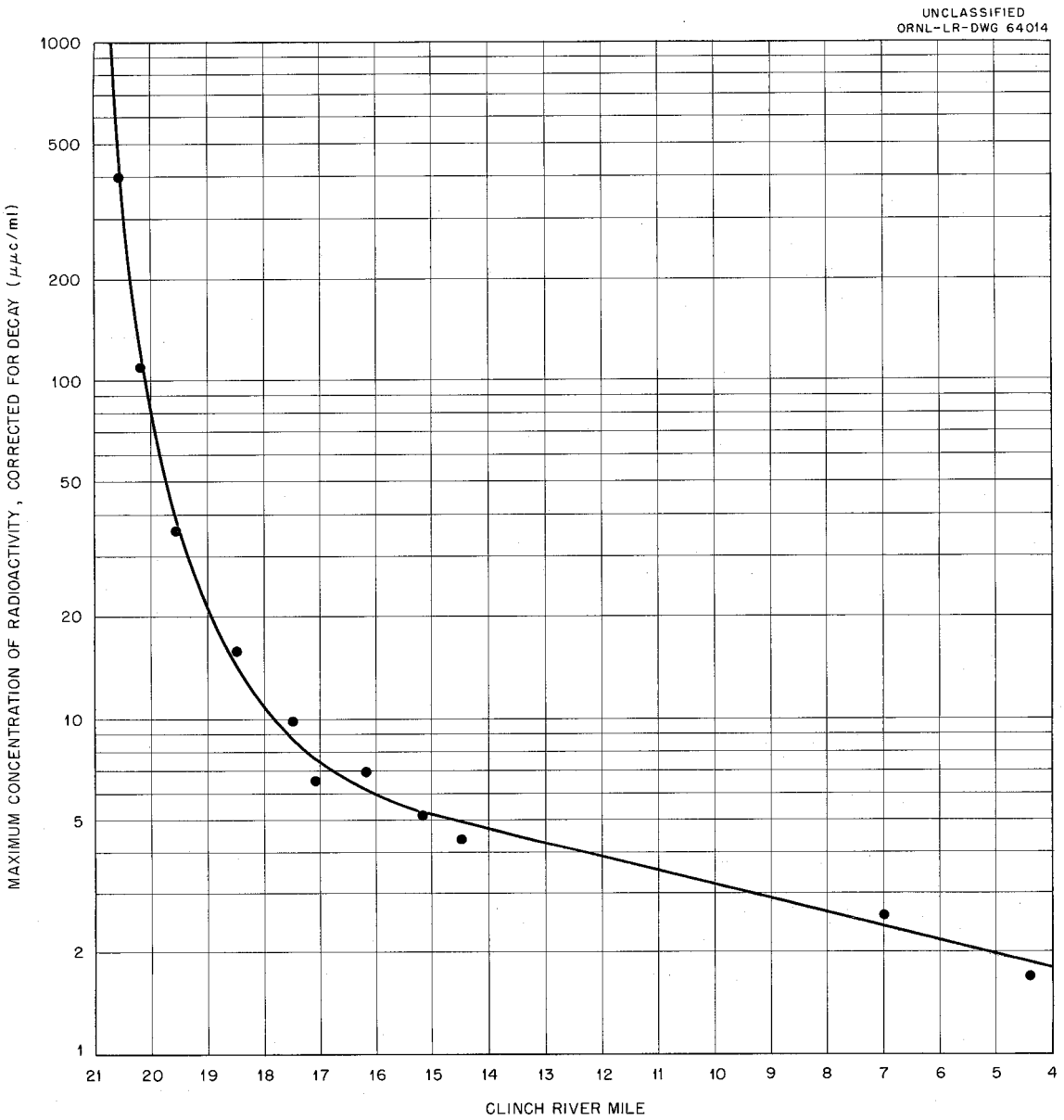

Fig. 24. Variation of Maximum concentration of gold-198 radioactivity with distance in Clinch River, tracer study of August 30-31, 1961.

Clinch River Dilution Factors

As a step in the determination of the diluent capacity of Clinch River, statistical studies of the simple volumetric dilution of discharges from White Oak Creek by flows in the Clinch River were initiated. The dilution factor has been defined as the ratio of the discharge in Clinch River at the gaging station near Scarboro, Tennessee, for a given period to the discharge in White Oak Creek at White Oak Dam for the same period.

The base period for these studies is from October 1, 1950, to September 30, 1960, ten water years (1951-1960). During this base period the cumulative departure of precipitation from the average precipitation for the long-term meteorological station at Clinton, Tennessee, is near zero. Records of discharge in Clinch River at the gaging station near Scarboro, Tennessee, are available for the entire period. Records of discharge in White Oak Creek at White Oak Dam, near Oak Ridge, Tennessee, are available for July 10, 1953, to October 14, 1956, and for August 1 to September 30, 1960. Discharges in White Oak Creek for the remaining portions of the base period were estimated on the basis of discharge records of White Oak Creek below ORNL near Oak Ridge, Tennessee, by methods of graphical correlation. The correlation coefficient was greater than 99%. The standard error of the graph was 0.074 log units (or ± 18% and - 15%).

Discharges from White Oak Creek are uncontrolled. The additions of waste waters to the basin at ORNL are relatively constant from day to day. Variations in discharge during the period, essentially, reflect the natural flow variations. Discharges in Clinch River are controlled at Norris Reservoir and variations in flow in the river reflect,

in large measure, the results of water-control operations at the reservoir. Large fluctuations in river discharge occur from day to day due to these operations.

Because of the controlled flow in Clinch River, these statistical studies should be considered as a historic presentation of dilution data, rather than for use as a predictive tool, at the present time.

Based on the mean annual discharges observed in Clinch River and White Oak Creek, the mean annual dilution factor is about 450. As shown in Fig. 25, the mean monthly dilution factor based on monthly discharges has been less than 450, on the average, for 5 months of a year. The minimum mean monthly dilution factors have been found to be 320 or less in all months of the year. In March and April these monthly dilution factors have been found to be always less than 450. Seasonal trends are shown to occur in the mean monthly dilution factors; low factors usually are observed from December through May.

From the duration curve of daily factors (Fig. 26), the median daily dilution factor is shown to be 570. The range in extremes of the daily dilution factor is from 5.1* to 4330.

Frequency studies of minimum dilution factors have been made for the lowest daily dilution factor and the lowest monthly dilution factor that occurred each year. Results of these studies are shown in Figs. 27 and 28. The recurrence interval is the average

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*The value 5.1 could not be plotted in Fig. 26 because it was equaled or exceeded 100% of time.

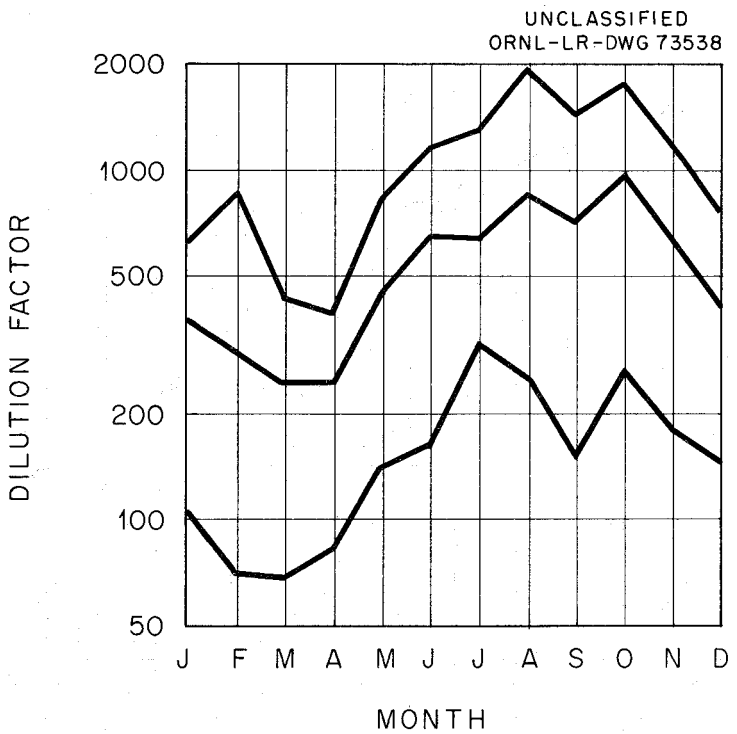

Fig. 25. Maximum, mean, and minimum monthly dilution factors, 1951-60.

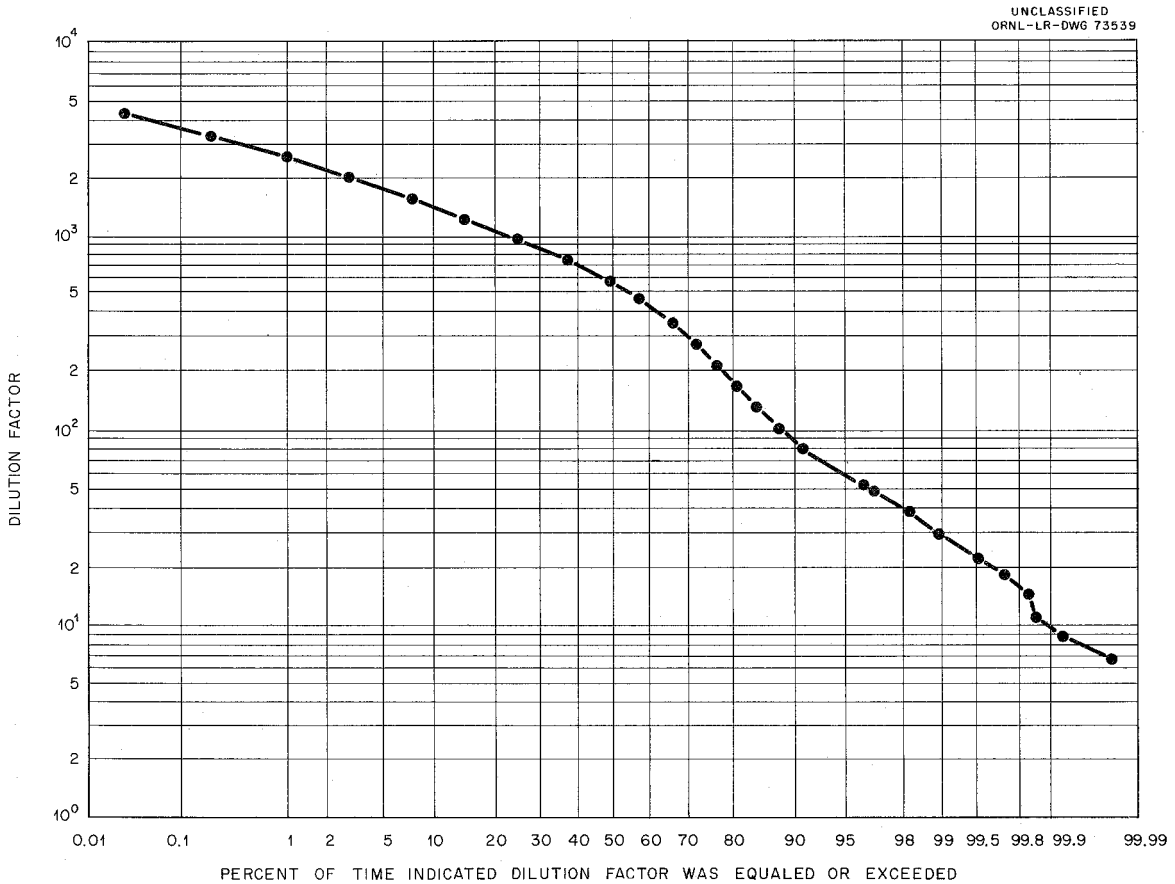

Fig. 26. Duration curve of daily dilution factors, 1951-60.

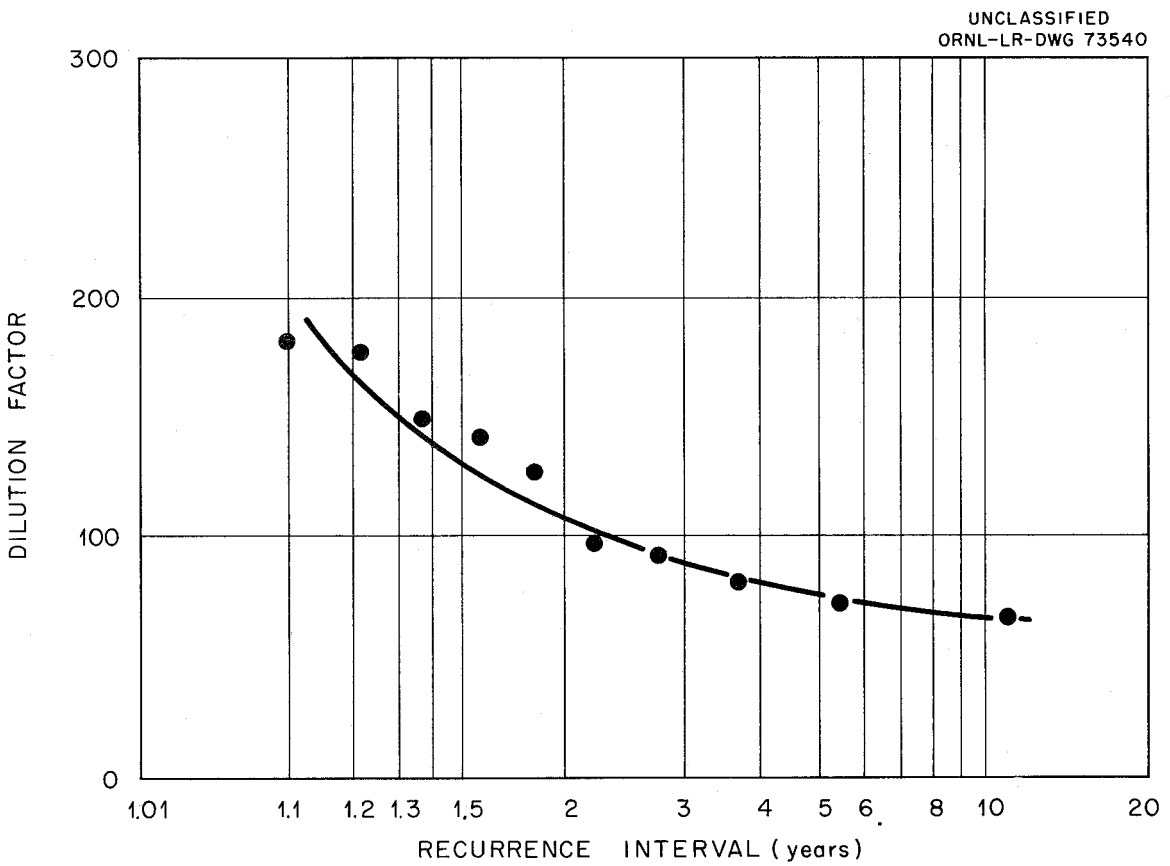

Fig. 27. Minimum monthly dilution factor frequency curve, annual series.

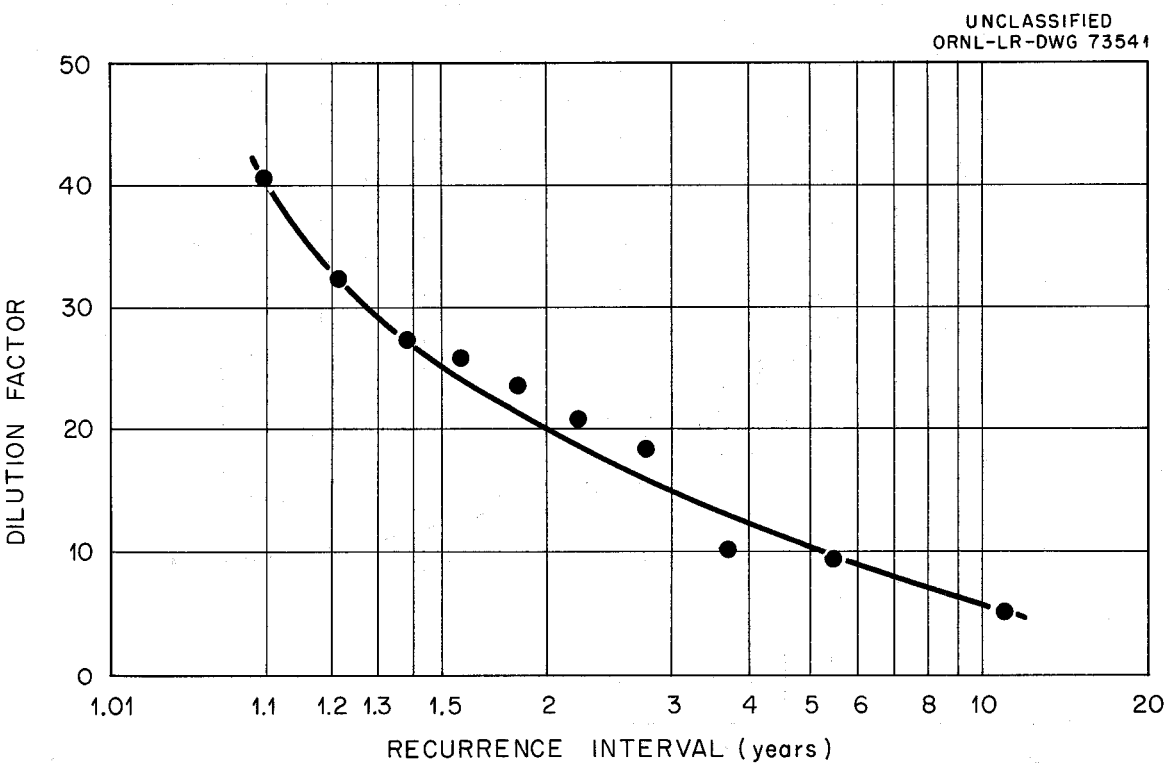

Fig. 28. Minimum daily dilution factor frequency curve, annual series.

interval of time within which a dilution factor will be less than or equal to a given magnitude once (a recurrence interval of 5 years is one that has a 20% chance of recurring any year). For a recurrence interval of 2 years (50% chance), the minimum daily and monthly dilution factors, respectively, are 20 and 109; for a recurrence interval of 10 years (10% chance), the minimum daily and monthly dilution factors, respectively, are 5.6 and 68.

Further work on the description of variability of dilution factors is contemplated. Efforts will be made to describe the effects of the independent variations in the flow of Clinch River and White Oak Creek on the dilution factors.

APPENDIX A

LOCATIONS AND RIVER MILES

Table A-1. Partial List of Locations and River Miles
Clinch and Tennessee Rivers

Location	River Mile	
Clinch River		
Norris Dam	CRM	79.8
Clinton, Tennessee	CRM	59.0
Bull Run Steam Plant, TVA	CRM	48.0
Oak Ridge Water Plant, Pumping Station	CRM	41.5
Gaging Station, Scarboro	CRM	39.0
EGCR - Gas-Cooled Reactor	CRM	32.5
Melton Hill Dam	CRM	23.1
White Wing Bridge, HY Tenn.95	CRM	21.7
Entry of White Oak Creek (WOCM 0.0)	CRM	20.8
White Oak Dam	WOCM	0.6
Gaging Station, Stage Only	CRM	19.1
ORGDP Water Plant, Intake	CRM	14.4
Reservoir Gage, near Wheat	CRM	14.5
Entry of Poplar Creek (PCM 0.0)	CRM	12.0
Sampling Station, near Centers Ferry	CRM	5.5
Centers Ferry	CRM	4.5
Entry of Emory River (ERM 0.0)	CRM	4.4
Harriman, Tennessee, Water Plant Intake	ERM	12.8
Kingston Steam Plant, TVA Stream Gage	CRM	2.6
Mouth of Clinch River (CRM 0.0)	TRM	567.7
Tennessee River		
Knoxville, Tennessee (Gay Street)	TRM	647.7
Fort Loudon Dam	TRM	602.3
Sampling Station, Loudon, Tennessee	TRM	591.4
Kingston, Tennessee, Water Plant Intake	TRM	568.2
Entry of Clinch River	TRM	567.7
Watts Bar Dam	TRM	529.9
Entry of Hiwassee River, Lower Entrance	TRM	499.4
Chickamauga Dam	TRM	471.0
Chattanooga, Tennessee, Water Plant Intake	TRM	465.5
Hales Bar Dam	TRM	431.1
Guntersville Dam	TRM	349.0
Wheeler Dam	TRM	274.9
Wilson Dam	TRM	259.4
Pickwick Landing Dam	TRM	206.7
Johnsonville Steam Plant, TVA Stream Gage	TRM	100.5
Kentucky Dam	TRM	22.4
Confluence of Tennessee and Ohio Rivers	TRM	0.0

APPENDIX B

MAPS OF CLINCH AND TENNESSEE RIVERS

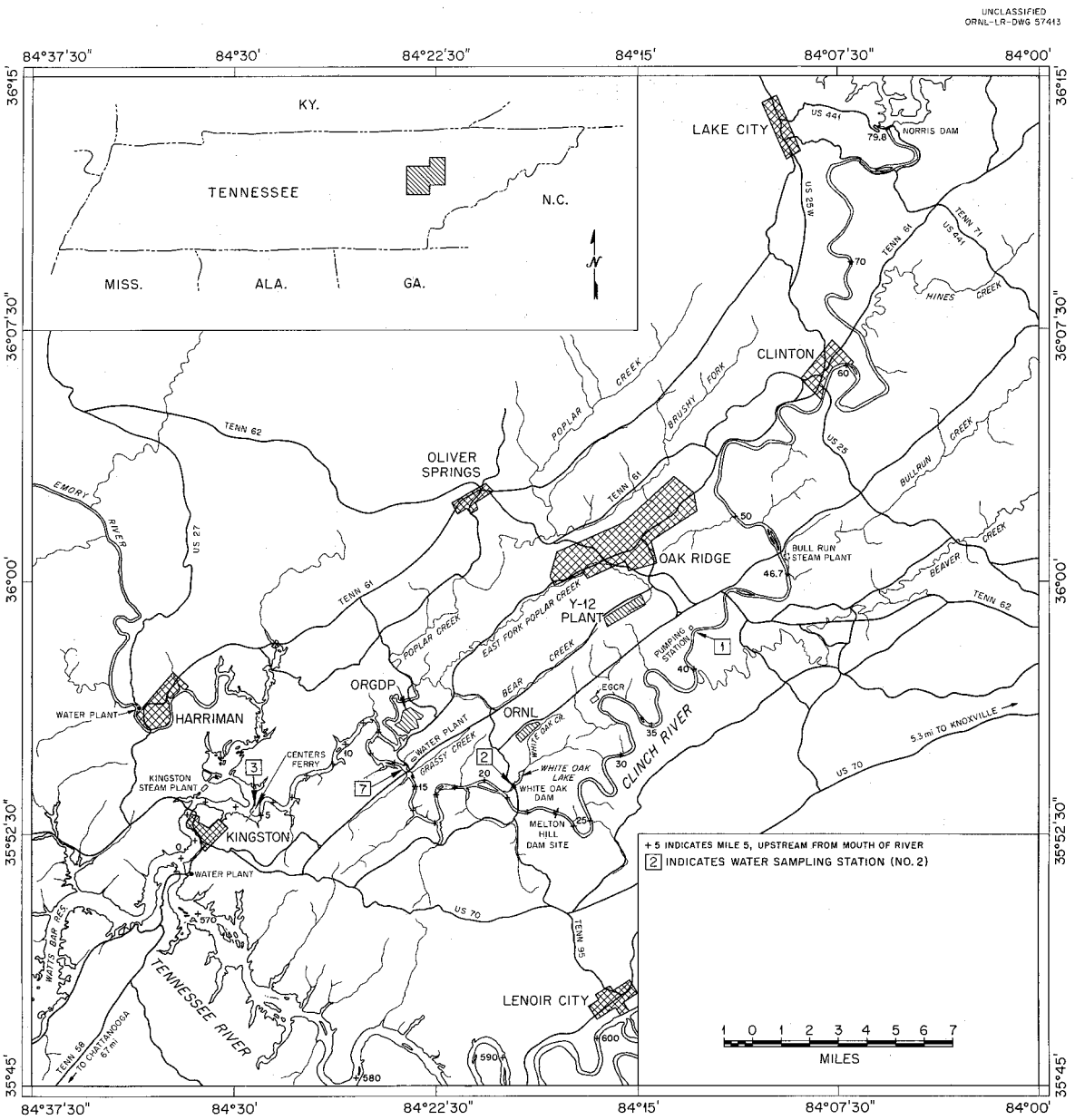

Fig. B-1. Map — lower Clinch River basin.

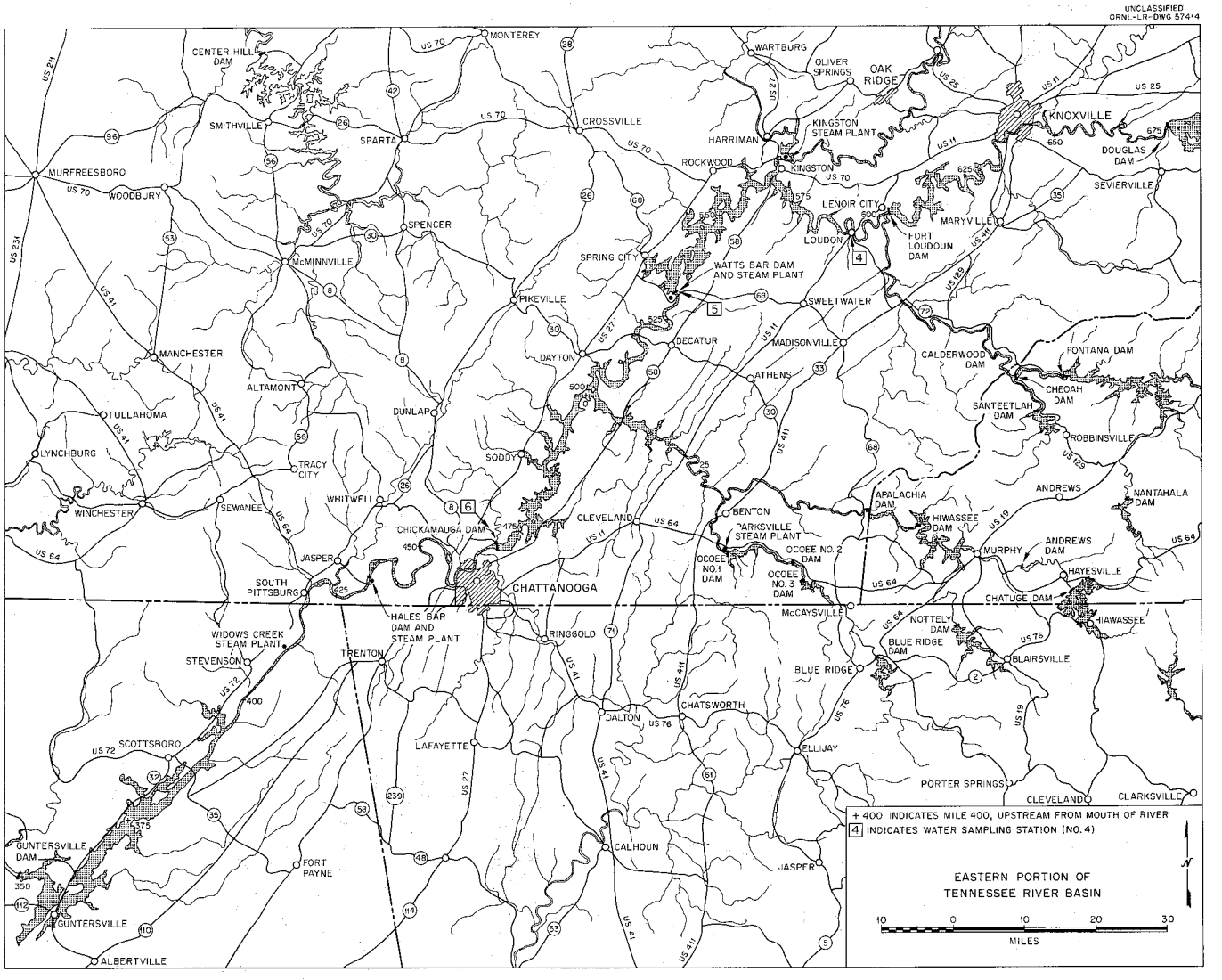

Fig. B-2. Map – eastern portion of Tennessee River basin.

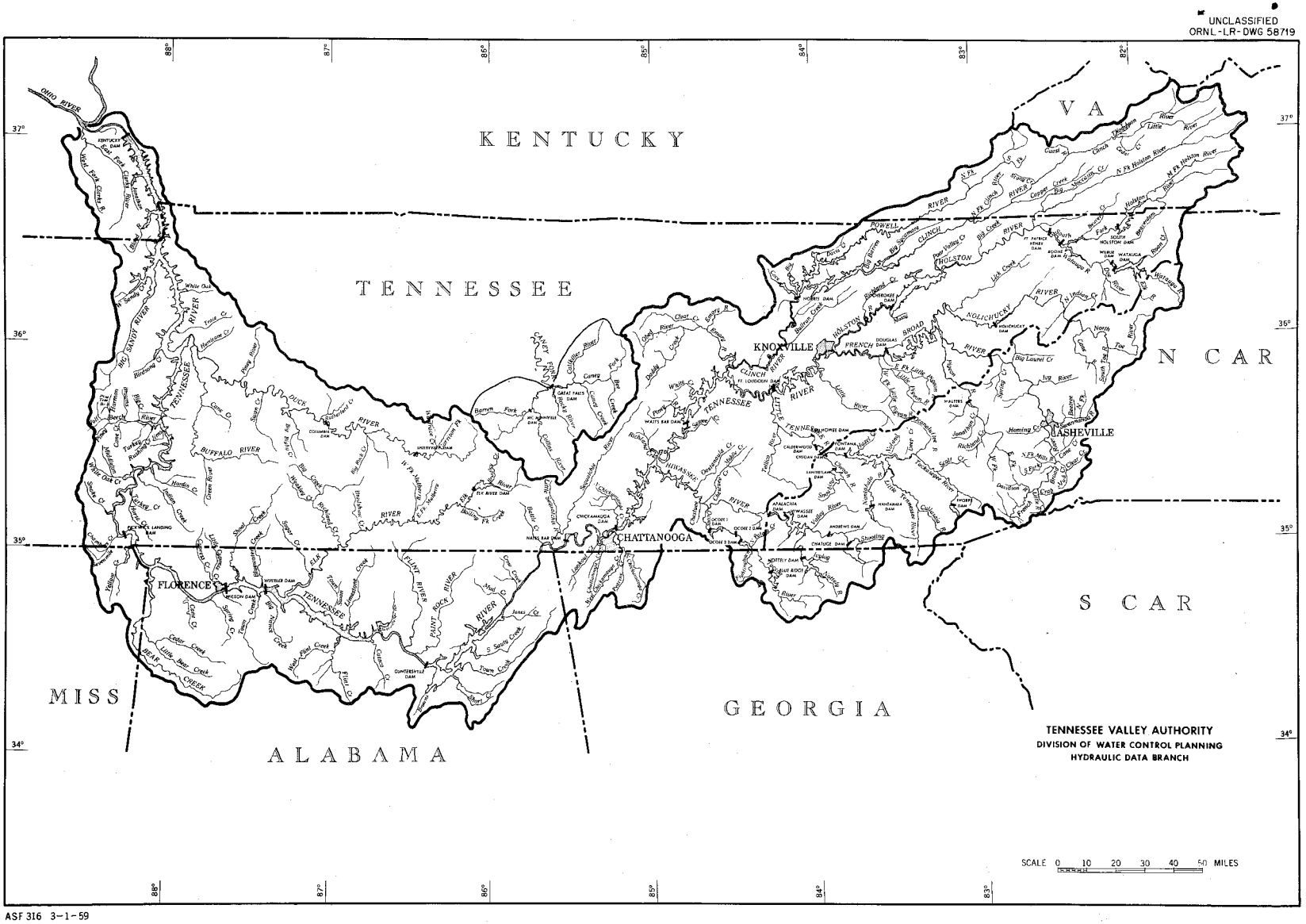

Fig. B-3. Map — Tennessee River basin.

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