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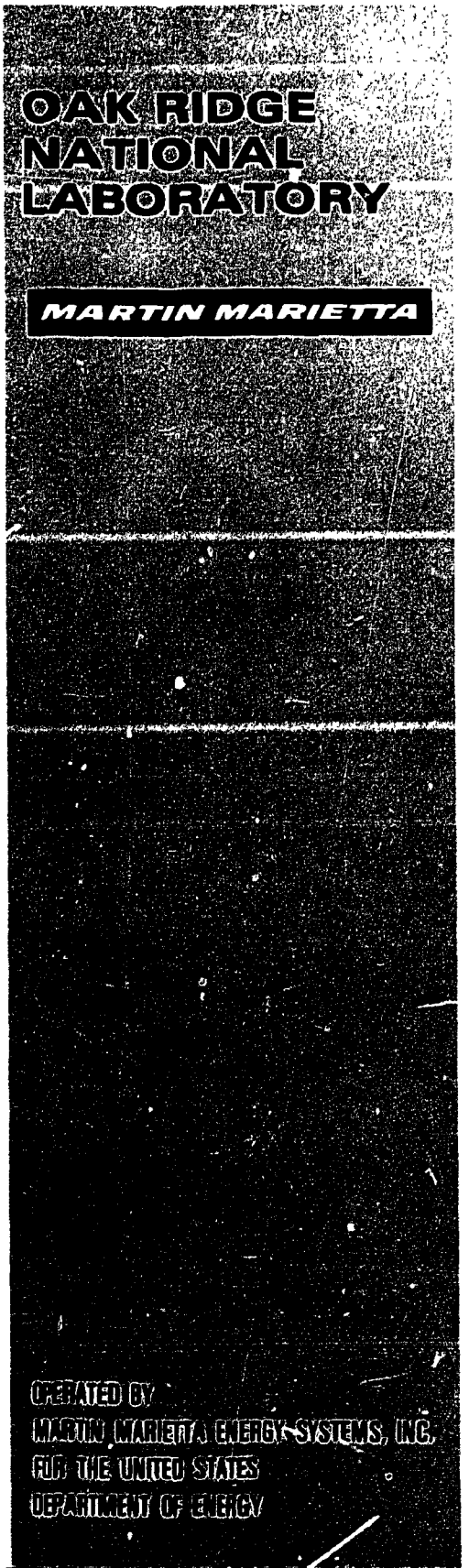

History of Disposal of Radioactive Wastes into the Ground at Oak Ridge National Laboratory

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HISTORY OF DISPOSAL OF RADIOACTIVE WASTES INTO THE GROUND AT OAK RIDGE NATIONAL LABORATORY

J. H. Coobs
J. R. Gissel

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I. ABSTRACT

Since the beginning of operations at the Oak Ridge National Laboratory (ORNL) in 1943, shallow land burial has been used for the disposal of solid low-level radioactive waste. These wastes have originated from nearly every operating facility, and from 1955 to 1963, ORNL's solid waste storage areas were designated by the Atomic Energy Commission (AEC) as the Southern Regional Burial Ground. During this period, about one million cubic feet of solid waste from various off-site installations were buried in solid waste storage areas (SWSAs) 4 and 5. Six SWSAs have been used since land burial operations began at ORNL in early 1944. The solid waste storage areas were numbered consecutively in the order in which they were first used. During burial operations, different problems have arisen at the SWSAs depending on the physical characteristics of the area in which they were sited and the methods of operation at the sites during different time periods.

ORNL has generated liquid radioactive waste since the separation of plutonium began in 1944. The majority of these wastes are classified as process (low-level) waste and are derived from evaporator condensate and cooling water from process vessels, and from building drains and surface drainage from contaminated areas. Process wastes are monitored at sampling stations located strategicially throughout the plant, and for nearly 15 years (1944-57) they were discharged directly into White Oak Creek without being treated chemically to remove radionuclides.

A smaller quantity of intermediate-level wastes (ILW) originate from the radiochemical separation process and from test reactors. The collection, treatment, and methods of disposal of ILW from the years

1943-1981 are described. Over this period of time there was a great deal of variation in the amounts and types of radioactive liquid wastes generated. Attitudes also changed concerning what constituted safe and economical disposal. These changing attitudes have been reflected in the evolution of new regulations and methods of management of radioactive wastes at ORNL.

Disposal methods for solid wastes which require special handling [transuranic (TRU) wastes and ^{235}U wastes] are described for the period begining in the 1940's and continuing to 1981. Prior to 1970 TRU and ^{235}U wastes were buried in a non-retrievable manner. In 1970, AEC imposed a restriction against ground disposal of waste containing more than 10 nCi/g of TRU material. TRU wastes above this limit are stored in a manner to allow retrievability for 20 years. ^{235}U wastes continue to be buried in either unlined earthen trenches or auger holes based upon the ^{235}U quantity or concentrations as well as geometry.

Various groups including ORNL, U. S. Geological Survey, the Tennessee Valley Authority and Edgerton, Germenhausen and Greer (EG&G) have conducted radiological surveys on the White Oak Creek Watershed, White Oak Lake and the Clinch River to determine the impact and extent of releases of radioactive effluent from ORNL. These surveys have included analysis of water samples, air samples, sediment samples, vegetation taken from the beds of the lake and river, and game living in or near White Oak Lake and the Clinch River. The animals were studied as part of an on-going project to analyze biological pathways of radiation to man. Calculations based on these releases show that the maximum potential radiation dose to individuals and population groups in uncontrolled areas is well within the

guidelines of DOE Manual Chapter 0524 on radiation protection standards for external and internal exposure.

II. INTRODUCTION

A. Purpose and Scope

Ground disposal of radioactive waste materials at the Oak Ridge National Laboratory (ORNL) has occurred at a number of locations over a period of nearly four decades. During this period many reports have been written on various aspects of disposal operations including the factors that affect leaching of radionuclides from buried wastes and their subsequent transport to uncontrolled areas. Some of the reports are reviews and they have been very helpful to the authors of the present report, who have as their goal the preparation of a comprehensive, up-to-date (current to October 1, 1981) review of all aspects of the ground disposal of solid and liquid radioactive wastes at ORNL during its entire history. This report is a compilation of the documents and information from personal communications made available to the authors. Included in this report are a brief consideration of the operations at the laboratory that have affected the quantity and type of wastes; available data on quantities and types of wastes buried and their burial locations; the evolving recognition of the limitations of ground disposal for long-term retention of radionuclides in the controlled area; and discussion of the inadequacies of the earlier disposal techniques and of the need for remedial actions. Monitoring of the movement of radionuclides from burial sites, including information on their dispersion outside the controlled area, is considered to be pertinent to the purpose of this report. Data obtained by monitoring surface water from Bethel Valley is of interest here only to the extent that it helps to determine the fraction of the radioactivity being discharged from White Oak Dam that comes from ground disposal operations and to determne ORNL's compliance. Since process waste disposal has also contributed to ground contamination, a brief review of process waste management history is included in the report.

Specifically excluded from the scope of this report is all information on the direct release of solid or gaseous radionuclides to the atmosphere, except for consideration of the possibility of such release occurring during or subsequent to ground disposal of waste materials.

B. History of the Oak Ridge National Laboratory

1. Oak Ridge Reservation

The Oak Ridge National Laboratory (ORNL) is located on the Oak Ridge Reservation. Because radioactive waste disposal was not a consideration in the site selection criteria, a brief history of why the Reservation was chosen is appropriate. The site was selected on September 19, 1942 by Colonel (later Major General) Leslie Groves as the location for the "Manhattan Project," the project that produced the atomic bomb, after several other possible sites had been considered. (Jo81) Its location in Tennessee is shown in the insert, Fig. II-1. Among the considerations that led to the choice of this East Tennessee location for the project are: ample and cheap land available for all the originally proposed plant facilities (pile for plutonium production; electromagnetic, gaseous diffusion, and thermal diffusion plants for ^{235}U separation); availability of electric power and water of good quality from the Tennesse Valley Authority (TVA); accessibility to rail and motor transportation; and the relatively isolated, inland location that minimized public awareness of the project's existence and provided safety from enemy attack. The thermal diffusion method of separating uranium isotopes was abandoned early, but large plants were built to produce enriched uranium-235 by gaseous diffusion (K-25) and electromagnetic separation (Y-12). One of the advantages of the Oak Ridge Reservation is the terrain which allows segregation of the plants in separate valleys: one or more ridges separate the three plants. The position of the plants in relation to Oak Ridge and area streams is shown in Fig. II-1.

2. Oak Ridge National Laboratory

The ORNL (X-10) site on the Oak Ridge Reservation (Fig. II-1) was originally selected as the location of the graphite reactor (or pile, as it was referred to initially) that was to serve as the prototype for the Hanford plutonium production reactors. The "Hot Pilot Plant," now Building 3019, was constructed to dissolve irradiated fuel elements and to separate plutonium from the solution using the bismuth phosphate precipitation method. The graphite reactor, the world's first uranium chain reactor with

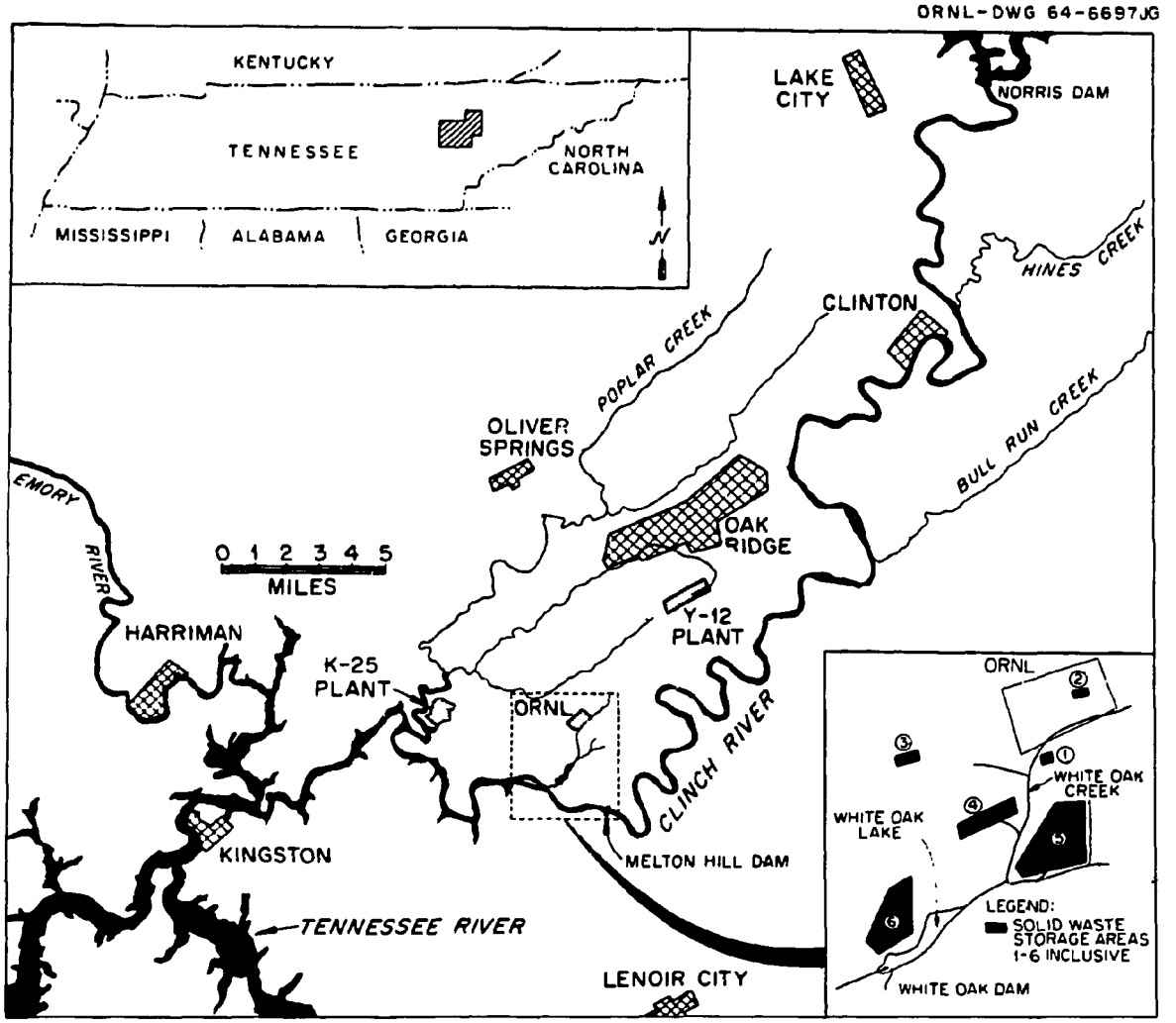

Fig. II-1. Location map of the Oak Ridge Reservation and vicinity.

production potential, went critical on November 4, 1943 and weighable quantities of plutonium were soon produced in these facilties.

Large quantities of fission-product and uranium-waste solutions resulted from the plutonium production work. These liquid waste materials were stored at first in large, underground concrete (Gunite) tanks. (Brow49)

From the completion of the ORNL plant until July 1, 1945, it was operated by the Metallurgical Laboratory of the University of Chicago. Monsanto Chemical Company then operated the X-10 facilities until February 1948 when the present operator, Union Carbide Corporation, took over.

Although it was expected that the mission of the X-10 site would be completed in one year, it was soon realized that the operations at this location needed to be extended. There have been many changes in the scope and direction of programs at ORNL over the years but the most important, from the standpoint of radioactive waste management, include continuation and expansion of fuel processing research, large scale production of radioactive isotopes, and operation of a variety of reactors in addition to the graphite reactor. These include the Low Intensity Test Reactor, the Bulk Shielding Facility, the Tower Shielding Facility, the Homogeneous Reactors, the Aircraft Reactor Experiment, the Molten Salt Reactor Experiment, the Health Physics Research Reactor, the Oak Ridge Research Reactor, and the High Flux Isotope Reactor. Several of these were experimental reactors that operated for varying lengths of time and were removed from service. The Experimental Gas-Cooled Reactor was never operated and, consequently, did not produce radioactive waste. The High Flux Isotope Reactor and its companion TRU processing plant produce an important part of the ORNL radioactive waste materials that are classified as transuranium (TRU) wastes.

A number of changes in the initial waste management plans have occurred that affected storage and eventual discharge of radioactive waste materials into uncontrolled areas. Such changes include: precipitation of uranium and plutonium plus part of the fission products in storage tanks, followed by decantation of the supernatant liquid which was subsequently diluted with process waste water prior to disposal in White Oak Creek; creation of a process waste settling basin of 5,625,000 liters (1,500,000

gallons) capacity in July 1944; concentration of highly active liquid waste in a pot-type evaporator from June, 1949 to June, 1954; construction and operation of open pits and covered trenches for ground disposal of intermediate-level liquid waste from 1951 to 1965; operation of the Metal Recovery Facility (Building 3505) from 1952 to 1957 for the reclamation of approximately 130 tons of uranium from stored waste; draining of White Oak Lake in 1955; completion in 1957 of a waste water treatment plant (low-level liquid waste) and a multicurie fission product pilot plant for the recovery of ^{90}Sr, ^{137}Cs and other isotopes from irradiated fuel elements which added significantly to the quantity of radioactive wastes to be disposed; and introduction of an automatic diversion valve in January, 1959, to divert process water flow to the treatment plant whenever the level of radioactivity exceeded a preestablished value. White Oak Dam, which is located 2.7 km (1.7 miles) downstream of the Laboratory and 1.0 km (0.6 mile) from the confluence of the creek with the Clinch River and its associated lake, represents the last point of control for release of radioisotopes to the river.

More recent changes include the installation of two 10 gpm evaporators in Building 2531 in 1965, initiation of hydrofracturing in 1965 for deep underground disposal of intermediate-level wastes, and the beginning of operation of the new process waste treatment plant in March 1976.

C. Regional Characteristics

1. Location and Demography

The Oak Ridge Reservation, as shown in Fig. II-1, is located in East Tennessee, in the portion of the Tennessee Valley and Ridge physiographic province which is characterized by a series of long, narrow ridges and broader intervening valleys, all having a northeast-southwest orientation. The reservation is bounded on the northeast, southeast, and southwest by the Clinch River and on the northwest by Black Oak Ridge. (ERDA77)

The area surrounding the reservation is generally rural to urban with the largest population center, Knoxville, located to the east. Other area population centers include Oak Ridge (1980 population approximately 27,000), the smaller towns of Clinton (northeast), Kingston (southwest),

and Harriman (west), and several smaller communities in Anderson and Roane counties (ERDA77). The population distribution is shown in Table II-1 as a function of distance and direction from ORNL. (ERDA77)

2. Geology

The Oak Ridge area is marked by a series of overthrust faults along which large blocks of rock roughly 3 km (2 miles) thick have been broken, tilted, and moved a number of kilometers to the northwest, overriding the similar sheet of rock to the northwest of it and, in turn, having been overridden by the sheet to the southeast. (ERDA77) The four principal geologic units of interest are the Knox, Conasauga, Rome and Chickamauga. (Fig. II-2) The oldest is the Rome Sandstone, of lower Cambrian age. It is overlain by the six formations of the Conasauga Group, which is about 610 meters (2000 ft) thick. The Pumpkin Valley shale, the lowermost member of the Conasauga Group is a dense, very thinly bedded, argillaceous shale about 91 km (300 ft) thick. The other formations in the Consauga Group are, in ascending order above the Pumpkin Valley Shale: Rutledge Limestone, Rogersville Shale, Maryville Limestone, Nolichucky Shale, and Maynardville Limestone. Because of the above mentioned overriding effect, different formations occur at the surface within relatively short distances.

3. Hydrology

As shown in Fig. II-1, streams in the vicinity of Oak Ridge National Laboratory drain into the Clinch River which, in turn, empties into the Tennessee River near Kingston. (ERDA77) A detailed study of the hydrology of the Oak Ridge area has been reported by McMaster. (McM67) The average flow rate of the Clinch River at Melton Hill Dam (Clinch River Mile 23.1) is about 4600 cubic feet per second. Flow in the Clinch River in this area is controlled by Norris, Melton Hill and Watts Bar Dams. There are no public water supplies taking water from the Clinch River between the discharge of White Oak Creek and the point where the Clinch River empties into the Tennessee River. However, the Oak Ridge Gaseous Diffusion Plant has a water intake at Clinch River Mile 14.5. The drainage area of this river is 11,430 hectares (4413 square miles). (Stru67)

Table II-1. Incremental Population Data for ORNL Site* (ERDA77)

Direction	Distance (Miles)											
	0-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50	50-60	60-70
N	0	0	0	0	1,490	5,578	2,177	1,441	2,223	4,509	13,686	7,314
NNE	0	0	0	0	1,461	13,783	4,362	11,189	12,674	6,119	7,978	17,980
NE	0	0	0	0	0	9,713	12,479	7,167	4,392	7,476	21,097	8,781
ENE	0	0	0	0	0	0	27,462	74,686	18,723	13,872	23,240	31,800
E	0	0	0	0	0	3,059	44,883	100,488	11,793	12,900	8,965	21,468
ESE	0	0	0	0	0	6,096	5,363	36,015	4,132	6,840	346	0
SE	0	0	0	0	0	1,167	4,304	15,010	46	0	0	0
SSE	0	0	0	0	1,374	7,277	1,200	4,091	469	0	0	0
S	0	0	0	0	0	943	8,742	7,309	6,560	1,222	4,101	2,055
SSW	0	0	0	0	0	721	2,055	7,897	21,582	10,527	17,018	34,253
SW	0	0	0	0	0	733	1,810	1,909	3,962	8,578	10,312	21,909
WSW	0	0	0	0	0	622	9,862	3,495	4,562	4,204	5,894	2,799
W	0	0	0	0	0	666	13,099	4,595	9,038	7,318	4,129	14,856
WNW	0	0	0	0	0	587	2,971	1,543	0	4,151	5,055	29,862
NW	0	0	0	0	0	1,073	4,804	1,538	1,896	7,552	2,396	9,358
NNW	0	0	0	0	0	1,495	0	1,152	4,559	4,676	2,097	8,030
TOTAL	0	0	0	0	4,325	53,518	145,673	279,525	106,611	99,433	126,314	210,465

*Based on the 1970 United States Census

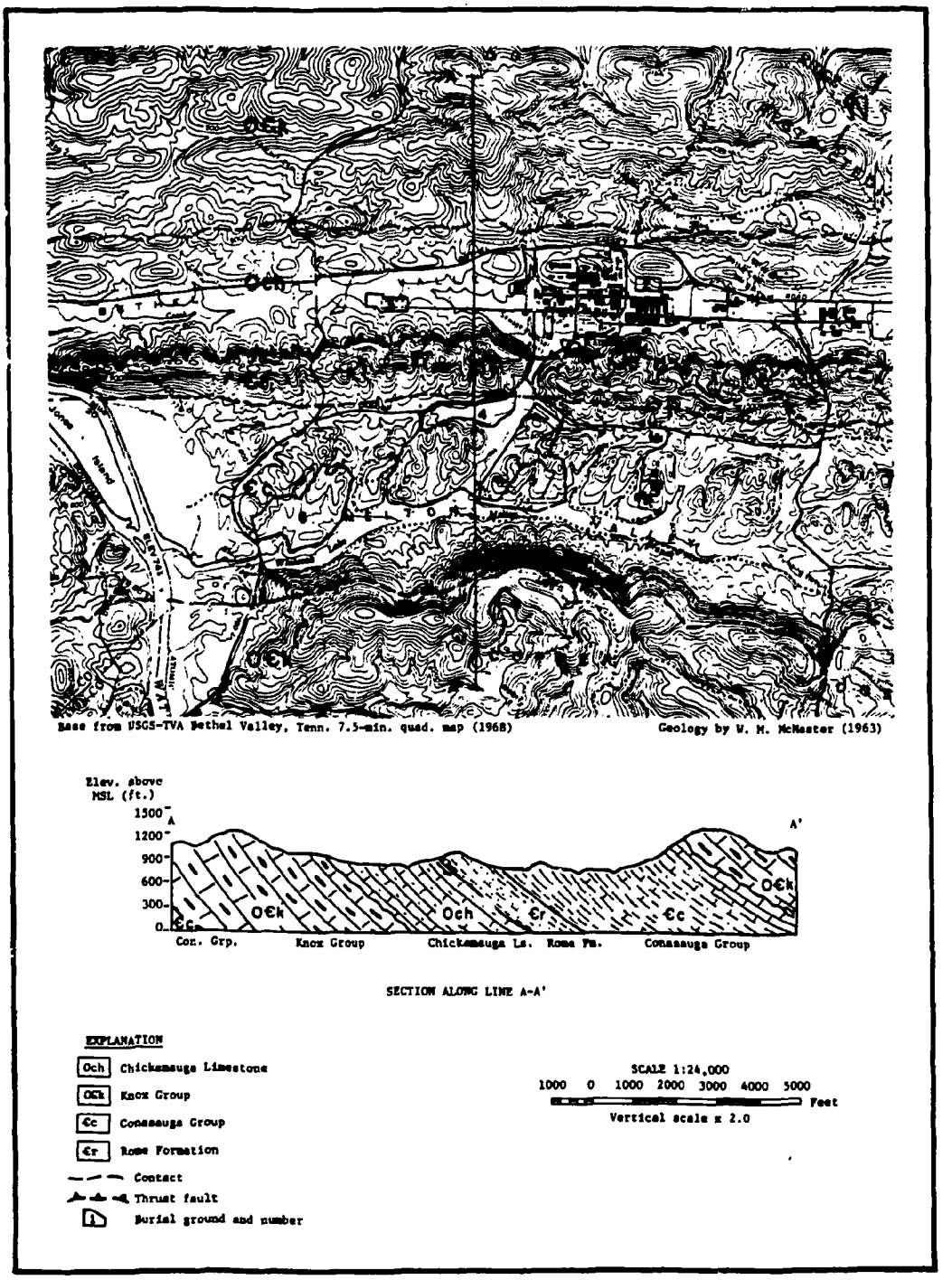

Fig. II-2. Geologic map of the Oak Ridge National Laboratory area and section along line A-A'.

4. Climate

The climate of the Oak Ridge area has been described as humid and subtropical, but humid and temperate may be a more accurate description. (Sto51) The average annual rainfall for the Oak Ridge area, measured for the period January 1951 through December 1971, is 136 cm (53.5 inches) and the average annual snowfall is 26 cm (10.3 inches). The annual mean temperature for this period is 14.4^{o}C (57.9^{o} F). Table II-2 gives the average monthly data for this period. (ATDL72) Although the data show wide variations in normal monthly rainfall and between maximum and minimum values for individual months, rainfall is distributed rather evenly throughout the year. Table II-2 also shows that the average minimum temperature is below freezing for the period December through February. The average maximum temperature for these three months ranges from 8.3 to 10.5^{o}C (46 to 51^{o}F). The limited below freezing period indicated by these data results in minimal freezing of the surface soil.

The average wind speed in the Oak Ridge area is reported to be 7.2 km (4.4 miles) per hour. (ATDL72) The peak gust of record is 95 km (59 miles) per hour. Storm tracks travel northwest to southeast. High intensity rainfall (77.6 cm or 3 inches per hour) is rare in the Oak Ridge area and tornado-velocity winds did not occur during the report period. (ATDL72)

5. Ecology

The Oak Ridge Reservation is typical of the landscape and of the ecological systems of the Appalachian Region. Five Appalachian forest types are found naturally in the reservation. The oak-hickory type shares equal prominence with the yellow pine-hardwood type. Core hardwoods are found interspersed between the dissected ridge systems and northern hardwoods occur in sheltered areas with a northern exposure. The white pine, which is of minor importance, is found along the northern boundary of the property. Large open areas were planted in pine between 1947 and 1956, creating a sixth forest type. (ERDA77) A list of plants which are rare, threatened, or of special concern was compiled by the Oak Ridge National Laboratory combining the candidate species included on lists made by: U.S.

Table II-2. Monthly Climatic Summary for the Oak Ridge Area Based on a Twenty Year Record (ATDL72)

Month	Temperature (°F)			Precipitation (in.)*	
	Mean	Maximum	Minimum	Rain	Snow
January	37.9	47.0	28.8	5.3	3.4
February	40.9	51.2	30.6	5.3	2.6
March	47.5	58.7	36.3	5.6	1.3
April	59.0	71.1	46.9	4.4	0.01
May	66.8	79.1	54.5	3.6	0
June	74.0	85.2	62.7	4.0	0
July	76.9	87.3	66.4	5.6	0
August	76.0	86.7	65.2	3.8	0
September	70.1	81.5	58.7	3.3	0
October	59.3	71.3	47.2	2.7	0
November	46.9	57.8	35.9	4.2	0.5
December	39.7	48.8	30.6	5.7	2.5
Annual	57.9			53.5	10.3

*The average annual precipitation in the Oak Ridge area ranges from more than 58 inches in the northwestern part of the area to about 46 in the northeastern part. (McM67) The annual precipitation for the Oak Ridge National Laboratory averages about 2 inches less than the Air Resources Atmospheric Turbulence and Diffusion Laboratory (ATDL) 1972 area report.

Department of Agriculture - Soil Conservation Service, U.S. Department of the Interior - Federal Register, Tennessee Committee for Rare Plants, and A.J. Sharp of the University of Tennessee. Eleven plants in this list are found on the Oak Ridge Reservation and are provided protection. These are: Bugbane, Tall Larkspur, Large Fothergilla, Goldenseal, Canada Lily, Ginseng, Sharp's Mock-Orange, Carey's Saxifrage, Lesser Ladies' Tresses, Nodding Mandarin, and Purple Coneflower. (Pa79, personal communication, P. Parr, ORNL, Dec. 1981)

Over 65 separate species of birds were observed in one survey. Typical species of mammals include mice, shrews, oppossums, raccoons, woodchucks, rabbits, foxes, groundhogs, skunks, and white-tail deer. (ERDA77)

6. Seismology

A seismic risk map of the United States (McC70) shows that the areas of high risk nearest to Oak Ridge are about 640 km (400 miles) away, to the southeast around Charleston, South Carolina, and to the west in the Mississippi Valley. The most recent earthquake experienced in this area (November 30, 1973) had an estimated intensity at ORNL of IV on the Modified Mercalli scale. It produced no observable damage.

D. Radioactive Waste Disposal at ORNL

The need for ground disposal of solid waste materials was recognized during early operations at ORNL. The first two solid waste storage areas (SWSAs) are located in Bethel Valley, close to the sources in the main plant area. These burial grounds were operated during the period 1944 to 1946. Waste materials were placed in unlined trenches and covered with approximately 60 cm (2 ft.) of soil. These two burial grounds covered an area of 2.0 hectares (5.0 acres). There are no records of the amount or type of radionuclides buried here. (Du75) After closure, most of the waste in SWSA 2 was removed and buried in SWSA 3. Stainless steel drums containing liquid plutonium waste were removed intact, but black iron drums containing beta-gamma solid waste had deteriorated to the extent that when they were removed, the surrounding earth also had to be removed for burial.

(Oa77) SWSA 3, also located in Bethel Valley but west of the main plant area, was operated from 1946 to 1951 in the same manner as SWSAs 1 and 2, except that numerous items of equipment were stored above ground within the fenced area. About 2.8 hectares (7 acres) were used. This area was underlain with rock, making excavations difficult. As in the case of SWSAs 1 and 2, there is little information available on the volume or character of materials buried there. Results of an investigation of radioactive release from this burial ground have been published. (Stu81)

Results of a geological survey of the ORNL area, conducted in 1951 under the direction of P.B. Stockdale, showed that the Melton Valley is preferable to Bethel Valley for radioactive waste disposal because the former is underlain by relatively impervious Conasauga shale. (Sto51) Consequently, SWSA 4 was opened in Melton Valley in 1951 and was operated until 1959. However, detailed geologic and hydrologic studies did not precede the selection of this site and it was found that the water table is close to the surface in some parts of the site. A panel of the National Academy of Sciences concluded in 1976 that this site was unacceptable and that remedial action would be desirable. (NAS76)

Beginning in 1951 with Chemical Waste Pit 1, pits and trenches were constructed near SWSA 4 for the disposal of intermediate level liquid waste (ILW). Pit 1 had limited use, apparently because of its location and relatively small size. Large quantities of ILW were discharged into pit 2 beginning in 1952. Other open pits or covered trenches, with their opening dates are: Pit 3, 1955; Pit 4, 1956; Trench 5, 1960; Trench 6, 1961 (short operation because of breakthrough of ^{90}Sr and ^{137}Cs); Trench 7, 1962. The last trench was taken out of service in 1965 when hydrofracture was used for the routine disposal of ILW. During operation of these pits and trenches, approximately 160 million liters (42 million gallons) of waste containing more than one million curies of mixed fission products were disposed of. The radionuclides of major significance in the waste were ^{90}Sr (190,000 Ci), ^{137}Cs (630,000 Ci), and ^{106}Ru (245,000 Ci). (Tabulated from the ORNL Radioactive Waste Disposal Operation Reports) Lesser amounts of trivalent rare earths (TRE) and ^{60}Co were also released into the pits and trenches. A study of migration of radionuclides from this area has been reported. (Du75)

SWSA 5 was opened in 1959 and closed to routine burial operations in 1973. A part of this burial ground, which covers 13.4 hectares (33 acres), continues to be used to provide retrievable storage for TRU wastes. Duguid (Du75) reported the presence of radioisotopes in water samples from the routine burial area, including ^{244}Cm. Measures have been taken to reduce water leaching of buried wastes and they have been at least partially successful.

SWSA 6, covering an area of 27.5 hectares (68 acres), was opened in 1973 and is currently used for routine burial of low-activity-level solid radioactive wastes and storage of fissile non-alpha (^{235}U) wastes. Like SWSA 5, it has a problem with leaching of buried low-level wastes due to high water table levels, particularly during the late winter-early spring rains.

III. CHARACTERISTICS OF BURIAL SITES

A. Topography, Geology, and Soils

In the ORNL area, the succession of ridges and valleys from southeast to northwest is Copper Ridge, Melton Valley, Haw Ridge, Bethel Valley, and Chestnut Ridge. Bethel Valley, the site of the principal buildings of ORNL and of the first three burial grounds, has been described as a portion of an elongated, northeast-southwest trending trough drained by several small streams that are tributaries to the Clinch River. (Sto51) It is underlain by non-resistant limestones and shaley limestones of the Chickamauga Formation. The trough is bounded on the southeast by Haw Ridge, made up of resistant sandstone of the Rome Formation, and on the other side by Chestnut Ridge with cherty dolomite of the Knox Formation. The floor of the trough has an average width of about 300 meters (1000 ft). The lowest elevation of the Bethel Valley floor is 235 meters (770 ft) where White Oak Creek passes through Haw Gap. The highest points on Haw Ridge have an elevation of approximately 317 meters (1040 ft). Melton Valley, between Haw Ridge and Copper Ridge, is underlain by members of the Conasauga Group which have a total thickness of approximately 457 meters (1500 ft). (Sto51) The base of this layer, referred to as the Pumpkin Valley unit, is the formation into which radioactive waste is injected by hydrofracture. (ERDA77) Because all of the geologic units dip to the southeast, each formation tends to outcrop in a long linear band; to the southeast of its outcrop area, Pumpkin Valley shale underlies other formations at increasingly greater depths. (personal communication, D. Webster, USGS, Dec. 1981) For example, the Pumpkin Valley Shale occurs at the surface in SWSA 4 but, in the vicinity of the hydrofracture facility, data obtained from examination of the core from the Joy Test Well indicated that this formation extends from 211 meters (692 ft) to 305.4 meters (1002 ft) below the surface. (deL68) Within SWSAs 5 and 6, two or more formations, including the Maryville Limestone, may occur at the surface. Therefore, the early conclusion that the surface in this area is underlain by "relatively impervious Conasauga Shale" has not been confirmed by later observations and operating experience. It would be more accurate to say that the area is underlain by the Conasauga Group which consists of a

number of interbedded shale, siltstone, and limestone units having varying degrees of permeability.

Webster (We76) summarizes results of geological studies of the ORNL area. (Sto51, Ba54, deL56, deL58, Lo61, Co61, McM63, McM65, Lo65) The Chickamuaga Limestone which underlies Bethel Valley and SWSAs 1, 2, and 3 (Fig. III-1) is composed primarily of limestone, but shales, siltstones and bedded chert are also present. Fractures and solution openings between beds of the Chickamauga Limestone result in uncertainty in regard to ground water movement and this makes radionuclide monitoring difficult. As a result, this formation is regarded as undesirable for waste disposal. The lithologic character of the Conasauga Group that underlies Melton Valley is variable, both along strike and in superposition, as was mentioned above. In the waste disposal areas, the unit contains shale, siltstone, and limestone. All the formations in the ORNL area strike northeast at about 56^{o} and have an overall dip of about 30^{o} to 40^{o} southeast.

Soils in the ORNL area have been characterized as silty, with considerable amounts of clay present, and with a pH ranging from 4.5 to 5.7. (Co61) The weathered zone in the areas underlain by the Chickamauga Limestone is thin, generally less than 3 meters (10 ft). In areas underlain by the Conasauga Group, the depth of weathering is related to topography: thin in low-lying areas and thicker on the ridges. At SWSA 4, the weathered zone ranges from 1.2 to 4.9 meters (4 to 16 ft) (Lo61); at SWSA 5, up to 12 meters (from "a few feet" to 40 ft) (Co61); at SWSA 6, generally, 1.5 meters or less to 12 meters (5 to 40 ft). (Lo65) The principal minerals in the weathered Conasauga Group are illite and vermiculite. The sorptive properties of each of the clay minerals vary for specific radionuclides. (We76)

B. Hydrology

1. Surface Water

An early study of hydrologic features of the ORNL site was made by DeBuchananne. (Sto51) He states that the section of Bethel Valley in which the main part of ORNL is located, is drained by White Oak Creek and its tributaries (Fig. III-1). As was mentioned in Section III.A above,

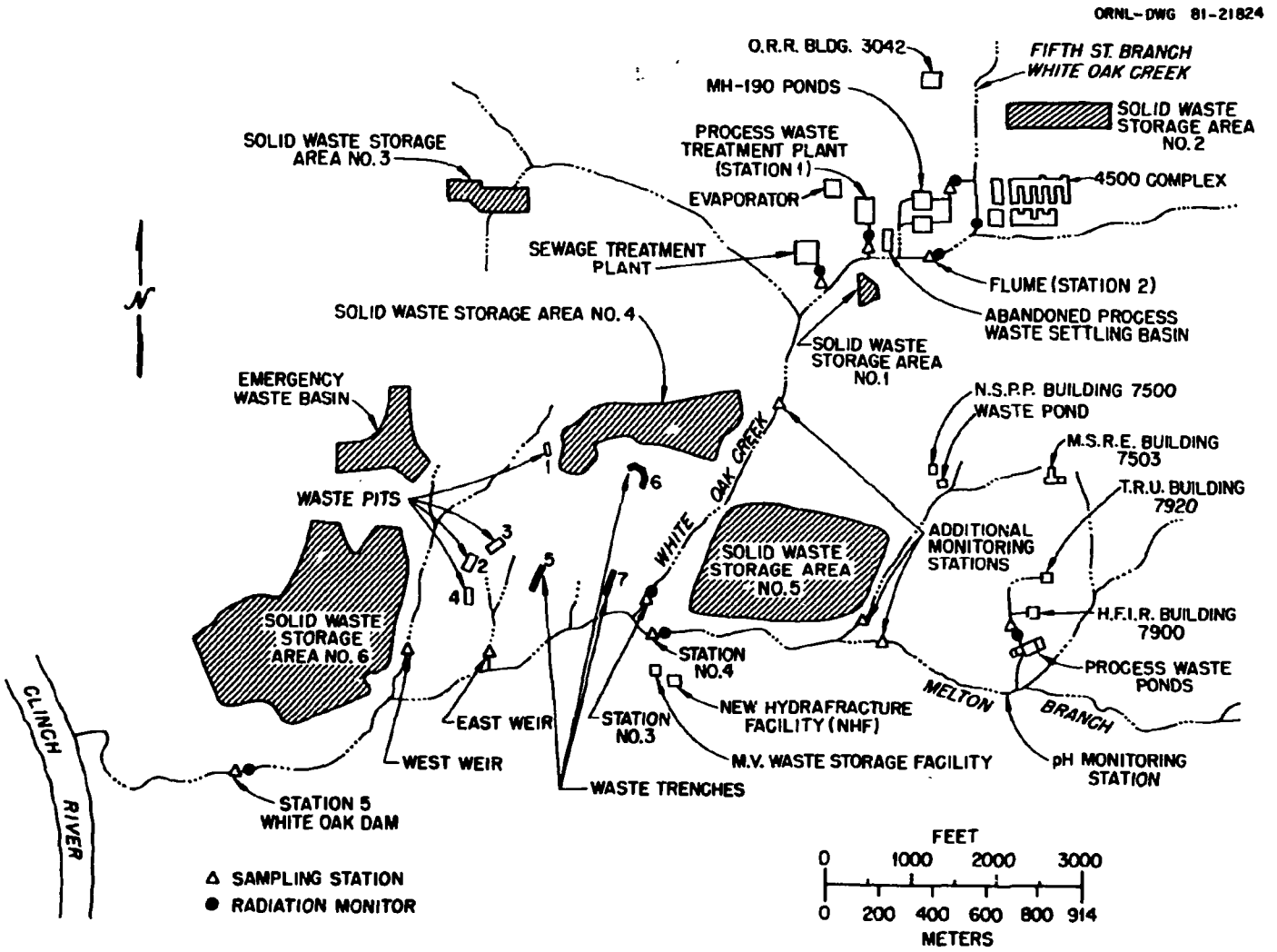

Fig. III-1. Bethel and Melton Valley watershed.

White Oak Creek flows out of Bethel Valley through Haw Gap at an elevation of 235 meters (770 ft). After passing through the gap, it is joined by Melton Branch and then flows south-southwest into the Clinch River, approximately 3.3 kilometers (2.0 miles) away. Flow to the Clinch River is controlled by White Oak Dam, located approximately 1.0 km (0.6 mile) from the mouth of the creek, which forms White Oak Lake.

A later study of the hydrology of the Oak Ridge area provides data on runoff in area streams. (McM67) The seasonal variation in runoff, averaged for the water years 1961-1964 and adjusted to the 1936-60 water years, is as follows in terms of percentage of annual runoff: October-December, 17%; January-March, 49%; April-June, 23%; July-September, 11%. McMaster states that a large part of the runoff is derived from discharge of stored ground water. The periods of maximum and minimum runoff correspond to the variations in rainfall. These data represent averages for the Oak Ridge area but they presumably apply to the burial ground sites.

Climatic conditions can have a significant effect on the near surface disposal of radioactive wastes. Richardson (Ri63) pointed out that climate is a primary factor affecting waste disposal at Oak Ridge. Richardson states:

> "The relatively large amount of rainfall at Oak Ridge has several effects. It causes the water table to occur at shallow depths and is responsible for seasonally large stream flow; it contributes to the development of a high drainage density, thereby reducing the distance between points of ground-water recharge and discharge and the length of time of ground water residence; it lowers soil pH and influences the development of clay minerals that can control or modify the migration of radioactive ions; and in a less direct fashion it governs the composition of the natural biological community. Thus, the ultimate behavior and safety of the burial grounds are related to climate." (Ri63)

Webster has summarized geologic and hydrologic information that affect movement of radionuclides from waste disposal sites at ORNL. (We76) According to Webster (We76), White Oak Creek is both the natural drainage and an integral part of the laboratory's waste distribution system,

conveying contaminants from various parts of the ORNL complex to points beyond the Reservation. He also pointed out that the natural flow of water into the creek is augmented by water piped into ORNL from outside the drainage basin and subsequently discharged to the creek as treated process waste water, laundry water, sanitary sewage, and reactor cooling water effluent. During prolonged periods of dry weather, the discharge from these sources often comprises a major fraction of creek flow.

2. Ground Water

Data on the ground water table in Bethel Valley were reported by DeBuchananne (Sto51) but the more recent studies in the Melton Valley cited by Webster (We76) are of greater interest because this is the area currently in use. Fig. III-2 shows the water table for Burial Ground 5 during December 1959 while Fig. III-3 gives less detailed data for the White Oak Creek drainage basin during March 1963. The maps show that the water table is a subdued replica of the topographic surface. The depth to the water table varies seasonally and is generally greatest during September and October and least during the period January through March. For Melton Valley, water has been found at a depth of less than one foot near drainages and as deep as 67 feet beneath the line of low hills along the northwest side of the valley. (We76)

McMaster says that the residual material over the Conasauga is less compact and the water-bearing openings are larger than unweathered bedrock. (McM67) As a consequence, the residuum bears most of the ground water in the Conasauga Group outcrop belt. The thickness of the residuum in these belts is less than 10 meters (30 ft) in most places. Consequently, the volume of ground water storage is small and is nearly depleted by September or October. He also states that annual water loss by evaporation and transpiration amounts to about 76 cm (30 inches), which is about 55% of the annual rainfall. During the July-September quarter at least 80% of the rainfall is returned to the atmosphere. Rainfall averages 29 cm (11.5 inches) and runoff, partly from ground water storage, averages only 5.8 cm (2.3 inches).

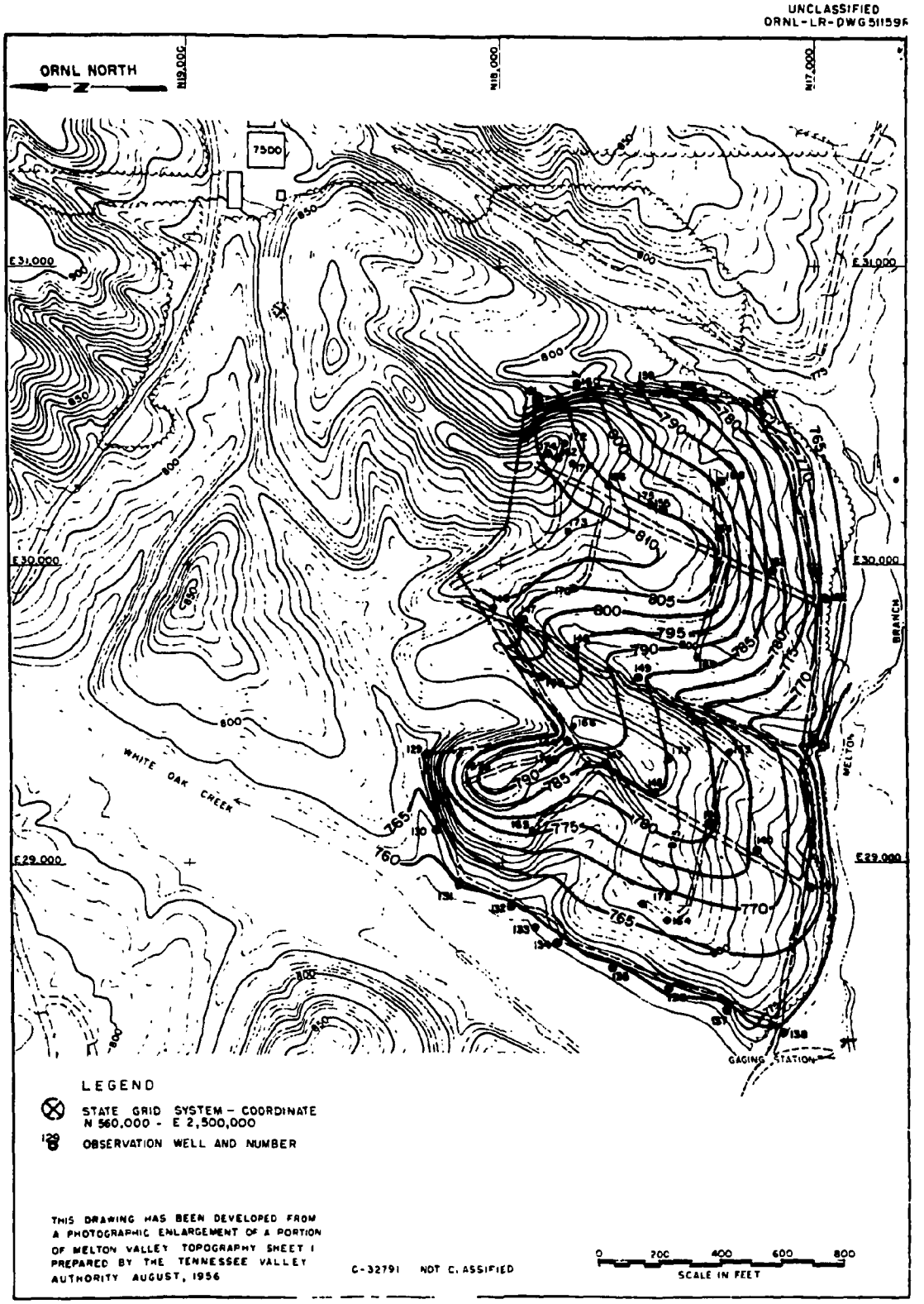

Fig. III-2. Water-table contour map for SWSA 5, December 1959.

Fig. III-3. Map showing general depth to groundwater in the White Oak Creek drainage basin during March 1963.

Webster points out that water table contour maps, such as that shown in Fig. III-2, can be useful in predicting the direction of ground water flow, indicating the areal hydraulic gradient from which the overall trend in movement can often be inferred. (We76) The influence is restricted to the residuum because the direction of movement in the underlying limestone and interbedded strata is influenced more strongly by directional differences in permeability. He further states that inspection of the maps in the above-mentioned figures indicates that water flow in the residuum in mapped areas is toward White Oak Creek or its tributaries, except in a small area in and west of SWSA 3. Webster recommended that detailed water maps be prepared for all existing and future burial grounds. Data on the water level in wells around three of the burial grounds for the period 1975-1979 are available, and data on the fourth is in press. (We81a, We81b, We81c)

Webster (We76) summarized and interpreted the results of four separate studies of fluid movement in the Conasauga Group of Melton Valley. (Mo54, Stru55, deL58, Co61, Lo64, and Lo67) He suggests that a composite picture of flow in the Conasauga Group through the total column of saturated material would show

1) a zone at and immediately below the water table where the largest component of flow corresponds to the direction of hydraulic gradient, especially during the spring when the water table is high. The probability of this zone being present decreases as the depth to the water table increases;

2) an underlying transitional zone where significant components of flow are oriented parallel to both strike and hydraulic gradient; and

3) a thick zone in the fractured rock where the major component of flow parallels the strike.

Thus, according to Webster, the available evidence suggests that those factors controlling ground water movement in the Conasauga Group change with depth.

Measurements of the rate of ground water movement in the Conasauga Group have been made by monitoring the movement of tracers from injection wells to observation wells. Measurement of the velocity of fluid movement

along strike from Chemical Waste Pits 2 and 3, under a steep hydraulic gradient, gave values ranging from .6 to 1.8 meters (2 to 6 ft) per day and from Chemical Waste Pit 4, 3 to 9 meters (10 to 30 ft) per day. (deL58) Movement across strike was found to range from 0.12 to 0.24 meters (0.4 to 0.8 ft) per day from Pits 2 and 3, and from [illegible] to 0.46 meters (0.1 to 1.5 ft) per day from Pit 4. (Bla57) A tracer study made three to four years after pit operation terminated, when it is presumed that the water table had receded to approximately its natural position, indicated a velocity of 0.17 meters (0.56 ft) per day along strike for the first 1.5 meters (5 ft) and only slightly less out to a distance of 3.05 meters (10 ft). (Lo67)

Upward movement of contaminated ground water can occur. Where the water table is shallow, evaporation of water into the atmosphere can be expected but, as Webster points out, the only radionuclide expected to migrate to any extent by this process is tritium. Studies near the waste pits (Au58) showed that ^{106}Ru had been accumulated from ground water by trees and deposited on the ground in fallen leaf litter. Other studies at ORNL (Stru62) showed that ^{60}Co, ^{137}Cs and ^{90}Sr can be translocated from ground water by this mechanism.

C. Climate

Climatic conditions in the ORNL area are not likely to be sufficiently different from those discussed in Section II.B.4 for the Oak Ridge area to warrant a separate discussion.

D. Ecology

1. Flora

The natural flora typical of the Oak Ridge Reservation (see Section II.C.5) that was probably originally present in the various areas used for waste disposal was removed prior to their use for burial of solid wastes or disposal of liquid wastes. In general, the growth of deep-rooted plants in these areas is discouraged both during use and after closure. The ground is seeded with a mixture of grass accompanied by application of lime and fertilizer in order to minimize erosion. (Ros81) An exception to the above general statement may be noted in the case of SWSA 3 where trees were

allowed to grow unhindered for a number of years after its closure in 1951. However, the trees were removed, along with items of contaminated equipment that were stored on the surface, in 1979. (We81a) The area was seeded with grass after it was cleared.

2. Fauna

The animal populations captured or observed on the Oak Ridge Reservation include small mammals (mice, chipmunks, and land shrews) and large mammals (squirrels, opossums, rats, muskrats, foxes, weasels, bobcats, groundhogs, skunks, and deer). Mammalian species inhabiting old field or disturbed areas are reported to be quite similar, whether the vegetative cover is grass or tree seedlings and shrubs. (Ki76) Small mammals trapped in a one-hectare study of such an area included rats, mice and shrews. Since an effort is made to keep the grass cut in seeded areas, this would tend to discourage the intrusion of deer but they do occasionally enter the area.

IV. DISPOSAL OF LOW-LEVEL RADIOACTIVE WASTE

A. Solid Wastes

1. Background

Oak Ridge National Laboratory (ORNL) is one of the oldest nuclear centers in the United States, having its origin in the Manhattan Project during World War II. Solid, liquid, and gaseous radioactive wastes have been produced at ORNL for nearly four decades and have been disposed of in a manner which is safe to its employees and the public. (We79) Over the years, a variety of liquid-waste treatment and disposal processes have been used at ORNL.

Shallow land burial has been used for disposal of solid low-level radioactive waste since the beginning of waste management operations at the Oak Ridge National Laboratory. (Du76a, Brow59, Ab55) These wastes have been routinely buried in shallow unlined trenches in the vicinity of the Laboratory and covered with soil, or concrete followed by soil. (Du75, We79)

The initial suggestion for burying waste appears in a memorandum dated January 5, 1943*, by Dr. S. T. Cantril of the Medical Department of the Central Safety Committee shortly after the graphite reactor attained criticality in late 1943 and plutonium separations began. (We79) Dr. Cantril stated:

> "It would seem that provision has not been made for the disposal of actively contaminated-broken glassware or materials not sufficiently clean to be used in other work. I am suggesting that a metal trash can with cover, with red lettering on the can, be provided for the disposal of such material as can be placed in the trash can. Mr. Schwertfeger has suggested that a suitable location for the burying of this material could be provided over on the burning ground. A suitable pit with enclosed fence could be made."

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*The date of this memorandum appears to have been a "turn-of-the-year" typographical error. Because the Laboratory did not become operational until the late fall of 1943, it seems probable that the correct date of the document is January 5, 1944.

This suggestion was accepted by the committee and solid waste storage area 1 was subsequently opened in early 1944. (We76) Therefore, it appears that the shallow land burial process began as a carryover from the method of disposing of municipal waste by burial in a sanitary landfill. (We79)

2. Operations Producing Waste (On- and Off-site)

Solid waste at ORNL originates from nearly every operating facility. The sources that contribute the bulk of the solid radioactive waste generated at ORNL are (GC80, 1977 Intralaboratory Correspondence from J.O. Duguid et al. to Distribution):

- o Reactors
- o Radioisotope operations
- o Particle accelerators
- o Hot cell operations
- o Physical, chemical, and biological research
- o Analytical laboratories

From 1955 to 1963, ORNL's solid waste storage areas were designated by the Atomic Energy Commission (AEC) as the Southern Regional Burial Ground. About one million cubic feet of solid waste from various off-site installations were buried in solid waste storage areas (SWSAs) 4 and 5. (1960 Intralaboratory Correspondence from E.G. Struxness to Distribution) During this period, ORNL served as a major disposal site for wastes from such facilities as Argonne National Laboratory, Knolls Atomic Power Laboratory, Mound Laboratories, Battelle Memorial Institute, General Electric Company in Evendale, Ohio, and about 50 other off-site installations. Among the other off-site sources were AEC installations, small contractors, research institutions, and numerous private and public isotope users. (Stra64)

Today, the ORNL burial grounds serve as disposal and storage areas for packaged and unpackaged solid radioactive wastes from operations at Oak Ridge. In addition, small amounts of off-site low-level solid wastes are

buried or stored (at ORNL) in special circumstances when the Department of Energy directs the Laboratory to do so. (1960 Intralaboratory Correspondence from E.G. Struxness to Distribution, personal communication, E. King, Oct. 1981)

3. Types of Wastes

a. Background

As mentioned earlier, a variety of radioactive wastes have been generated and disposed of at ORNL since waste disposal operations began in early 1944. The bulkiest and least contaminated wastes generated on-site have been laboratory refuse. These wastes consist mainly of paper, glassware, scrap metal, dirt, various filter media and frames, lumber, oils, powder, wire, depleted uranium, animal carcasses used for biological experiments, and experimental equipment that cannot be economically decontaminated. (GC80, NAS76, B165, Brow59) An additional source, but lesser volume of waste, comes from a variety of chemical and physical research and development activities. Worn out contaminated equipment and concrete flooring and building materials contaminated by spills or leaks has also been buried. (NAS76)

The variety, character, and exact amount of wastes which came from off-site installation during the period from 1955 to 1963, when ORNL served as the Southern Regional Burial Ground, is not known, but it is estimated that about 50% of the burial space in SWSA 4 was used during this period. (Brow59, Lo61, NAS76) A summary of the waste disposed for 1957 and 1958 in SWSA 4 is shown in Table IV-1. (Lo61) The volumes of solid low-level non-TRU radioactive wastes buried in SWSAs 5 and 6 from 1970 through 1978 are given in Table IV-2. (Ga79)

b. Methods of Collection, Treatment, and Conditioning

The prime considerations in collecting contaminated solid wastes at ORNL have been personnel safety and the prevention of the spread of contamination. Galvanized garbage cans, painted yellow and marked with a radiation symbol, have been used as solid waste collectors. These cans are leak-proof and fitted with a plastic liner and a suitable cover to prevent

Table IV-1. Solid-Waste Burials for 1957 and 1958 (Lo61)

Agency	1957		1958	
	Volume ($ft^3 \times 10^3$)	Percentage	Volume ($ft^3 \times 10^3$)	Percentage
ORNL	142	55.7	158	47.0
Y-12	10	3.9	15	4.4
U.T. Agricultural Experimental Station	4	1.6	4	1.3
ORINS	1	0.4	1	0.3
Oak Ridge Processing Co.	6	2.3	16	4.8
Knoxville Iron Co.	4	1.6	11	3.2
K-25	4	1.6		
Off-Site Shippers				
KAPL	25	9.8	52	15.5
ANL	29	11.4	34	10.1
GE	7	2.7	19	5.6
Mound Laboratory	14	5.5	11	3.3
Radiological Service Co.	4	1.6	4	1.2
BMI			4	1.2
Others	5	1.9	7	2.1
Totals	255	100	336	100

Table IV-2. Summary of Volumes of Solid Low-Level Non-TRU Radwastes Buried and Burial Space used from 1970 through 1978 and Forcasted Burial Land Requirements from 1979 through 1985 at ORNL (Ga79)

	Volume[a] (x1000) ft3	Burial Space at Areas 5 and 6[b] Used and Forecasted, acres
1970	163	0.8[c]
1971	134	0.8[c]
1972	122	0.6[c]
1973	103	d
1974	116	d
1975	108	d
1976	119	d
1977	76	d
1978	82	d
1979-1985	80/year	0.85/year
TOTAL		11.9

Reference: personal communication from Julian R. Gissel, UCC-ORNL, December 29, 1978, and Julian Gissel and Edward King, UCC-ORNL, January 26, 1979.

[a]Radwaste quantities include solid beta-gamma radwaste and relatively minor amounts of uranium contaminated materials. These volumes do not include TRU radwastes which are being retrievably stored at the Solid Waste Storage Area 5. Volumes include radwastes generated during routine D&D activities, i.e., modifications to existing structures and laboratories. Beginning in 1979 and continuing through 1981, there are planned D&D activities that could considerably increase the forecasted radwaste volumes at ORNL, although actual estimates for nonroutine D&D activities are not available. The estimated 80,000 ft^3/yr includes routine D&D volumes, but does not take into account potential nonroutine D&D activities.

[b]This acreage is located in the Solid Waste Storage Area 5 and 6, and includes lost space due to roads, space between trenches, etc. It does not include unusable acreage due to terrain, shallow water table, etc.

[c]Radwastes for these years were buried in Area 5; thereafter, Area 5 was closed except for retrievable storage of TRU contaminated radwastes.

[d]For this six year period (1973 through 1978), non-TRU radwastes were buried in Area 6, and a total cumulative burial space of 5.9 acres was used.

the spread of contamination during handling. Larger volume wastes are placed in Dempster Dumpsters which are located outside certain buildings. Personnel who handle radioactive solid wastes are provided with protective coveralls, shoes or boots, and cloth or rubber covered gloves, as required.

The only current treatment of solid low-level waste is segregation and compaction. Solid, low-level noncompactible waste is collected in yellow Dempster Dumpsters located at about 20 points within the laboratory and transported to solid waste storage area 6 for disposal. (GC80) Solid, low-level compactible waste (<200 mR/hr) is placed in plastic bags and collected in yellow walk-in dumpsters. When these dumpsters are full, wastes are transported to the compactor facility where they are compacted before burial. (personal communication, E. King, ORNL, Oct. 1981)

A Consolidated Baling Company compactor is used to compact waste and produces bales in rectangular cardboard boxes about 0.50 x 0.76 x 1 meters (0.4 m^3 or 15 ft^3) weighing 300 kg (670 lbs). Use of the compactor began in July 1978. Presently, about 17% of ORNL's solid low-level waste is compacted. (GC80, personal communication, E. King, Oct. 1981) Before compaction, about 90% of the solid low-level waste has a radiation level of less than 10 mR/hr while the remaining 10 percent ranges from 10 to 200 mR/hr. (GC80) Current operations are achieving a compaction ratio of about 9 to 1 (Fig. IV-1).

c. Modes of Disposal

The methods used in the beginning and throughout the ensuing period of shallow land burial operations at ORNL are not significantly different than present methods. Present burial methods are somewhat similar to sanitary landfill operations, but the areas require a greater amount of surveillance and maintenance because of the radioactivity of the contents. Waste had been placed in unlined trenches and covered with about 60 cm (2 ft.) of soil to provide shielding against direct exposure. (Du75) Currently the waste is covered with about 90 cm (3 ft.) of soil. (personal communication, T. Grizzard, ORNL, Oct. 1981) In some areas, trenches containing alpha contamination have been covered with concrete prior to

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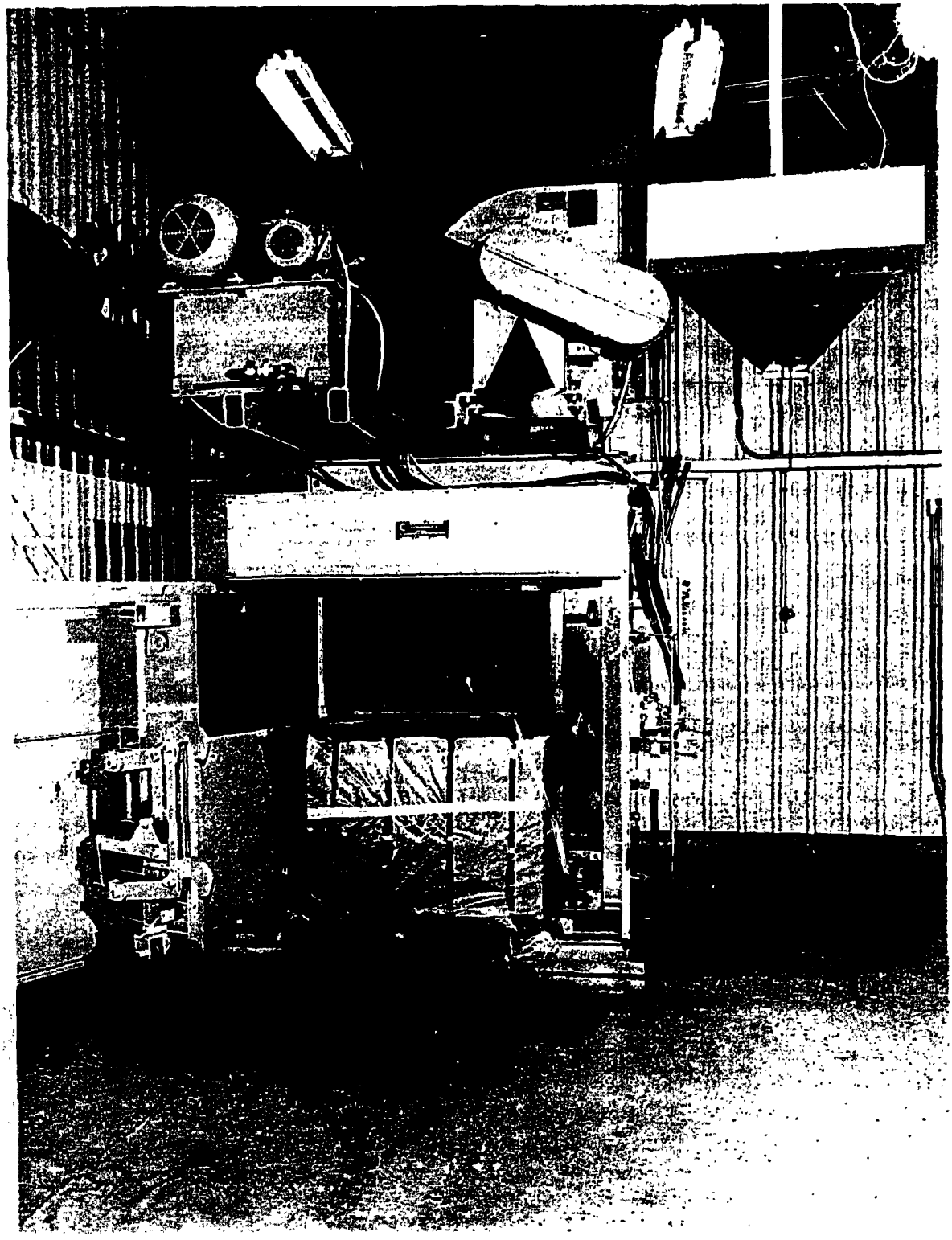


Fig. IV-1. Compactor.

back filling with soil. Higher-level solid waste was disposed of in auger holes in such a way as to assure criticality control.

4. Specific Storage Areas

a. Background

Six solid waste storage areas (SWSA) have been used since 1944. (1972 Intralaboratory Correspondence from W.O. Burch et al. to Distribution, Oa79c, Du76a) These burial grounds were numbered consecutively in the order in which they were first used (Table IV-3).

The Oak Ridge SWSAs are located in either Bethel or Melton Valley and are separated by Haw Ridge. SWSAs 1, 2, and 3 are sited in Bethel Valley while 4, 5, and 6 are located in Melton Valley. (Oa79c) During the operational periods of SWSAs 1, 2, and 3, wastes were placed into trenches and backfilled. However, few historical records are available for these burial areas, and records which were kept for SWSAs 3, 4 and part of SWSA 5 were accidentally destroyed by fire in 1961. (1972 Intralaboratory Correspondence from W.D. Burch et al. to Distribution, NAS76)

b. Site Selection

ORNL was intended to be a temporary facility, as was the burial of radioactive wastes generated during its operation. (We79) The first three SWSAs were located primarily for convenience, with very little geologic or hydrologic considerations given to site selections. (We76) As the volume of waste at ORNL increased and the quantity and variety of solids from off-site agencies expanded when ORNL was the Southern Regional Burial Ground, greater attention was given to the selection of sites for burial areas. (Co61, 1977 Intralaboratory Correspondence from J.O. Duguid et al. to Distribution, Oa79c) The following criteria are currently used in selecting burial sites: "representative" hydrogeological properties, accessibility, available space, and approval by the Operations Division. (Cu80)

Table IV-3
Operational Status OF ORNL Solid Waste Disposal Areas (GC80)

Site	Operating Dates	Status	Acreage	Notes
1	1944	Closed	1.5	No geologic or hydrologic exploration
2	1944-1946	Closed	3.5	
3	1946 - 1951	Closed	7	
4	1951 - 1959	Closed	23	Shale
5	1959 - 1973	Closed except for TRU waste	33	3.5 acres available for retrievable storage
6	1969 - Present	Operating	68	

c. SWSA 1

SWSA 1 is a 0.6 hectare (1.5 acre) site located on the north side and at the foot of the Haw Ridge and southeast of White Oak Creek in Bethel Valley. It appears that the specific location was selected primarily on the basis of its proximity to the laboratory with no consideration of the potential of waste leaking into nearby water systems. (Oa79c, We76)

The earliest record of burials is contained in a memorandum from O.H. Greayer to M.F. Acken-J.B. Sutton on April 28, 1944. On that date, cans with red tops were placed in the 706-A Building for the collection of waste materials that could not be disposed of through the drains, such as Lusteroid bottoms and cloths used to wipe up minor spills. According to one oral account (reported in We76), the first cans were dumped in a long, curving ravine at the foot of Haw Ridge. An inspection of the topographic maps made in 1942 by the Stone and Webster Engineering Corporation suggests that this is the shallow depression that lies immediately east and outside of the area now designated as SWSA 1. According to another account, the cans were first placed in auger holes at the east end of the designated site, and later trenches were excavated to receive the waste. However, only a small number of trenches were dug, and it is reported that the site was abandoned when water was found in a trench excavated north of the present road that crosses the burial ground. (J.E. Brandon, oral communication to D.A. Webster, 1974) This burial ground lies in the path of surface water drainage from Haw Ridge to White Oak Creek, thus making it susceptible to marsh development in the topographically low portions of the area following periods of heavy rains and wet seasons. A diagram showing the orientation and approximate location of the trenches is given in Figure IV-2.

It is suspected that only a small amount of solid radioactive waste was buried in SWSA 1 since fissionable material was conserved and the operations did not include isotope separation and concentration during its use. (NAS76) There are no available records showing the quantity or types of solid waste disposed of in SWSA 1. (Oa79c)

Aside from a site survey of surface contamination in 1946 and 1975, respectively, very little monitoring data are available for this

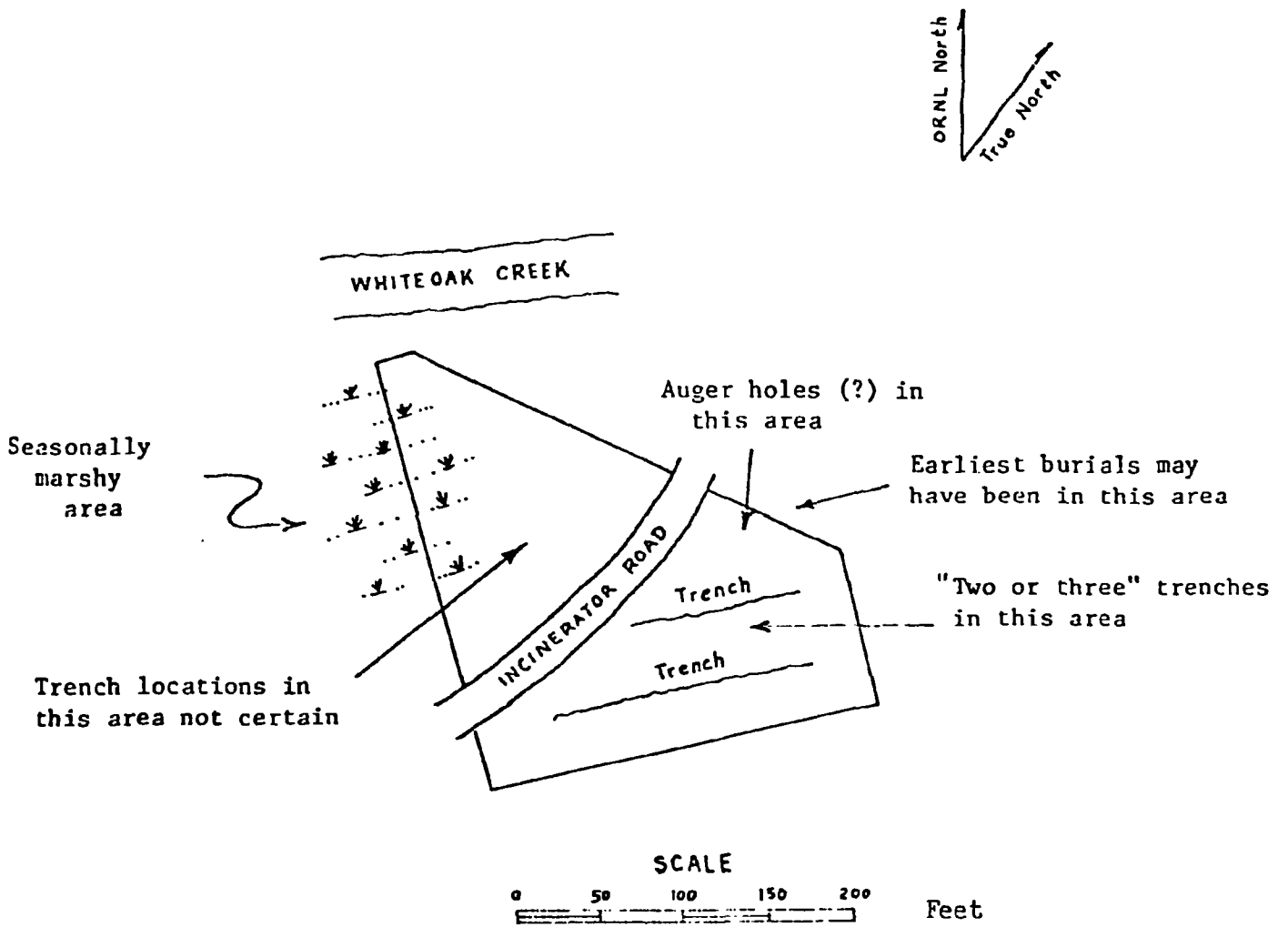


Fig. IV-2. Schematic diagram showing the orientation and approximate location of trenches in SWSA 1.

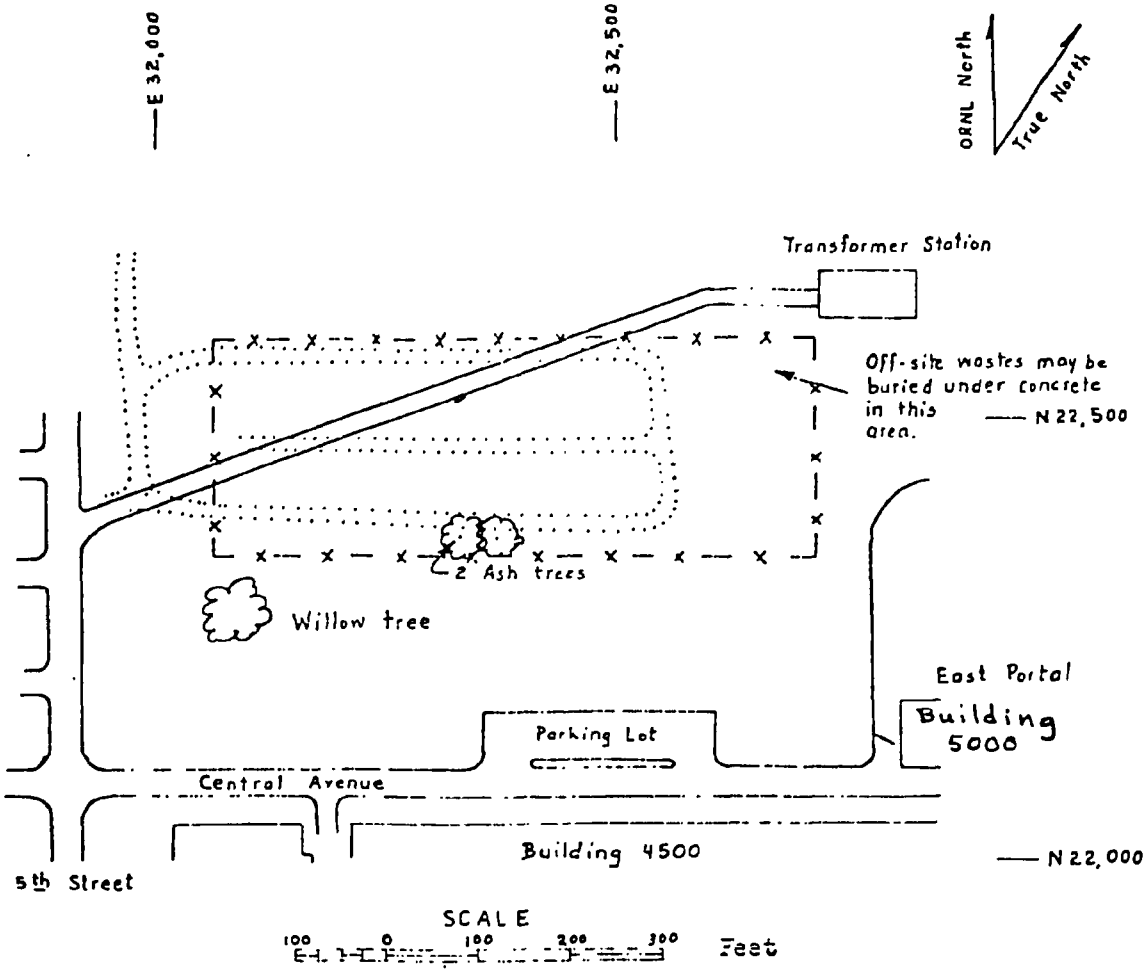
disposal area. Burial ground monitoring was first documented in 1946 when SWSA 1 was surveyed for ground contamination. Seven soil samples were collected and analyzed for alpha activity in 1946 and showed that only two areas had radioactive contamination above background levels. However soil analysis in 1946 was questionable. (personal communication, T. Tamura, ORNL, Dec. 1981) The next recorded monitoring activity at this site occurred in 1973 when water samples were taken from a seep and two wells (subsequently removed) near, but outside of, the lower end of the burial ground. Analyses indicated that water from one of the wells contained a minor concentration of ^{90}Sr. In 1975, water samples from two wells and a surface seep were analyzed for ^{90}Sr, ^{137}Cs and transuranic elements. The results from one of the wells indicated low concentration of ^{90}Sr (9.4 dpm/ml) and no detectable quantities of ^{137}Cs or transuranic elements. (Oa79c, Du76b, Du75)

d. SWSA 2

SWSA 2 began operation after closure of SWSA 1 in 1944. It is a site of about 1.2 hectares (3 acres) located in Bethel Valley, north of SWSA 1 and northwest of White Oak Creek, on the lower half of a hill near the east entrance of ORNL. (Oa79c, NAS76, We76) The site's boundaries and probable location of the site's two trenches are shown in Fig. IV-3.

It is not certain what the criteria were for selection of SWSA 2. The primary consideration may have been the reduction of personnel exposure during transportion of waste. An additional possibility is that, since the site is near the graphite reactor and chemical separations plant, it would be a convenient location to dispose of laboratory wastes. Other factors, suggested by persons knowledgeable of events at that time, include the desirability of an area with all-weather access, little potential for future construction of buildings, and the absence of swampy conditions. (We76)

There are no available records documenting the quantity or type of waste disposed of in SWSA 2. However, it has been established that beta- and gamma-contaminated solid waste was placed in black iron drums and buried in the trenches. In addition, liquid waste contaminated with



EXPLANATION

X—X—X—X— Former fence around burial ground.

:::::::::::: Roads in and near burial ground at time of use.

Fig. IV-3. Diagram showing location of SWSA 2 relative to present features.

NOTE: Diagram of SWSA 2 based on comments by persons familiar with the former site. The site's boundary, based on an old map is indicated by the fenced line. However, the most probable location of the two trenches is between the roads shown on the diagram. (We76)

plutonium was placed in stainless steel drums and either buried in trenches or stored above ground in a ravine in the denuded slope that eroded. (We76) SWSA 2 was closed in 1946 when it was determined that it was not compatible with the long-range land-use planning at the Laboratory. Following closure of SWSA 2, the stainless steel drums containing plutonium-contaminated liquid waste were removed intact and transferred to SWSA 3, but the iron drums containing beta- and gamma-contaminated solid waste had deteriorated, thus requiring careful removal. Due to the deteriorated state of the iron drums, the drums and the surrounding soil in SWSA 2 were also removed and reburied in SWSA 3. Sometime during the period 1946-1949, the hillside of SWSA 2 was bulldozed, backfilled and contoured to smooth out the irregularities, and seeded. (Oa77, NAS76)

In 1977, core samples were taken at various points in SWSA 2 and water samples were then collected from the core holes. The soil was analyzed for uranium, plutonium, and ^{137}Cs; the results indicated lower levels than samples collected in 1976 from 16 sites throughout eastern and central Tennessee. Likewise, water samples, which were analyzed for tritium, gross alpha, and gross beta activity, had levels not significantly different from background samples. (Oa76)

SWSA 2 is currently neither fenced nor marked to readily identify its location on the hillside north of Building 4500. (Fig. IV-4) The site is now covered by grass that has stabilized the soil. To further reduce erosion, a contour ditch was installed to direct runoff from points above the burial ground around the hillside without crossing the trench area. Surface water runoff from within the site is carried by another ditch to the storm sewer system.

e. SWSA 3

SWSA 3 was opened in 1946 and was used primarily for the disposal of contaminated trash, laboratory equipment, and other discarded materials. It is located in Bethel Valley, about 0.8 km (0.5 mi.) west of SWSA 1, and 1 km (0.6 mi.) west of the west entrance to ORNL. (Oa79c) A diagram of the burial ground is shown in Fig. IV-5. As in the case of SWSAs 1 and 2, little information is available on the volume, character, and location of

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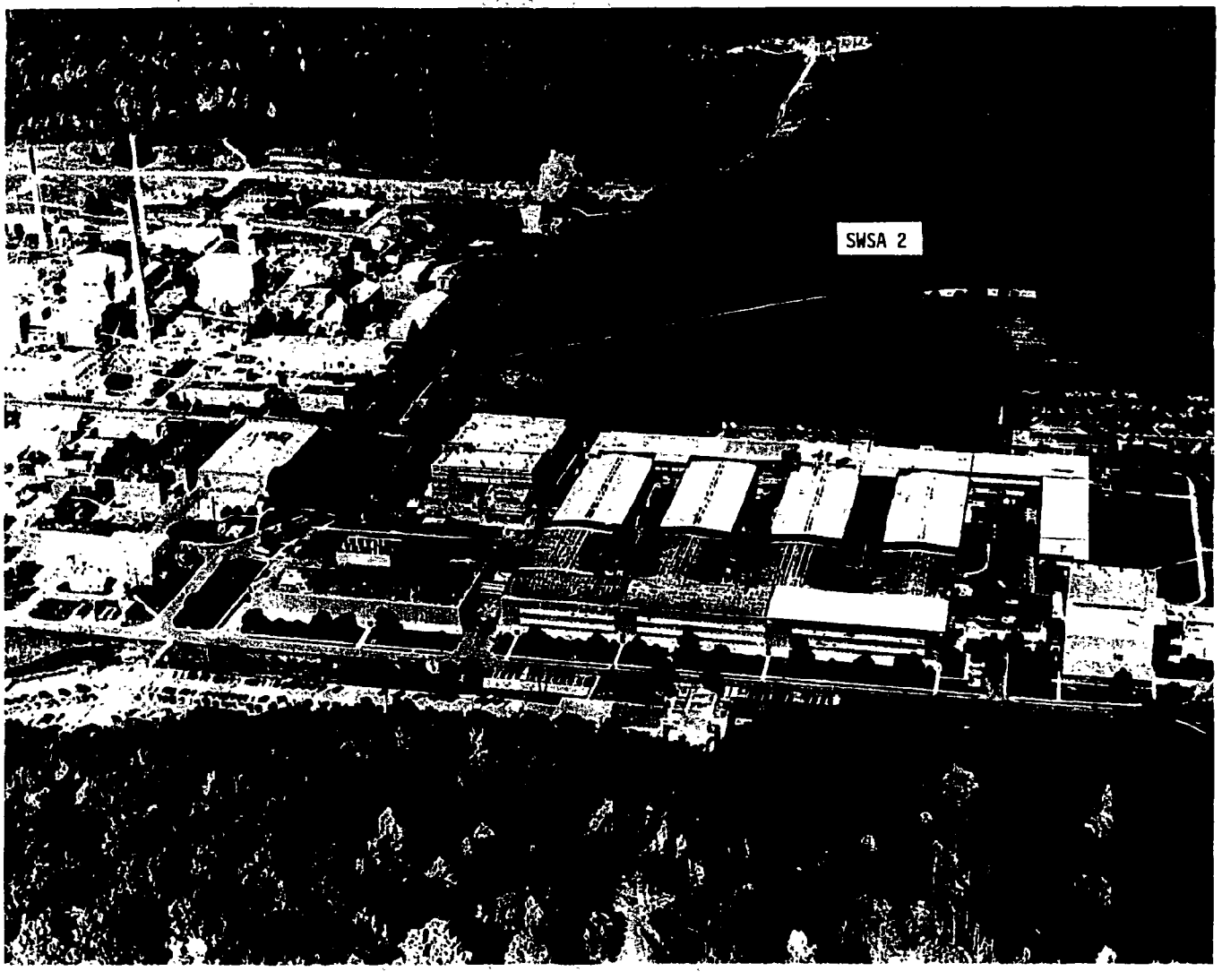

Fig. IV-4. Photograph of SWSA 2.

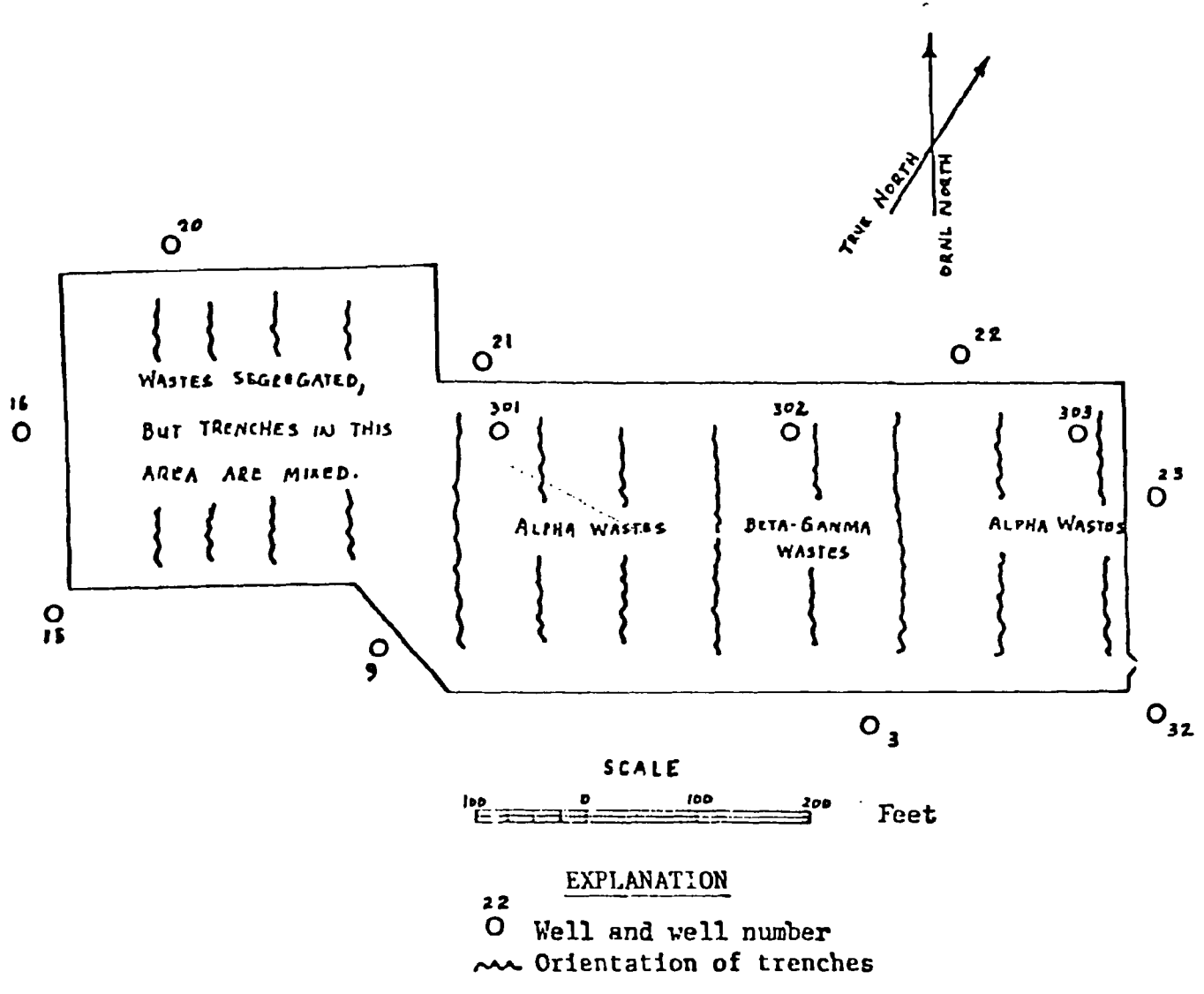

Fig. IV-5. Schematic diagram showing the orientation and general location of alpha and beta-gamma trenches and location of wells in SWSA 3.

the material buried in SWSA 3. (1977 Intralaboratory Correspondence from J.O. Duguid et al. to Distribution, NAS76) However, large items of equipment that were slightly contaminated and either too awkward to bury or which were salvageable, were stored above ground within the fence surrounding the burial area (Fig. IV-6). These surface-stored items were removed in 1979 (Fig. IV-7). Items having potential for further use were moved to a newly designated storage garden between SWSA 4 and the Chemical Waste Pits; other items were buried in SWSAs 5 and 6. (personal communication, D. Webster, USGS, Dec. 1981) During the early operational period of SWSA 3, alpha wastes in drums were deposited in concrete-lined trenches in the NE end of the burial ground but were later placed directly into unlined trenches and covered with concrete as the burial ground was extended to the west. Beta-gamma wastes were buried in separate, unlined trenches and backfilled with the excavated soil. It is thought that SWSA 3 was chosen because of its proximity to ORNL, its out-of-sight location, and because the soil could readily be excavated. (We76)

When the site was expanded westward, it was found to be underlain with rock, which made excavation for new burial trenches difficult. SWSA 3 was closed in 1951, after about seven acres had been used for burial. (1977 Intralaboratory Correspondence from J.O. Duguid et al. to Distribution, We76)

In 1964, well water samples were analyzed and indicated small amounts of the trivalent rare earths (TRE), ^{90}Sr, ^{89}Sr, and tritium. (We76) Well water samples collected in 1973 indicated ^{90}Sr levels up to 3.0 dpm/ml. Soil samples analyzed in 1978 indicated higher than natural soil background levels which had been determined in 1976. (Oa79c, El79, Oa76)

SWSA 3 is currently fenced, grassed, and shows no significant sign of erosion. Runoff is directed to White Oak Creek via shallow drainage ditches located immediately outside the fence on both the east and west end of the site.

f. SWSA 4

Following a study of the geology and hydrology of the Laboratory site during 1948-1950, it was recommended that future waste disposal

ORNL PHOTO 1372-79

Fig. IV-6. Photograph of SWSA 3.

ORNL PHOTO 5064-80

Fig. IV-7. View of SWSA 3 from east to west November 1979, following site renovation.

operations be conducted in the Conasauga Shale Group. (Sto51) Therefore, SWSA 4 was established in 1951 in the area closest to ORNL underlain by Conasauga Shale. (Oa79c) It appears that this site was chosen both for its geology and its proximity to ORNL buildings. (We79)

SWSA 4 is located in Melton Valley on the south side and at the foot of Haw Ridge, west of White Oak Creek (Fig. IV-8). The burial area was initially established at the toe of Haw Ridge and adjacent to the floodplain of White Oak Creek. However, during the 8 years it was used, operations were expanded to include the lower slope of a small drainage basin. (We79)

Records of the types and volumes of waste disposed of in SWSA 4 prior to 1957 are incomplete because the records were destroyed in a fire. The total volume of waste buried in SWSA 4 during 1957 and 1958 was about 7200 m^3 (255,000 ft^3) and 9500 m^3 (336,000 ft^3), respectively. (See Fig. IV-1) During this time, ORNL produced about 50% of the waste, while other Oak Ridge installations and off-site generators contributed the remainder. Argonne National Laboratory, Knolls Atomic Power Laboratory, Mound Laboratory, and the General Electric Company of Evendale, Ohio were the principal off-site shippers, but over 50 agencies also used SWSA 4. (Lo61) Information was provided on external radiation associated with each off-site shipment because of hazards associated with handling such material. However, little information was available as to the types, concentrations, and quantities of wastes disposed of in SWSA 4.

At SWSA 4, the water table is relatively shallow and fluctuates at or near the land surface in low areas of the burial ground and attains a maximum depth of about 5 m (15 ft) at higher elevations. Waste burial was limited to higher elevations during the wet periods and lower elevations were utilized during dry summer months. (Lo61) However, this did not isolate buried wastes from infiltrating water. (personal communications, N. Cutshall, ORNL, Oct. 1981) Also until late 1973, the area was used for the disposal of uncontaminated fill material. The fill, in thicknesses ranging up to 6 meters (20 ft.), contributed to a general rise in the water table. (Du75) Several semi-permanent perched water bodies and associated seeps developed in SWSA 4 because of the "bathtub effect." The "bathtub effect" refers to a trench where one end of the trench is at a lower

ORNL PHOTO 7803-80

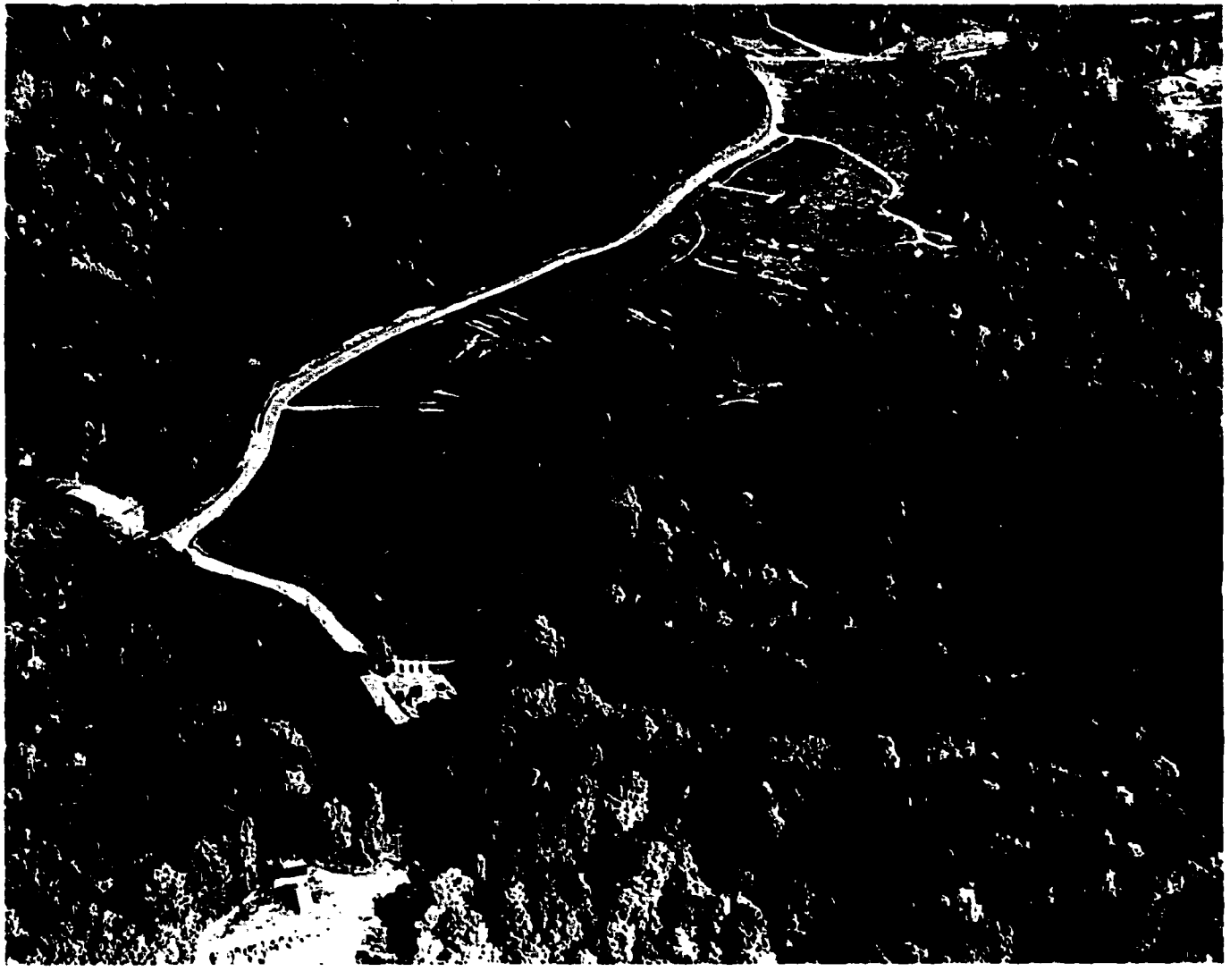

Fig. IV-8. Photograph of SWSA 4.

elevation than the other, precipitation infiltrates the trench, reaches the less permeable bottom, and flows to the lower end of the trench where it overflows like a tilted bathtub. In addition, SWSA 4 is located low in a valley of a tributary of White Oak Creek. The valley slope rises about 60 m (200 ft) above the area on its north side. Therefore, the area serves not only as a catchment for precipitation, but also receives runoff from the hillside and lateral inflow of ground water from upslope. As a result, burial trenches and their contents are often in contact with water and most of the burial area is saturated. (We76, DM78, We79)

In an effort to decrease the impact of water intrusion, a surface runoff collector and diversion system was constructed in 1975. This system consists partly of a shallow, asphalt-lined ditch along the north side of the burial ground. Surface water runoff is then diverted across the disposal area by means of three asphalt-lined conductor ditches and one unlined, natural drainage ditch at the northeast edge of the burial ground. The diversion system carries large amounts of water during heavy rains and small amounts of water for several days afterwards. However, this corrective measure has not been effective in decreasing ^{90}Sr discharge from this solid waste storage area, which is currently the largest contributor of ^{90}Sr to White Oak Creek. The drainage ditches do not continue all the way across the trench area to the creek on the other side. At the point where the ditches stop, the water fans out. Therefore, although the water from the drainage ditches is not released directly over the trenches, the area to where most of the radionuclides have migrated from SWSA 4 is impacted and the radionuclides are being leached and transported by groundwater and surface runoff toward White Oak Creek.

Seeps have developed in various parts of SWSA 4. A small number of seeps have developed near the rim of the terrace in the center third of the area. Others are reported to have developed in more central parts of the area, at the base of the steep slope bordering the terrace, and on the flood-plain below the terrace. (We76, Oa79a) During 1959 and 1960, sampling of wells and streams in and near SWSA 4 showed that both ground water and surface water were contaminated. Water samples taken from eight of the sixteen wells showed beta-gamma contamination and one contained alpha activity. Identifiable radioactive contaminants included ^{90}Sr, ^{106}Ru

and trivalent rare earths (TRE). (We76) Alpha and beta activity were found in water from seeps and in the intermittent stream that borders the burial area to the south. Contaminants in two seeps included ^{90}Sr, ^{137}Cs, ^{60}Co, and TRE and in the intermittent stream, ^{106}Ru, ^{90}Sr, ^{210}Po, ^{239}Pu and TRE.

In 1964, water samples were taken from six wells and one seep at SWSA 4 and each was found to contain ^{90}Sr, tritium, TRE and small amounts of ^{106}Ru (We76)

In 1973, eight wells sampled on the burial ground surface indicated contamination of ^{90}Sr while two of the wells showed measurable contamination of ^{125}Sb. (We76, Oa79c) In September of 1974 analysis was begun for tritium at SWSA 4. (Du76) Although the principal radionuclides present in the ground water in and near SWSA 4 are tritium and ^{90}Sr, occasional water samples are found to contain small amounts of ^{60}Co, ^{125}Sb, and ^{137}Cs. (Du76b)

SWSA 4 was closed in 1959 as available burial space was nearly exhausted.

g. SWSA 5

SWSA 5 is located in Melton Valley, along Melton Branch, and east of the confluence of Melton Branch and White Oak Creek (Fig. IV-9). It consists of two sections on the hillside east of White Oak Creek and south of Haw Ridge. SWSA 5 was opened in 1958 after burial space in SWSA 4 was nearly exhausted. Criteria considered in the selection of SWSA 5 were size, topography, soil, distance from the laboratory, accessibility by private roads, no surface flooding, and depth to the groundwater table. The area was subjected to detailed geologic and hydrologic investigations. (We76) TRU waste is stored in the northern section while the south section was used for low-level solid waste. (Oa79c)

Problems caused by infiltration of precipitation were aggravated because of poor trench orientation. Trenches in this burial ground were excavated with their long axes downslope, paralleling the hydraulic gradient of the water table. (We76) The extent of water seepage might have been less if the long axis of the trenches paralleled the hillslope

Fig. IV-9. Photograph of SWSA 5.

contours and crossed the hydraulic gradient. Some of these trenches filled with water which seeped out the lower ends of the trenches. The water in the seeps contained measurable amounts of alpha-emitting radionuclides (primarily ^{244}Cm and ^{238}Pu), ^{90}Sr, ^{3}H, and ^{125}Sb. (Du75)

In May 1975, corrective actions were taken to reduce the seepage in an area found to have relatively high amounts of ^{90}Sr and measurable amounts of ^{244}Cm and ^{238}Pu. Initially, about 0.6 m (2 ft) of overburden was removed from the area overlying four of the burial trenches. Two underground dams, one of concrete and one of bentonite-shale, were then installed across two parallel trenches. The stripped area was covered with a PVC membrane and the overburden was replaced.

The cover was planted with grass to inhibit erosion. In addition to the placement of subsurface dams and a PVC membrane in the south section of SWSA 5, a near-surface seal consisting of a bentonite-shale mixture was placed over 14 trenches in the TRU waste area (northern section of SWSA 5) to prevent excessive infiltration of precipitation. Other corrective measures taken in SWSA 5 include filling of collapsed trench caps, installation of concrete drainage ditches, and surface contouring for better drainage. (Ta80)

Both groundwater and surface water drainage in SWSA 5 is predominantly southeast towards Melton Branch and southwest towards White Oak Creek. The water table contour map shows that the steepest gradient is in the direction of Melton Branch which implies that the prevailing movement is to the southeast. Therefore, most of the potential radionuclide transport by surface water is monitored at Station 4 on Melton Branch.

In 1964, radiochemical analyses were made on water samples collected from several wells and from the drainage that divides the site into two sections (5 south area and 5 north area). The principal contaminants found were ^{90}Sr, ^{106}Ru, ^{3}H, and trivalent rare earths. Only minor movement of ^{106}Ru, ^{137}Cs, and ^{60}Co from trenches were observed from analyzed core samples of new wells. (We76, Oa79c)

Water samples collected from seeps from SWSA 5 in 1974 indicated that ^{90}Sr and ^{3}H were principal contaminants. The average concentration of ^{3}H in the samples was 3.9×10^{5} dpm/ml, or 0.2 mCi/ml. Water samples collected at a sampling station about 1.6 km (1 mile) downstream from the

confluence of Melton Branch with White Oak Creek have indicated that several thousand curies of ^{3}H had passed that point annually since the mid 1960's. Most of the ^{3}H found at the station is believed to have been discharged to Melton Branch in ground water from SWSA 5. (We76, We79)

h. SWSA 6

SWSA 6 was selected using the same siting criteria as for SWSA 5. Although contaminated waste was buried at the site in 1969 it was not the principal burial site until SWSA 5 was closed in 1973. (We76) SWSA 6 is located in Melton Valley immediately northwest of White Oak Lake and southeast of Lagoon Road and Haw Ridge and bounded by White Oak Dam (Fig. IV-10). (We76, Ar81) More than one half of the 28 hectares (68 acres) comprising SWSA 6 is unsuitable for shallow land burial because of the steep slopes on a wooded hillside and the presence of shallow ground water.

Table IV-4 shows volumes of wastes received, buried and stored during the periods October 1976 through September 1980. Currently ^{235}U waste generated is buried in SWSA 6. (1979 ORNL Radioactive Solid Waste Operations Manual)

Periodic water table measurements in a study section covered with a bentonite seal indicated the presence of a water table in a majority of the 49 trenches studied throughout the year. (Ar81) In an attempt to decrease infiltration of precipitation in SWSA 6, a near-surface seal consisting of a bentonite-shale mixture was applied to three sections of SWSA 6. Studies were performed in the laboratory to develop an optimal bentonite-shale mixture with the appropriate moisture content to insure maximum compacted density. A composition of 15 percent bentonite by weight, compacted at 20 percent moisture content, was chosen on the basis of the laboratory results. This was expected to result in a seal density approximately 1522-1889 kg/m^3. (Ar81) During the initial installation, 0.6 m (2 ft) of topsoil and overburden were removed from the site. Granular grade Volclay Saline Seal 100 (American Colloid Company) was then spread over the area at a rate of 19.5 kg/m^2 (4 lb/ft^2) and was mixed into the top 7.5 cm (3 in) of exposed soil with a disc harrow to produce a 15 percent bentonite-shale mixture. The area was disked, water was added to

ORNL PHOTO 0079-78

Fig. IV-10. Photograph of SWSA 6.

Table IV-4. Radioactive Waste Handled at ORNL Burial Ground, October 1976 through September 1980 (m^3)
(Information taken from ORNL Waste Management Operations Annual Progress Report for Period Ending September 30, 1980)

	General Beta-Gamma Radioactive Waste						TRU Waste[a]
Period	Received	Buried in Trenches and Auger Holes	Landfill	Compactible As Received	Waste After Compaction	Savings Due to Landfill and Compaction	Stored
Oct-Dec '76	475	475					24
Jan-Mar '77	556	556					15
Apr-June '77	596	596					23
July-Sept '77	514[b]	514					22
Oct-Dec '77	753	753					21
Jan-Mar '78	601	601					19
Apr-June '78	434	420	13			13	13
July-Sept '78	587	481	28	88	10	106	22
Oct-Dec '78	606	473	43	101	10	134	26
Jan-Mar '79	432[c]	311	32	99	10	121	14
Apr-June '79	374[d]	266	36	81	9	108	16
July-Sept '79	543[e]	467	6	80	10	76	19
Oct-Dec '79	590[f]	481	8	113	11	109	14
Jan-Mar '80	402[g]	337	0	74	9	65	18
Apr-June '80	822[h]	516	218	100	11	307	12
July-Sept '80	595	532	5	66	8	63	11

[a] Reduction of the volume of TRU Wastes for retrievable storage was not emphasized in this program; these are included to complete the list and volume of waste handled.
[b] Of this, $282m^3$ are construction waste.
[c] Not including $342m^3$ of waste from cleanup of Burial Ground 3.
[d] Not including $59m^3$ of waste from cleanup of Burial Ground 3; includes $174m^3$ construction waste.
[e] Not including $189m^3$ waste from cleanup of Burial Ground 3; includes $182m^3$ construction waste.
[f] Includes $66m^3$ of construction waste.
[g] Includes $119m^3$ of construction waste.
[h] Includes $195m^3$ of construction waste.

attain a moisture content of about 20 percent (determined gravimetrically at several locations in the area), and the material was compacted. The topsoil and overburden were then replaced and the area was covered with grass to permit some evapotranspiration and to reduce soil erosion. (Ar81)

The application of the near-surface, bentonite-shale mixture was not successful in hydrologic isolation of the waste in the trenches. It is thought that both lateral migration and vertical infiltration contribute to groundwater movement beneath the seal, so the actual effectiveness of the near-surface seal is unknown.

B. Liquid Waste

This section has been included because in the early operations of the laboratory the low-level liquid (process) waste was not chemically treated and contributed to ground contamination of the intermediate pond, equalization basin, retention ponds at several facilities, White Oak Lake and the Clinch River. When the low-level waste treatment plant became operational in 1957, the sludge containing radionuclides was disposed of in chemical waste pits. The sludge from the new treatment plant (1976) was disposed of in a PVC lined basin, until the process was changed in late 1981 to eliminate the generation of sludge. (personal communication, J. Gissel, ORNL, April 1982)

1. Operations Producing Waste

ORNL has generated significant quantities of liquid radioactive waste since separation of plutonium from fuel elements irradiated in the Graphite Reactor began in the Hot Pilot Plant during the early part of 1944. Some of the wastes resulting from these operations were low-level liquid (process waste). In addition to waste solutions generated by reactor and fuel processing operations, contaminated waste water or process waste resulted from floor drains, decontamination pad drains, storage canals, and other processes and operations. (May 31, 1960 Intralaboratory correspondence from E.G. Struxness to F.L. Culler, Ro79)

Table IV-5 shows the eight major contributors of process waste discharged to the lime-soda treatment plant in August 1964. The percentage

Table IV-5. Process Waste Discharges, August 1964
(ORNL Operations Division Monthly Radioactive Waste Disposal Reports, 1964)

Source	Gross beta activity Average, c/m/ml	GROSS BETA ACTIVITY[1] Ci	% of Total	VOLUME Gal x 10^6	% of Total
1. Reactor Operations	12	0.49	9.0	2.95	15.7
2. Radioisotope Processing Area	28	0.39	7.2	1.01	5.4
3. Building 3503 and 3508	3	0.06	1.1	1.44	7.7
4. Buildings 3025, 3026, and 3550	4	0.07	1.3	1.16	6.2
5. Building 3019	11	0.43	7.9	2.78	14.8
6. Fission Products Development Laboratory	--	3.0[2]	55.4	0.03	0.2
7. 4500 Area	8	0.98	18.1	8.71	46.5
8. Building 3525	0	--	--	0.66	3.5

[1] Approximation - The method of analysis used in determining gross beta activity is not sensitive to energies below that of ^{90}Sr.

[2] Approximation based on analysis of diversion box sample. The activity entered the process waste system downstream of the sampler in the FPDL tributary.

of total volume for each remained fairly constant from the 1950's until October 1964. ORNL had been experiencing a two-fold problem resulting from a large volume of waste from the 4500 complex (most of it was very low-level) and occasional malfunction of the treatment plant. As a result, several million liters of process waste water were discharged directly into White Oak Creek without being treated chemically to remove radioactivity. (ORNL Operations Division Monthly Radioactive Waste Disposal Reports, 1964)

The Homogeneous Reactor Test (HRT) experiment located in the 7500 area generated low-level liquid during the early 1960's. The Nuclear Safety Pilot Plant (NSPP) located in Cell B of building 7500 also started operations about this time. Low-level liquid waste from the HRT, and NSPP, were discharged to a settling basin near these two facilities. (1977 Intralaboratory correspondence from J. O. Duguid et.al. to Distribution) Low-level liquids resulting from the decontamination of tools and from the laboratory hot sink were also allowed to settle in the HRT settling basin. (Par63) Records of waste volumes and characterization are not available for the HRT basin but later water analysis of Melton Branch near the area of the basin indicate that about 10% of the ^{90}Sr which entered Melton Branch came from the area of the basin. Soil samples taken from this area have shown higher than background concentrations of ^{239}Pu. (1977 Intralaboratory correspondence from J. O. Duguid, et.al. to Distribution)

Two retention ponds were constructed at the Low Intensity Test Reactor (LITR) located within the main ORNL area. These ponds were used to retain the primary coolant (water), when the reactor was drained, leaking coolant, and cooling water from irradiation experiments. Most of the radioactivity in the waste water was attributed to ^{24}Na, which has a half-life of 15 hours. After the radioactivity decayed to less than 100 gross beta and gamma d/m/ml, the supernate was discharged to White Oak Creek. (Brow59) These ponds are no longer in use. (personal communication, T.P. Hamrick, ORNL, Dec. 1981) A retention pond at the Aircraft Reactor Test (ART) which is located in the Melton Valley area has not been used since the 1950's. (Brow59, personal communication, T.P. Hamrick, ORNL, Dec. 1981)

There is also a retention pond at the High Flux Isotope Reactor (HFIR) facility. It is part of the low-level waste system and in the past has been used primarily to store activation products. (Bu76) The liquid was

pumped from the pond after decay or settling of suspended radionuclides. The HFIR pond had a gamma exposure level of 50-100 mR/h during a 1974 survey. (Bu76) This pond is still used at times. (personal communication, T.P. Hamrick, ORNL, Dec. 1981)

2. Storage and Treatment

a. Early Handling of Waste

Beginning in 1944, large volumes of process waste were conveyed by a network of pipes and discharged into White Oak Creek. In 1950 when the Laboratory was greatly expanded in size and scope of operations, weirs were installed in the underground sewer system that collected this waste. The weirs permitted measurement of the waste volume and proportional sampling for radioactive contamination from each source. (Brow59) Whenever the activity approached or exceeded 150 d/m/ml the cause of the increase was located. This helped eliminate any continued excessive radioactive discharges from the source. (Co58b)

The wastes were then discharged into streams leading to White Oak Creek where the concentration of radioactivity was reduced by dilution. Further dilution occurred when the waste entered the Clinch River. Part of the released radioactivity was attributed to drainage around underground waste storage tanks holding intermediate level waste.

White Oak Dam, which created the 10 hectare (25 acre) White Oak Lake, was constructed in 1943 to provide hold-up for the waste. For a short period of time the solution was discharged to an intermedate pond (1943-1944) for settling, dilution, and decay of short lived radioisotopes before entering White Oak Creek. After July 1944, liquid waste flowed to the lake from the 5.6×10^6 liter settling basin where the first settling of radioactive solids occurred.

The process waste and supernatant liquid resulting from precipitation of uranium, plutonium, and some fission products in the Gunite storage tanks were mixed and discharged into this basin. The activity level in the settling basin was monitored from 1944 to 1948 by taking periodic grab samples. In 1948 sampling was conducted every four hours and measurements of flow into the basin were made with a V-notch

weir. Additionally, in late 1950, a V-notch weir, a water-stage recorder, and a proportional sampler were installed for measurements at the outlet of the settling basin which led to White Oak Creek. Much of the radioactivity in the low-level waste discharged from the settling basin was due to isotopes of rare earths, strontium, and cesium. Smaller amounts of activity resulted from isotopes of zirconium, cobalt, iodine, ruthenium, barium, and niobium. (Co58b) The build-up of sediments on the bottom and sides of the basin influenced the chemical and physical nature of released waste. External radiation was increased due to accumulation of radionuclides onto the sediment: (May 31, 1960 Intralaboratory correspondence from E.G. Struxness to F.L. Culler)

The volume of processed waste released from ORNL from 1950 to 1957 ranged from a low of 620 million liters in 1954 to a high of 1120 million liters in 1951. Yearly gross beta releases to White Oak Creek, estimated for the same period, ranged from 172 to 498 curies/year. Surprisingly, the smallest amount of activity was released in 1951 when the highest volume release occurred.

In October 1964 two 655,000 liter (170,000 gallon) waste ponds were constructed to hold process waste water from the 4500 complex. If the concentration of radioactivity reached a certain level, the water was pumped to the treatment plant. Otherwise, the wastes were released into White Oak Creek. During the first month of operations of the waste ponds, 1.5 million gallons of effluent were diverted into the creek. (L.D. Lasher to Distribution, December 11, 1964 Radioactive Waste Disposal Report for the Month of October 1964, ORNL-CF-64-12-15)

b. Treatment by Lime-Soda Process

As operations at ORNL expanded during the 1950's, the methods previously used to control discharges of radioactivity were no longer adequate. At times the level of radioactivity exceeded the recommended concentration guides (referred to as maximum permissible concentration in early papers) in the receiving waters. (Co58b) White Oak Lake was drained in 1955 to provide for emergency hold-up, but additional facilities were needed to decontaminate the process waste. Studies of six types of

treatment facilities and processes were conducted to determine their efficiencies for removing ^{90}Sr, ^{137}Cs, ^{106}Ru, and trivalent rare earths. (May 31, 1960 Intralaboratory correspondence from E.G. Struxness to F.C. Culler) The treatment process using excess lime-soda was chosen as the most efficient and maintainable process. Later, Grundite clay, a commercially available clay high in illite, was added for removing ^{137}Cs.

The process treatment design incorporated a recycle route for effluent and sludge which required extra treatment, and a diversion system for routing process waste around the plant when the waste did not require chemical treatment. The excess lime-soda treatment plant was put into operation in August 1957. (May 31, 1960 Intralaboratory correspondence from E.G. Struxness to F.L. Culler) Figure IV-11 shows a diagram of the process waste system.

After leaving the last coagulation compartment in the system, the mixed waste moved through a settling basin in the plant where sludge was collected for removal. The sludge was pumped to 16,000-gal. sludge storage tanks where further settling occurred. The settled sludge was transported by tank trucks to the waste disposal area and discharged into Chemical Waste Pit 3 and later 4. (May 31, 1960 Intralaboratory correspondence from E.G. Struxness to F.L. Culler)

The effluent was monitored before being discharged into White Oak Creek. Studies showed that much of the radioactive material in the effluent was in the form of suspended solids. Therefore, in 1961 the effluent was rerouted through the large earth settling basin to allow further settling of suspended solids. (Co66) If retreatment was required, the effluent was recycled to the inlet pumps.

The average amount of process waste generated from Sept. 1957 to Aug. 1965 ranged from a high of 2.9×10^6 liters/day (1.1×10^9 l/y) in 1957 to a low of 1.7×10^6 liters/day (0.7×10^9 l/y) in 1962. In this eight year period 79% of the process waste was treated at the plant. 1.9×10^3 Ci of $^{89,90}Sr$, 4.4×10^3 Ci of ^{137}Cs, and 3.2 Ci of TRE were removed from process waste. Removal efficiencies were 80% for strontium and the rare earths, 70% for ruthenium and 65% for cobalt. The removal efficiency for ^{137}Cs was low (10-25%) until addition of illite clay (Grundite) began in late 1958. This resulted in better removal efficiency for ^{137}Cs. Continuing

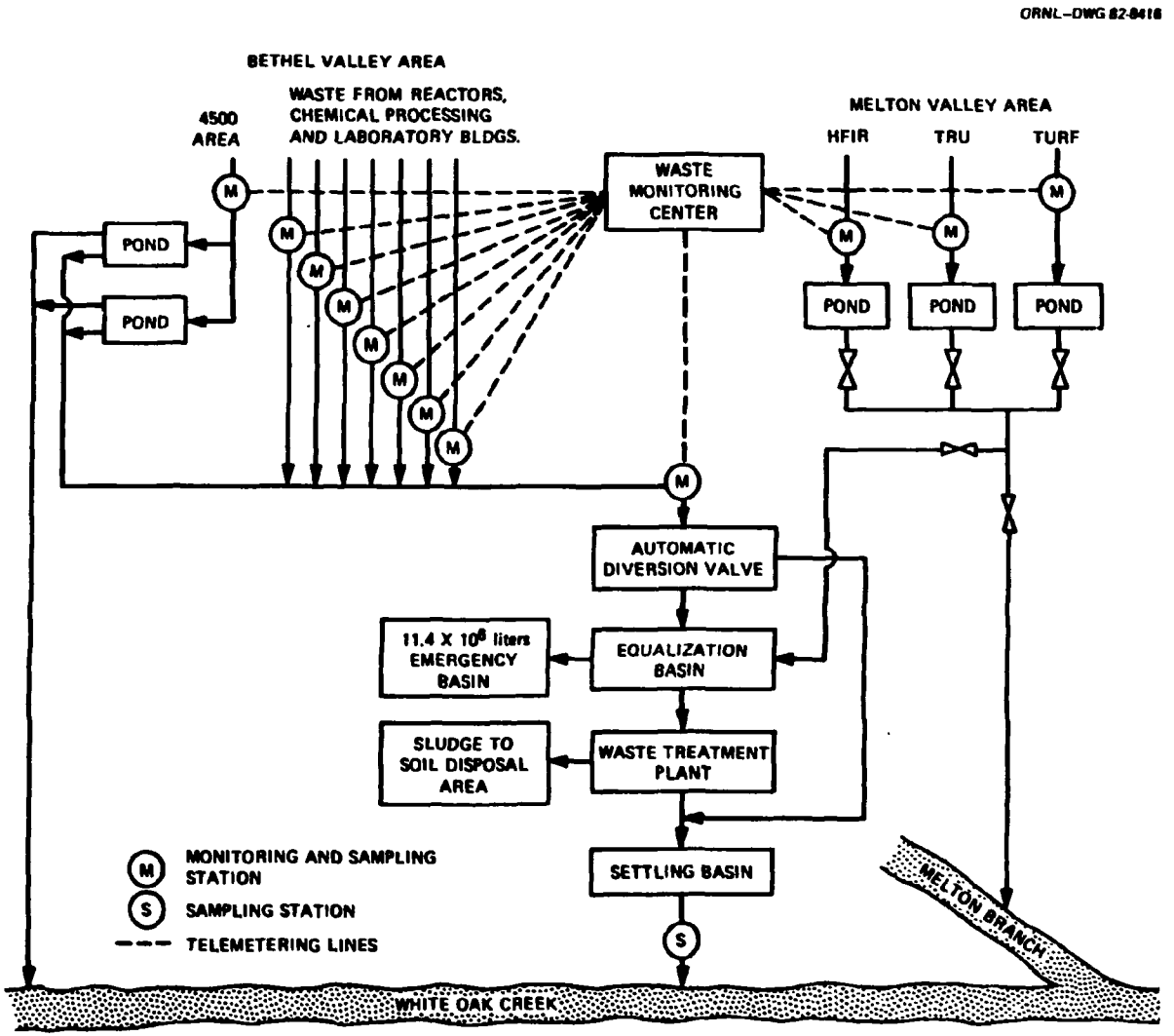

Fig. IV-11. Diagram of process waste system in 1964.

experimental efforts were conducted to increase the removal efficiencies by using different amounts of lime, soda ash, and clay. (Co66)

c. Treatment by Scavenging Precipitation-Ion Exchange Process

ORNL developed a new treatment process, the Scavenging Precipitation - Ion Exchange Process (SP-IX), for large volumes of low-activity waste or process waste in the early 1960's. (Broo63, Ho63) In April 1976, ORNL began operation of a new process waste treatment facility using the SP-IX technique to handle large volumes of liquid waste and increase the total decontamination efficiency for ^{90}Sr and ^{137}Cs. (Ro79)

This treatment plant is presently in use. It uses the existing equalization basin as a storage pond for process waste which requires treatment by the SP-IX process. Not all process waste receives the treatment. Much of the process waste is monitored for gross beta and alpha activity and is discharged directly into White Oak Creek when the count rate is less than 40 d/m/ml of beta-activity. Process waste which exceeds this count rate, or which is not monitored, is treated. The process waste water flows from the equalization basin into the SP-IX facility (ORNL building 3544). (Ro79) Figure IV-12 shows a drawing of the major components of the SP-IX facility. Until 1976, sludge removed from the facility was discharged into Chemical Waste Pit No. 4. From 1976 to 1981 they were pumped through polyvinyl chloride pipe to a 435 m^3 sludge disposal basin located in SWDA 5. This basin is lined with polyvinyl chloride to contain solids and supernate. Once the solids settled, the supernate was pumped back to the equalization basin for reprocessing, if needed. (Ro79)

3. Surveys of White Oak Lake

In 1954 the radioactive isotopes adsorbed on the sediments of White Oak Lake reached equilibrium with dissolved activity and the lake lost its ability to further adsorb radioactive isotopes from solution and to hold them on the lake bottom. (Stru57) Further, in case of an emergency or uncontrolled liquid release, there was no means to detain the water if the

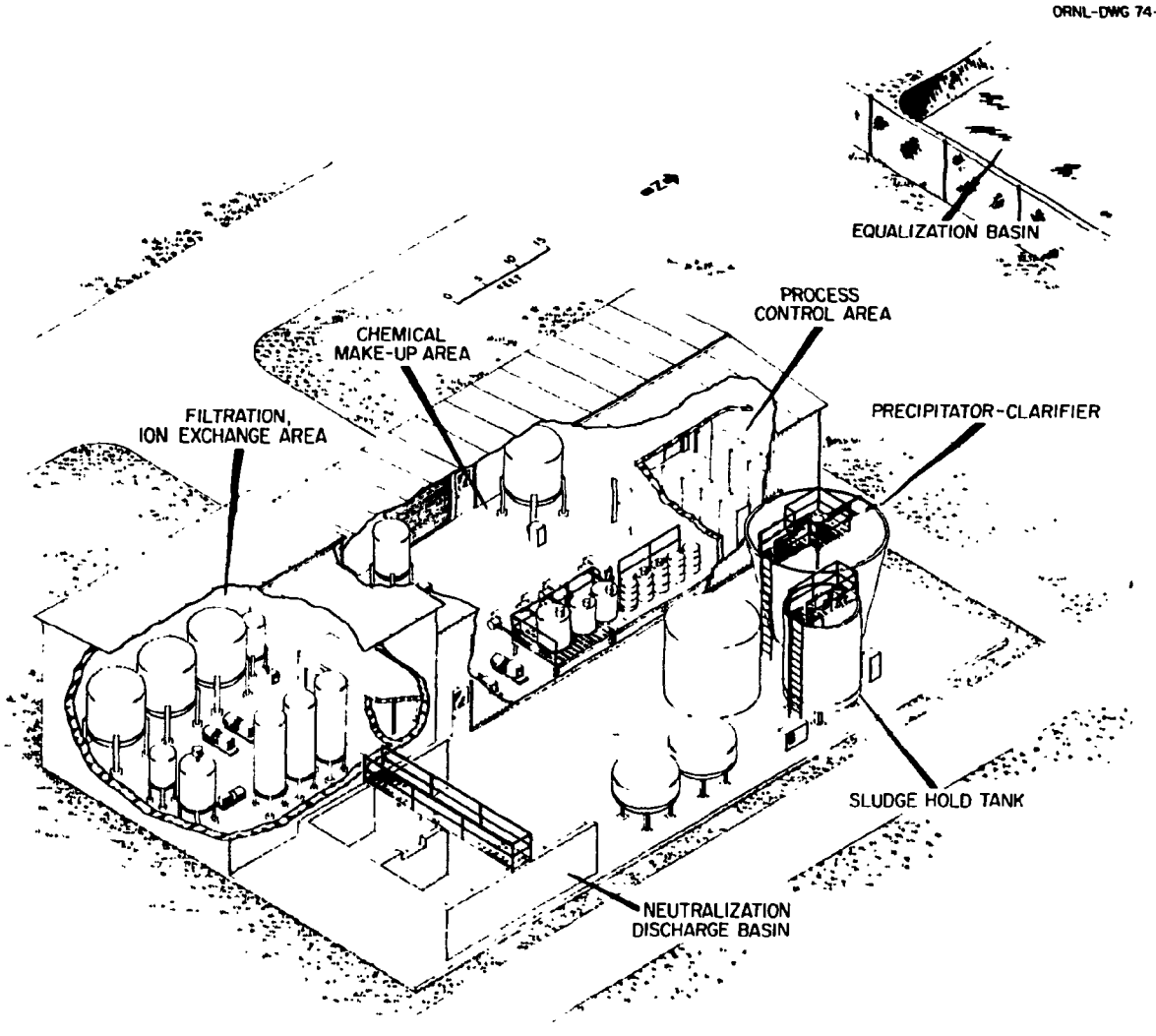

Fig. IV-12. Isometric view of process treatment plant (SP-IX).

settling basin and the lake were both full. There was also a concern that ducks and other migratory animals would take up residence at the contaminated lake and spread the contamination. (Oa79a)

Therefore, White Oak Lake was drained in October 1955 to create storage capacity for holding contaminated water in case of an emergency release of process waste water. During drainage of the lake, a significant quantity of contaminated sediment moved into the Clinch River. Various surveys were conducted on the lake bed and area to determine the extent of residual contamination in the sediments. The bed was divided into three zones for the analyses, which were conducted over a three year period. Fig. IV-13 shows a map of the three zones. It was estimated that the lake bed sediments contained about 11 curies of ^{90}Sr, 480 curies of ^{137}Cs, and 60 curies of ^{60}Co in 1960; the rare earths were limited to about 7 curies in zone 1. (May 31, 1960 Intralaboratory correspondence from E.G. Struxness to F.L. Culler) In 1958 radiation measurements were made on the lake bed using a cutie-pie ionization chamber. The observed radiation was about 90% gamma. The mean of the measurements was 16 mR/hr, with readings approximating 50 mR/hr in areas of the lake bed where ^{106}Ru was deposited. It was also concluded that most of the radionuclides were heterogeneously distributed in the top 10 cm (4 in) of the soil. Figure IV-14 shows the radiation field of the lake bed 1 meter above the surface. (Oa79a)

Ecological studies were begun in 1957 in the White Oak Lake bed emphasizing the uptake and food-chain transfer of ^{90}Sr, ^{137}Cs, and other radioisotopes. Comparisons were made of the upper and lower parts of the lake bed. Part of the upper bed received radioactive materials from seepage of the intermediate-level waste pits. The material entered the bed from the east seep, and spread over the bed in a delta fan pattern. Routine analyses of large numbers of soil samples were taken during 1956, 1957, and 1958. Besides sampling and evaluating native vegetation and insect populations for radionuclide content, three species of forage crops were studied in an agricultural experiment spanning areas of high and low radionuclide contamination on the lake bed. (Au59)

Ecological studies at the White Oak Lake area continued in 1961 with the sampling of plants, herbivorous insects, predaceous insects and small mammals. Concentration factors for radionuclides from this study

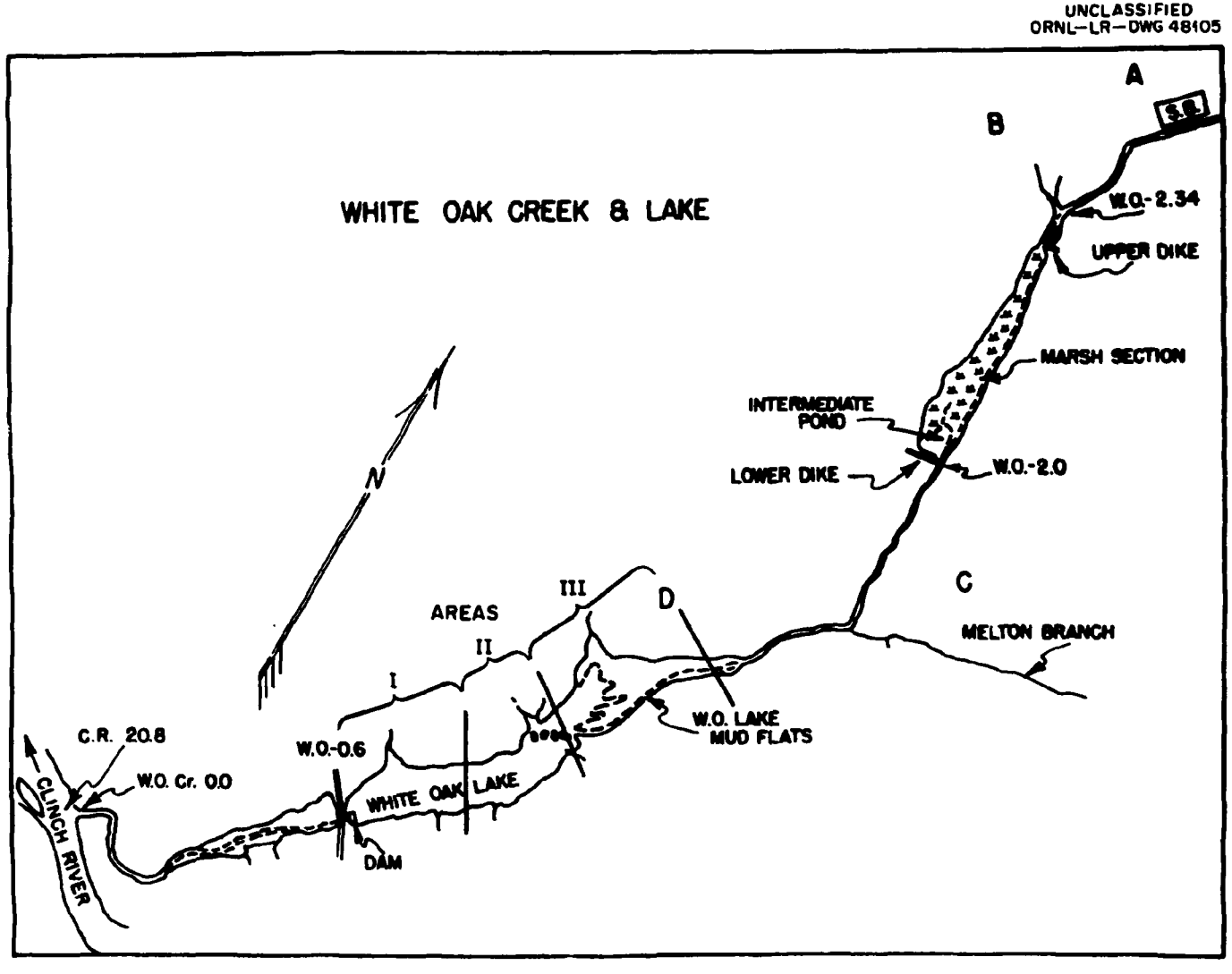

Fig. IV-13. White Oak Creek and lake bed.

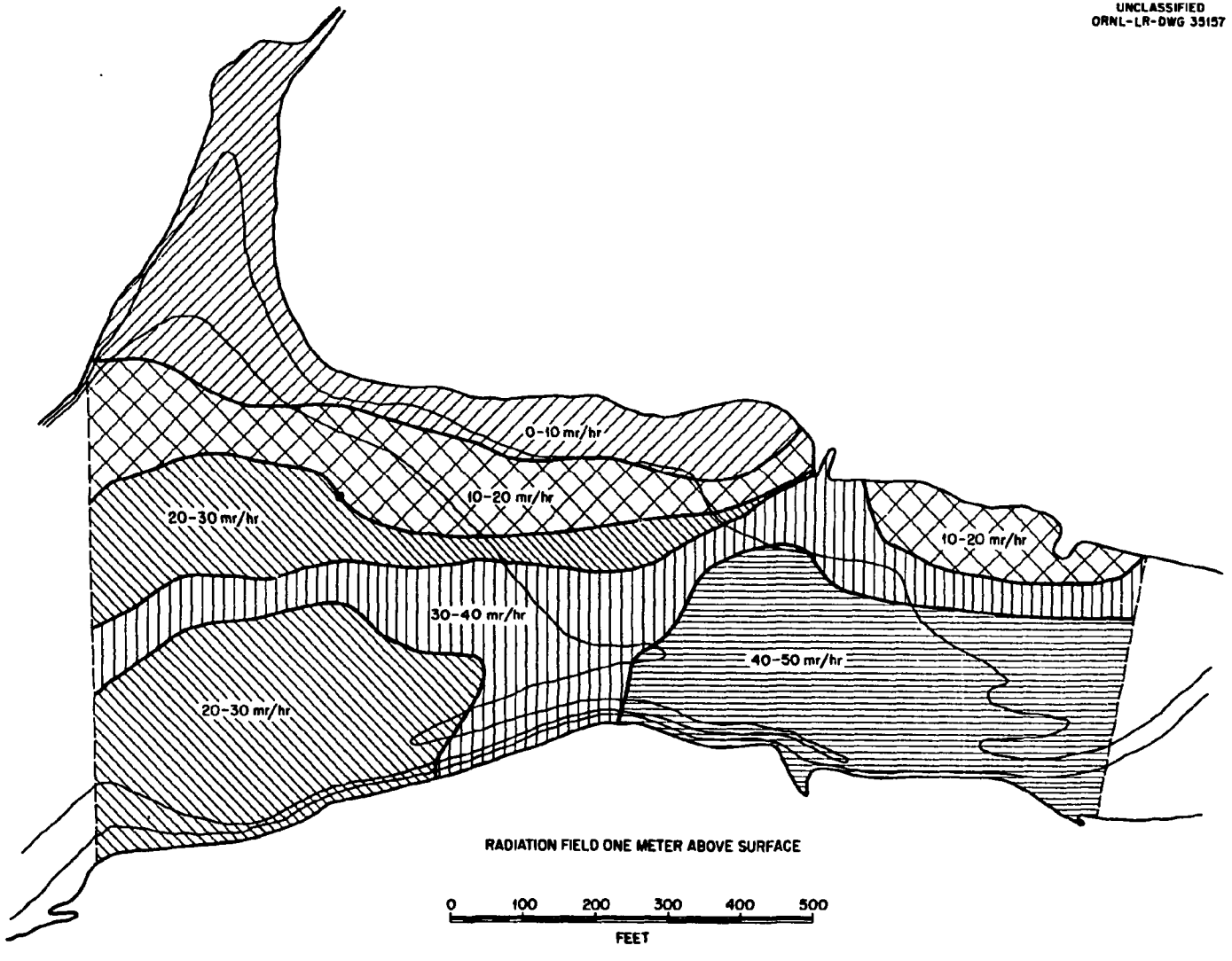

Fig. IV-14. Ecology study area (Upper White Oak Lake bed).

reinforced the 1956-58 studies. Significant concentrations of ten different radionuclides were detected in remains of several mammal types taken from the upper zone of the lake bed. Rice rats fed in close proximity to the seep from the burial grounds and consequently showed a significant uptake of ^{106}Ru, which was the predominant radionuclide escaping at that time. (Au62)

Starting in 1961, White Oak Lake was used again to retain effluent before it was discharged into the Clinch River, although most wastes were treated before they entered the lake.

A survey was conducted on the lake bed in 1962 and cores were taken for analyses. The highest activity in the first 15 cm was due to ^{106}Ru, 594 pCi/g. Other activities were 10 pCi/g for ^{90}Sr, 119 pCi/g for ^{60}Co, and 468 pCi/g for ^{137}Cs. Additional sampling of cores was conducted in 1972. Most of the activity was between 16 to 34 cm from the surface. The activity of ^{106}Ru had also greatly decreased from previously measured values. (Oa79a) The decrease in ^{106}Ru activity was due to much smaller quantities being produced and subsequently less waste products generated for disposal. Also because it has a relatively short half-life, most of the previously released ^{106}Ru had decayed.

An extensive survey of the lake and lake bed was conducted in late November and December 1979, after ORNL experienced a malfunction of the gates of the dam. Twelve cores were taken from the lake bed with several of them taken near the dam. The area near the dam had the greatest potential for a release of activity to the public via the Clinch River. Initially, only the top 15 cm of the cores were analyzed. The average concentrations were 96 pCi/g of ^{60}Co, 41 pCi/g of ^{90}Sr, and 475 pCi/g of ^{137}Cs (all weights are wet weight). The concentration of ^{60}Co decreased with depth, while the concentration of ^{137}Cs increased with depth, and ^{90}Sr remained fairly constant throughout the first 15 cm. (Oa79a). Oakes estimated the amount of activity in the sediment of White Oak Lake, assuming sediment input of 2832 m^3/y based on data from the 1962 and 1972 survey. Table IV-6 lists estimates of the quantities of several radionuclides in White Oak Lake Sediment in 1979.

Table IV-6.

Estimates of Total Activities in White Oak Lake Sediment in 1979 (Oa79a)

Radionuclide	Quantity of Activity Ci
^{137}Cs	591
^{60}Co	33
^{90}Sr	20
^{238}Pu[a]	.096
^{239}Pu[a]	.250
^{241}Am[a]	.024
^{244}Cm[a]	.498

[a]Data only for top 15 cm.

The deposition and migration of radionuclides in White Oak Lake is dynamic and therefore projections of future concentrations of radioactivity in the lake bed would be questionable.

V. DISPOSAL OF INTERMEDIATE-LEVEL RADIOACTIVE WASTES

A. Liquid Wastes

Intermediate-level radioactive wastes have been generated at ORNL since the beginning of irradiated fuel reprocessing operations in the early months of 1944. Present operations at ORNL generate up to two million gallons of intermediate-level waste *(ILW) solution per year. (ERDA77) Intermediate-level wastes, as defined by ORNL, are liquids having activities greater than 4 mCi/gal and no greater than 5 Ci/gal. (personal communication, L. Lasher, ORNL, Oct. 1981) The Intermediate-Level Waste System is designed to be able to collect, neutralize, concentrate, and store radioactive waste solutions having radionuclide concentrations as high as 20 Ci/gal in the ILW stream. That currently being collected averages about 0.03 Ci/gal. (Bi79)

1. Operations Producing Waste

Intermediate-level liquid wastes are generated by production operations and by research and development programs. Included are wastes from:

- o Basic radiochemistry studies,
- o Development of reactor fuel reprocessing methods,
- o Chemical pilot plants, production of radioisotopes for medical, industrial, and research use,
- o Production of transuranium isotopes for research,
- o Operation of nuclear research reactors,
- o Equipment and facility decontamination,
- o Supporting service facilities.

The principal sources of ILW are the Chemical Separations facility, Oak Ridge Research Reactor and Bulk Shielding Reactor, High Flux Isotope Reactor, 4500 Research Lab and the Radioisotope Area. (Bi79)

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*In earlier papers intermediate-level liquid wastes were referred to as "Highly radioactive" liquid waste (normally 0.001-0.02 curies per gallon).

2. Confinement (Storage, Monitoring)

When the laboratory was established in 1943, large underground concrete (Gunite) tanks were constructed to store all the intermediate-liquid chemical waste and the liquid uranium waste. An extensive underground piping system was installed in 1943 to transport the waste from the points of generation to the storage site. Initially, an operational period of one year was planned for ORNL but continuation and expansion of the scope of work at the Laboratory required expanding the waste management system to deal with the increased quantities of liquid waste. To reduce the volume of liquid waste in storage, a large fraction of the radioisotopes in the storage tanks was precipitated by adding caustic. The supernatant liquid was decanted and diluted with the Laboratory's large volume of process (low-level) waste water. This solution was dispersed into an intermediate pond, for settling, before being discharged into White Oak Creek. The intermediate pond was built in 1943 and destroyed by a flood in 1944 (Fig. V-1.), leaving a contaminated land surface. (Stru67)

Four earthen-diked ponds were later created in the Settling Basin Area; one with 6,000 m^3 (1,600,000 gal), one with 120 m^3 (32,000 gal) and two with 1,100 m^3 (293,000 gal) capacity for hold-up of the ILW waste stream. The two 293,000 gal capacity ponds provided emergency hold-up when the ILW waste stream flow was too great for the collection tanks to provide sufficient time for active decay. (Brow49) After the Chemical Waste Pits became operational for routine disposal of ILW in 1952, the ponds used for emergency hold-up were no longer needed. These ponds were separated by an earthen divider that was removed in about 1953 or 54, creating one large pond. (personal communication, O.H. Sharp, ORNL, Oct. 1981) This pond became the equalization basin for the Process Waste Stream. The 6,000 m^3 (1,600,000 gal) capacity settling basin allowed radioactive solids to settle and radioactive liquids to be diluted with large volumes of non-active waste prior to discharge to White Oak Creek. It served as a settling basin and as a sampling facility for the effluent from the old Process Waste Treatment Plant from 1957 until it was removed from service in 1976. (Brow59) The 120 m^3 capacity pond, known as the retention pond,

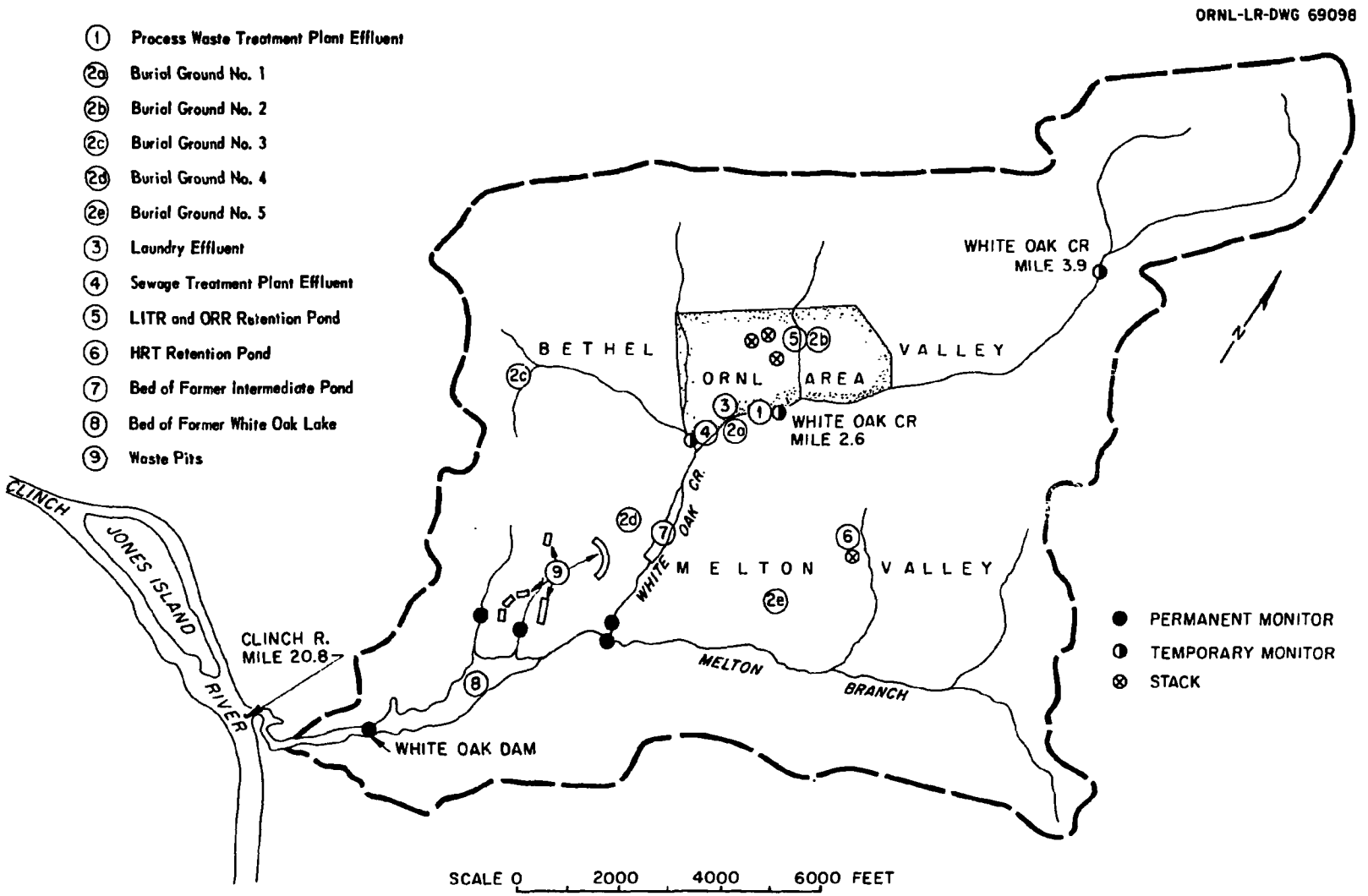

Fig. V-1. Map of White Oak Creek basin showing sources of radioactive contamination and stream monitoring stations.

was decommissioned in 1957. The old Process Waste Water Treatment Plant was built just east of this site. Figure V-2 shows the settling basin, the equalization basin, and the North and South ponds which were completed in 1964 to receive the process waste water from the 4500 complex.

The equalization pond and North and South process water ponds are still in operation. The bottom sediments of the large settling basin have been sampled and analyzed (Ta77) and are currently being used as a research area by the Environmental Sciences Division.

White Oak Lake provided further dilution and settling of radioactive solids before discharge into the Clinch River. (Brow59)

In 1949, more stringent liquid waste disposal requirements were instituted and from June, 1949 until June, 1954 the decanted intermediate level liquid wastes from the storage tanks were concentrated in a pot-type evaporator. (Fig. V-3) The condensate was transferred to the process waste system and the concentrate was transferred to the storage tanks. The evaporator was taken out of service when the chemical waste pits were used for the routine disposal of ILW. (Bi79)

In 1950, due to expansion in size and scope of operations, monitoring systems were devised for liquid wastes. Underground stainless steel tanks were installed near the buildings generating ILW which allowed the separate monitoring of waste. A network of 5 and 8 cm (2 and 3 inch) stainless steel lines directed the waste from "hot" drains to the Gunite storage tanks. The tanks allowed sampling and measurement of waste volumes and rates of accumulation from each source. Each tank had connections to either the intermediate-level liquid waste system or to the process waste water system depending on the composition and radioactivity level. (Brow59) Reduction in activity by decay of radionuclides with short half-lives was attained by holding waste in the monitoring tanks up to one month before transferring the material to the storage tanks where it was decanted to:

- o The settling basin (1944-1948)
- o Evaporator (1949-1954)
- o Disposal pits and trenches (1952-1966)
- o Evaporator and then on the hydrofracture site (1965 to present)

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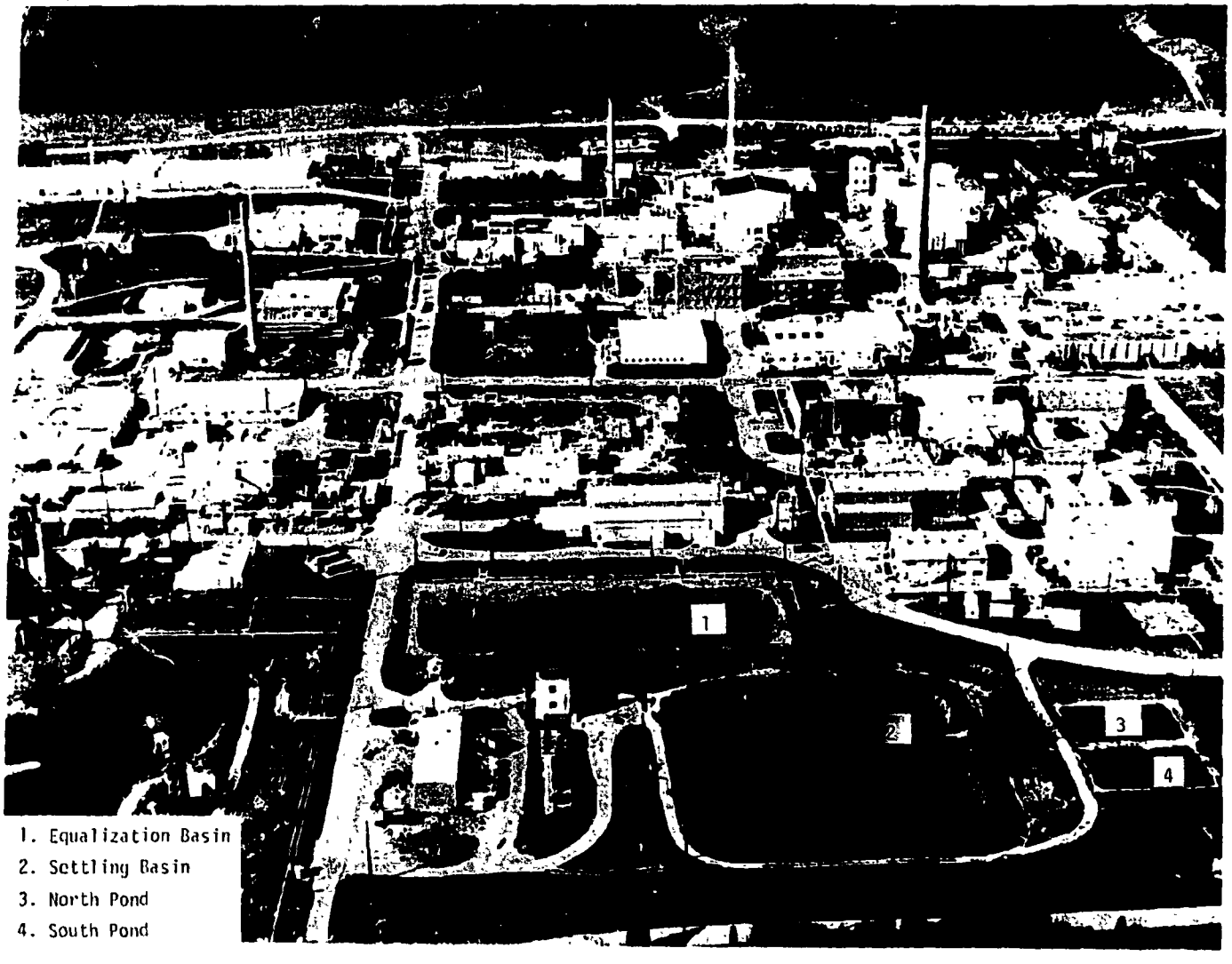

1. Equalization Basin
2. Settling Basin
3. North Pond
4. South Pond

Fig. V-2. Hold-up ponds and settling basin.

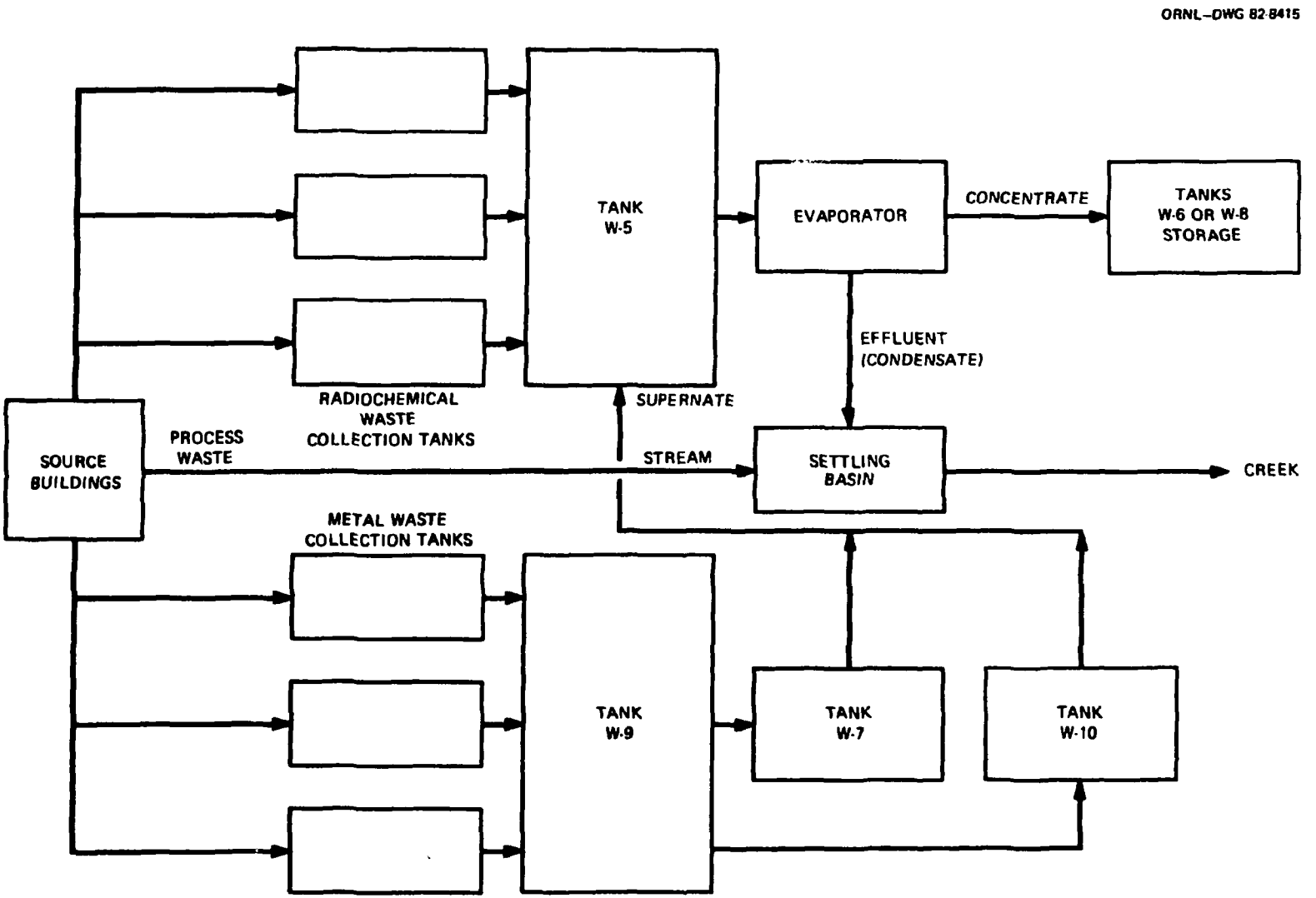

Fig. V-3. ORNL liquid waste flow sheet.

After 1965 waste was fed to an evaporator which concentrated the liquid by a factor of 20 to 30 by use of steam coils located in the bottom of the evaporator vessel (Bi79), and the concentrate was temporarily stored in another Gunite tank at the tank farm prior to disposal. (ERDA77) Modifications in 1978 connected the lines from the monitoring tanks at the source buildings to a six-inch stainless steel collection header which directed the flow to stainless steel storage tanks near the evaporator annex. (Bi79) Waste from the storage tanks is now transferred to one of two evaporators. The second evaporator was put into service in 1979. Condensate from the evaporators may be directed to the Low-Level Waste System or it may be processed further and the concentrate jetted to a stainless steel receiving tank. The concentrate stored at the evaporator is periodically transferred through 1740 meters (5700 ft) of cathodically protected doubly-contained stainless steel line, constructed in 1978 to replace the original transfer line, to the waste storage tanks near the hydrofracture site. The concentrate is presently disposed of by hydrofracture into the shale formation and the condensate is transferred to the process waste system.

3. Recovery, Treatment, and Disposal

Sodium hydroxide added to the metal waste solution caused most of the dissolved materials to settle in the Gunite tanks as a sludge. The sludge contains >99% of the transuranium nuclides from the uranium liquid wastes as well as some of the radioactive fission products from the metal waste stream. (ERDA77) Most of the ^{90}Sr from the metal waste stream was precipitated as a coprecipitate of calcium carbonate and, therefore, only a small portion was transferred in the form of suspended solids in the supernate. (Du76a) The liquid uranium waste supernate, after settling for about two months following precipitation of the uranium and plutonium in the collection tanks, was decanted to the ILW system and the supernate-radiochemical waste mixture was fed to the evaporator. (Brow49) In 1953 and 1954 the metal recovery plant was used to recover uranium and plutonium from the precipitated sludge.

Acid corrosion caused some leakage from the ILW stainless steel monitoring tanks and three had to be emptied and abandoned. Caustic soda was added in 1952 to neutralize incoming acid waste to eliminate this problem. (Brow59, Be64, Bl65) The waste was then pumped through stainless steel lines to the Gunite storage tanks. (Mo63)

The first experimental Chemical Waste Pit was opened in 1951, but its use for disposal of ILW was discontinued almost immediately because of its poor location. (Oa79c) The original purpose of Chemical Waste Pit No. 1 was to store the concentrated intermediate liquid waste in the tight, impermeable formation (Conasauga shale). (personal communications, T. Lomenick, ORNL, Oct. 1981) The chemical treatment of the ILW wastes received prior to disposal resulted in a high pH and reduced the mobility of those radionuclides having low aqueous solubility. (Me76) When it was discovered that the liquids seeped out but the formation retained a high percentage of the radioactive isotopes, this information was used to aid in the location and construction of additional disposal "seepage" pits. (personal communications, T. Lomenick, ORNL, Oct. 1981)

The second pit was built in 1952 with a capacity of approximately 3,800 m^3 (1,000,000 gal) and two more pits of similar size were added in 1955 and 1956. A 2.4 km (1 1/2 mile) long underground, two-inch diameter, cast iron pipeline was installed to transport the waste from the collection tank area to the disposal pit area (September 1962 Plant Engineering Report). This pipeline replaced the tank truck previously used to transport the liquid waste. In 1958, sections of this pipeline developed leaks because of corrosion and was replaced with carbon steel flanged lines. An outlet from the Process Waste Treatment Plant to the waste pits was also provided in case a major release to the Process Waste System could not be sufficiently decontaminated by the plant. (Laboratory Facilities - Waste Disposal Report for 1958 by E. J. Witkowski)

Chemical Waste Pits 2, 3, and 4 were excavated in weathered shale, much broken by little joints into small prisms. These pits are arranged end to end on the crest of a low ridge and operated as a unit. (Fig. V-4) Weathering extends to a depth 9 to 12 m (30 to 40 feet) under the low ridges and in many places the bottom of the weathered zone is at the water table. A seepage pit raised the water table in its vicinity. (deL58) When

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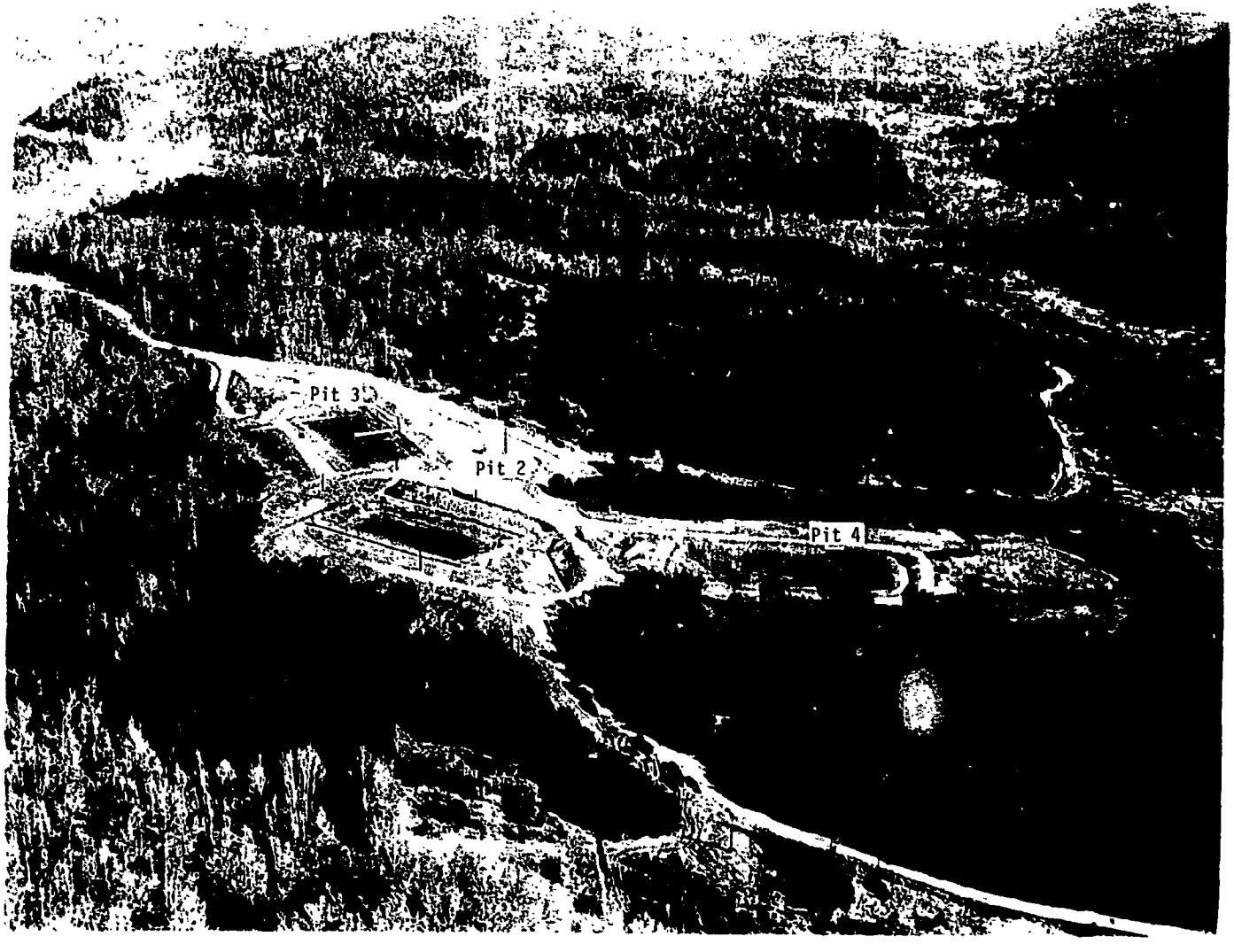


Fig. V-4. ORNL chemical waste pits.

the waste pit liquid level was high, the waste leaked out rapidly raising the water table. When the pit was empty the water table fell until more liquid was added to the pit. The pits were 4.6 m (15 ft) deep with sides sloping at an angle of 30^{o}. The top dimensions were 64 m by 30 m (210 ft by 100 ft). By the end of 1958, approximately 44,296 m^3 (11,703,000 gal) of waste containing 167,000 Ci had been discharged to the pits. NaOH was added to the liquid wastes in the pits and trenches to raise the pH to approximately 12 to increase reactions with the fill and to coprecipitate strontium with calcium carbonate and calcium phosphate. (April 1981, Intralaboratory Correspondence from C. R. Olsen, et.al. to Distribution). The only radioisotopes detected in the seepage from the pits were ^{106}Ru, ^{60}Co, and ^{125}Sb. (Brow59)

^{106}Ru migration was reported from the beginning of the operation of the chemical waste pits and in 1959 the pits became "overloaded" and large releases of ^{106}Ru occurred. The increase was attributed to the experimental processing of short-time-cooled reactor fuel in the Hot Pilot Plant. (Co60) It produced the highest concentration of radioactive waste (20 Ci/l) in laboratory history. Approximately 280,000 Ci of this waste was mixed with 13,500 m^3 of ILW and sent to the chemical waste pits. (Be64) In 1965 stainless steel tanks with water cooling coils and jackets were installed to store high level radioactive waste. (Bl65) The amount of ruthenium estimated to have seeped to the bed of White Oak Lake in 1958 was 160 Ci. (Co60) Annual discharges for the years 1959-1970 are listed in Table V-1. (Oa79c) To reduce the amounts of ruthenium leaving the pits, subsequent discharge of ^{106}Ru was curtailed and seepage from the east side of Pit 4 was intercepted and pumped back into the pit. (Co60) To further reduce ^{106}Ru release, ten tons of sodium sulfide was introduced into the pits (Laboratory Facilities - Waste Disposal Report for June 1962 by J.F. Manneschmidt). The sodium sulfide was of no significant help in reducing the release. (personal communication, S. Rimshaw, ORNL, Oct. 1981) In 1962 Pits 2, 3, and 4 were taken out of routine service. Chemical Waste Pit 3 was backfilled with earth and paved over with asphalt in 1962 and Pit 2 in 1963. (Information from Oak Ridge National Laboratory Waste Disposal Operations Monthly Reports) Chemical Waste Pit 1 continued to be used for disposal of liquids used in decontamination and decommissioning processes,

Table V-1. Annual discharges of ^{106}Ru to the Clinch River (Oa79c)

Year	^{106}Ru Discharge (Ci)	Year	^{106}Ru Discharge (Ci)
1959	520	1965	69
1960	1900	1966	29
1961	2000	1967	17
1962	1400	1968	5
1963	430	1969	2
1964	191	1970	1

(personal communication, L. Lasher, ORNL, Nov. 1981) and Pit 4 for the disposal of sludge. (Du75) As late as 1976 sludge from the Process Waste Treatment Plant (approximately 30,000 l/week or 8000 gal/week and 10 t % solids) was deposited in Chemical Waste Pit 4. (June 21, 1974 Radioactive Waste Management Plant, Oak Ridge National Laboratory, ORO-723, personal communication, L. Lasher, ORNL, Oct. 1981)

In July 1981 this pit was paved over with asphalt. (personal communication, J. Gissel, ORNL, April 1982) When the new Process Waste Treatment Plant became operational in 1976, the generated sludge went to a 435 m^3 lined basin. This liner, of thick plasticized polyvinyl chloride, holds the solids and liquids. After the sludge settled the supernate was pumped back to the equalization basin. (Ro79) This process was changed in late 1981 to eliminate the generation of sludge.

Studies of the seepage pits indicated that most of the waste solution moves to the east and to the west, parallel with the bedding. Therefore, beginning in 1960, the chemical waste pits were constructed as long, narrow seepage trenches 4.6 m (15 ft) deep with sides sloping so that the width at the bottom was about 3 m (10 ft). The top dimensions were about 92 m (300 ft) by 1.2 m (4 ft) (Trench 5), 150 m (500 ft) by 1.2 m (4 ft) (Trench 6) and 62 m (200 ft) by 1.2 m (4 ft) (Trench 7). The orientation was east-west, at right angles to the bedding so that the liquid would have maximum contact with the comparatively more permeable zones between the shale beds. (Du75, personal communication, D. Webster, USGS, Dec. 1981) The trenches were filled with coarse crushed limestone and a mound of dirt compacted over it to reduce the radiation field. (personal communication, L. Lasher, ORNL, Oct. 1981) Trench 5 (the first covered trench) became operational in 1960, Trench 6 in 1961 and Trench 7 in 1962. (Du75) Trench 6 operated only from Sept. 7 to Oct. 10, 1961 because of rapid migration of radioactivity from the trench to surface seeps; this rapid movement was attributed to groundwater flow through fractures in the Conasauga shale. (Du75) Trench 7 was constructed of two separate sections with an overflow line connecting them. The liquids were added to one section until it was filled and then to the second section. (April 1981 Intralaboratory Correspondence from C. R. Olsen, et.al. to Distribution) Trench 7 was the last seepage trench used for disposal of radioactive waste at ORNL.

(Du76a) The seepage pits and trenches were used to dispose of approximately 159 million liters (42 million gallons) of waste, containing over 1 million curies of mixed fission products. (Table V-2)

A study for disposing of ILW, based on the oil field technique of hydraulic fracturing, was intitiated in 1959. (deL68) The first experimental injections were made with a mixture tagged with ^{137}Cs. Core drilling and gamma-ray loggings followed to verify that the grout sheets followed the bedding planes and that the fractures were essentially horizontal. Measurements were also made on surface uplift and wellhead and observation well pressures in developing an understanding of the mechanics of fracture formation. Subsequent experimental injections resulted in the safe disposal of approximately 1,600 m^3 (430,000 gal) of waste containing 11,500 Ci total activity. These injections showed that it was possible to halt the injection, clear the well and equipment, make repairs, and resume operations without undue hazard to the operating personnel. (Bo68) Prior to injections, the waste tanks were agitated and sampled. The samples were mixed with the cement mix that would be used in the injection so that the pumping time and other characteristics of the waste-cement mix could be verified and adjusted if necessary. Routine disposal of the ILW by hydrofracture began in the fall of 1966. A well is drilled into the formation, cased and cemented to prevent the ground water from entering the well. When an injection is to be performed, the casing is perforated at the desired depth and water is pumped into the well until the pressure builds and produces a fracture in the formation. (Bo68) The ILW wastes are then mixed with a cement-base blend of dry solids to produce a slurry. The cement combines chemically with the radiostrontium in the waste, providing satisfactory retention of that nuclide. A small quantity of cement (5 lb/gal) is used and Attapulgite clay is added to prevent phase separation of the slurry. Radiocesium, the major radionuclide in the waste, is retained by illite clay. It was found that when fly ash was substituted for some of the cement (about half) it not only reduced the cost but improved strontium retention. The formula for the mix is usually modified slightly for each injection to compensate for small differences in composition and concentration. In general the slurry provide for about 99% retention of all radionuclides as measured by water-leaching tests.

TABLE V-2

ILW Discharged to Chemical Waste Pits (Du76a)

Chemical Waste Pit	Volume (gal)	Activity (Curies) ^{90}Sr	^{137}Cs	^{106}Ru
1*	0.012×10^6	--	--	--
2,3,4	24.0×10^6	43,500	201,000	236,000
5	9.5×10^6	96,500	207,000	5,000
6	0.13×10^6	125	660	50
7a	4.5×10^6	24,400	117,000	1,750
7b	4.0×10^6	23,500	102,000	1,480
TOTAL	42.1×10^6	188,000	628,000	244,000
Average Concentration (uCi/ml)		1.2	3.9	1.5
Residual Quantity as of Dec. 1981 (Curies)		125,000	418,000	<0.1

*Information taken from Oak Ridge National Laboratory Waste Disposal Operations Monthly Reports.

An estimated 400 Ci of activity had been released to Pit 1

(ORNL70) This slurry is injected into the impermeable shale formation at a specified depth between 200 and 300 m (700 to 1000 ft). (Wee80a) The injected grout forms a thin, approximately horizontal, sheet filling the crack between layers of shale. (Fig. V-5) The grout mix sets shortly after the injection, permanently fixing the radionuclides in the formation. Subsequent injections form new grout sheets above and parallel to the preceding sheets. All waste injections are made through slots cut in the casing and surrounding cement of the injection well. A summary of injections is included on Table V-3. (Wee80a)

4. Sludge Storage and Disposal

The six Gunite waste tanks located in the ORNL tank farm contain approximately 1,514 m^3 (400,000 gal) of sludge that has precipitated from liquid waste accumulated over a period of 35 years. (Wee80b) It has been proposed that this sludge be resuspended by hydraulic sluicing and pumped from the tanks. The resuspended sludge would be treated to keep the particles in suspension and pumped to the waste storage tanks at the hydrofracture site. There the sludge would be pumped from the tanks, combined with the cement-base mix, and disposed of by hydrofracturing. (Wee80b)

Shielding and handling limitations restricted the old hydrofracturing facility to waste solutions containing no more than approximately 1 Ci/gallon. (July 23, 1976, Radioactive Waste Management Plans, Oak Ridge National Laboratory, ORO-723). However the new hydrofracturing facility, completed in 1981, is capable of handling waste concentrate up to 20 Ci/gallon. The new hydrofracture facility uses a new injection well and will also have a network of monitoring wells. The facility, which will be able to dispose of the stored sludge, is currently being tested and is scheduled to receive the first injection in the spring of 1982. (personal communication, L. Lasher, ORNL, Nov. 1981)

5. Monitoring

The Operations Division is responsible for the management of radioactive wastes and waste disposal facilities. (Mo63) Surveys,

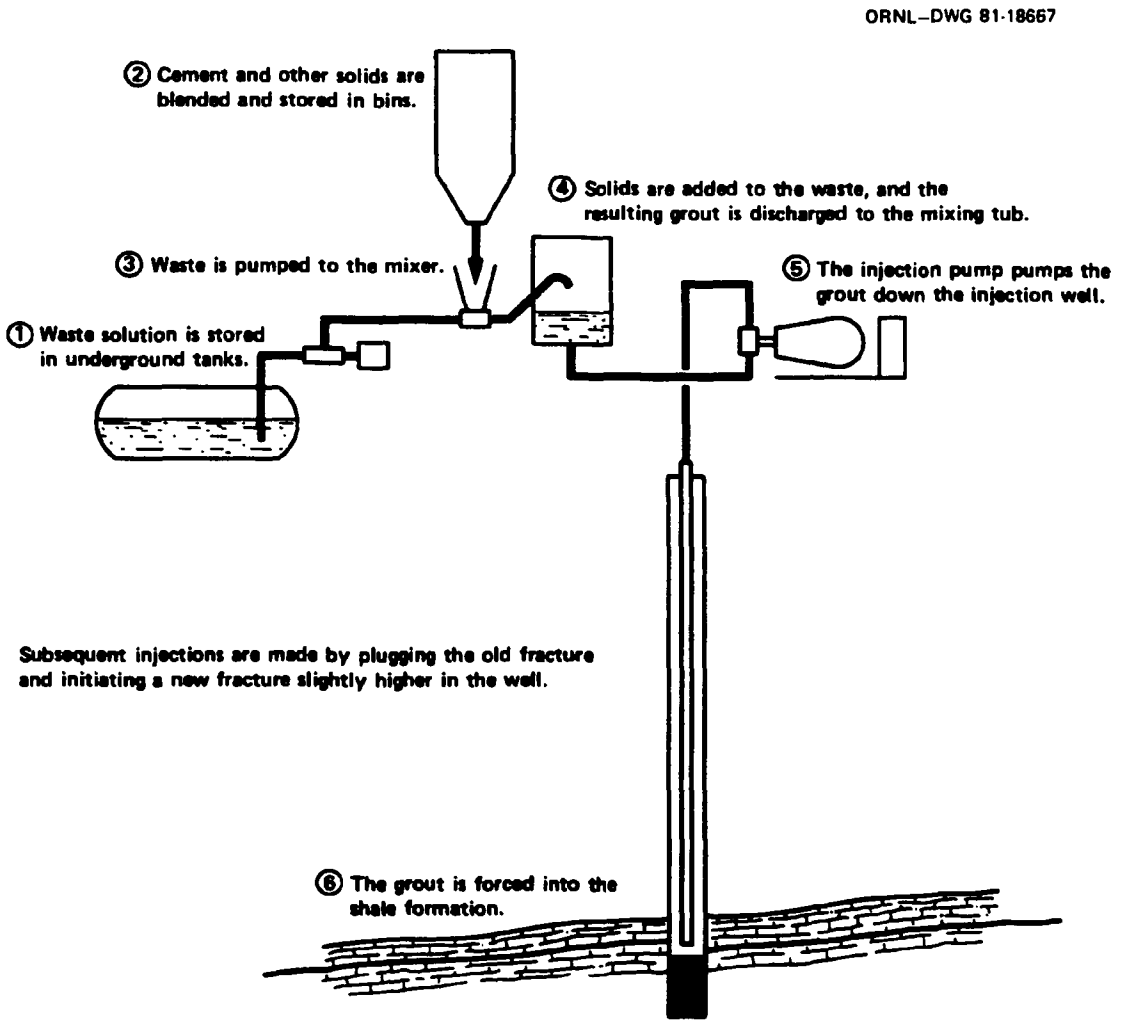


Fig. V-5. Schematic of hydraulic fracturing operations.

Table V-3. Summary of injection of ILW by Hydraulic Fracturing (Wee??a)

Injection number	Date	Depth (m)	Grout Volume (ℓ)	Water Volume (ℓ)	^{90}Sr (Ci)	^{137}Cs (Ci)	^{244}Cm (Ci)	^{239}Pu (Ci)
Experimental injections								
1-7	Feb. 1964 - Aug. 1965	288-266		2,566,000	1,436	5,237		
Operational injections								
ILW1A	Dec. 12, 1966	266	136,260	360,300				
ILW1B	Dec. 13, 1966	266	94,410		3	19,95	NA	NA
ILW2A	Apr. 20, 1967	263	325,500	872,100				
ILW2B	Apr. 24, 1967	263	234,700		1,050	58,500	NA	NA
ILW3A	Nov. 28, 1967	263	117,300	555,500				
ILW3B	Nov. 29, 1967	263			9,000	17,000	NA	NA
Water Test	Dec. 13, 1967	260						
ILW4A	Apr. 3, 1968	260	90,900					
ILW4B	Apr. 4, 1968	260	235,400	494,600	4,300	51,900	NA	1.10
ILW5	Oct. 30, 1968	257	309,600	435,900	500	69,400	NA	1.15
ILW6	*June 11, 1969*	*257*	*300,300*	*478,200*	*8,900*	*89,000*	*NA*	*0.24*
ILW7	Sept. 23, 1970	257	314,200	551,400	2,747	44,833	19.2	1.77
ILW8	Sept. 29, 1972	254	275,200	411,100	45	28,000	0.20	0.13
ILW9	Oct. 17, 1972	254	258,500	431,500	231	23,400	6.51	None
ILW10	Nov. 8, 1972	254	320,800	503,300	1,220	18,800	26.67	0.37
ILW11	Dec. 5, 1972	254	286,800	475,000	1,100	23,500	155.74	None
ILIW12	Jan. 24, 1975	251	97,300	159,300	1,324	12,752	1.02	None
ILW13	Apr. 29, 1975	251	306,600	477,300	3,368	35,750	17.83	0.03
ILW14	June 20, 1975	251	313,000	525,000	2,874	30.592	3.58	None
ILW15	June 30, 1977	251	344,400	549,000	138	26,390	None	0.66
ILW16	Nov. 17, 1977	248	208,900	300,900	1,618	14,964	None	None
ILW17	Sept. 1, 1978	244	311,500	520,400	90	22,270	2.27	0.07
ILW18	May 18, 1979	241	313,200	526,100	28	16,880	0.19	0.29
Total ILW			5,397,600	8,796,000	38,640	603,881		

monitoring, evaluating potential hazards of disposal, and environmental studies are conducted by the Industrial Safety and Applied Health Physics Division and the Environmental Sciences Division in cooperation with the Operations Division. This has included composite sampling and analysis of the wastes, estimation of losses by evaporation and seepage, and estimates of the dispersion based on radio-logging and sampling of test wells, and analysis of surface drainage below the disposal area. (USAEC59) The safety of ground disposal practices is ultimately evaluated in terms of their effect on the uncontrolled environment, particularly the Clinch River. (USAEC59)

The function of the monitoring tanks which received the raw wastes from "hot" drains was to collect the waste, provide a means of sampling it, and to measure its volume. The sampling was used as a basis for determining to which system (ILW or Process Waste) the stream was directed for further treatment before disposal. The tanks were equipped with "dry wells" to detect leakage. The rate of accumulation was continuously recorded at a central station by a telemetering system, plus periodic visits to each tank in case of a failure in the telemetering system. (Brow59) When the tanks became full the waste (ILW) was pumped to the centrally located Gunite storage tanks. These tanks were also equipped with "dry wells" to determine any leakage, volume gauges and samplers. (Brow59)

Surface runoff and basal flow from the White Oak drainage basin were collected and monitored before the ILW left the controlled area. Liquid levels in the pits were determined by means of a staff gauge, and continuous records maintained through use of a stilling well and "float" recorder. Wells were installed to provide geologic and hydrologic information and to detect the underground movement of waste. Volumes of wastes transferred were determined by measuring the amounts of liquids pumped from the collection tanks, and volumes of wastes to individual pits (which were connected by overflow pipe lines) were based on staff gauge readings and pit rating curves that equated liquid stage and volume. When Pit 4 became operational the overflow waste was passed from Pit 3, through Pit 2 until it became filled and its overflow was passed into Pit 4. The concentration of fission products was reduced as the waste was transferred.

Cesium and ruthenium were reduced by about 75 to 80%, strontium about 94% and essentially all the rare earths were removed. Reductions were the result of precipitation, sorption on the side walls of the pits, dilution by rainfall, and radioactive decay. Composite samples were analyzed for specific chemical ions and radionuclides.

The rate of seepage from the pits was determined from the net loss considering the waste pumped in, rainfall, and evaporation. It was found that the rates of seepage were influenced by the liquid stage, depth to water table, viscosity of the liquid waste, and the permeability of the soil. (Co58a) Small seeps developed in association with the pits and trenches. (Fig. V-6) (Me76) Additional sources of contamination were formed by leaks in the ILW transfer pipe lines. (Me76) Movement of stable chemical ions and radioactive ions out of the three disposal pits was monitored by well logging and sampling in fifty observation wells in the area and by analysis of samples taken from surface seeps and streams. The wells were sampled at pre-selected depths, based in part on logging results. Levels of activity in the observation wells fluctuated in response to the amount of waste in the pits and to the rate at which the pit was leaking. The lag in response, and the time required for activity to reach the well after the pit was filled gave a measure of the rate of movement from the pit. After a period of time the whole well tended to become radioactive and the record blurred. (1960 Intralaboratory correspondence from E.G. Struxness to F.L. Culler)

As of July 1958, ^{90}Sr and ^{137}Cs had not been detected in waste escaping from the pits in test wells, but ecological studies detected ^{137}Cs in trees and their litter in the pit area. Leaves, twigs and litter were sampled and concentrations of ^{106}Ru, ^{137}Cs, ^{95}Zr, ^{60}Co, and ^{144}Ce were found in various parts of the trees and litter. Since some of these trees were not in contact with ground seeps, it was thought that the movement was due to wind action on the exposed sides of the pits during periods of low liquid levels. (Au58) Therefore air monitoring stations were installed around the pits and the gross activity collected by standard gum paper. The analyses showed the amount of airborne activity was about twice that of off-site stations. (Co58a)

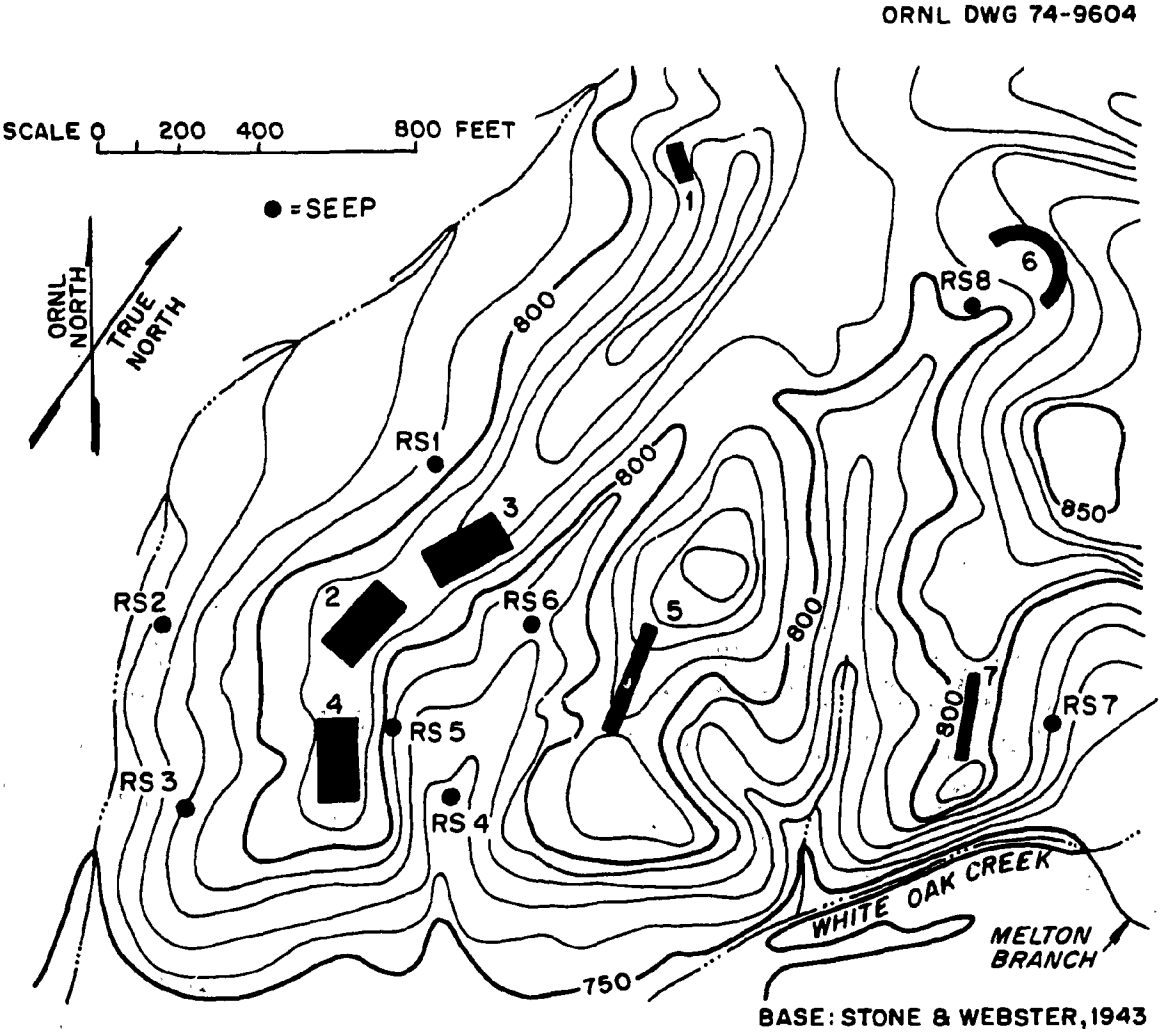


Fig. V-6. Location of small seeps associated with seepage pits 1, 2, 3, and 4 and trenches 5, 6, and 7.

The detailed study (well sampling, well logging, and budgeting of liquids, chemicals and fission products in the pits and seeps below them) was discontinued in 1960, and routine long-range monitoring procedures were initiated. (Co60) Weirs were installed in 1956 on the east and west streams draining the pit area to obtain records of stream flow. By using these records the quantities of activity being transported by the streams could be more accurately calculated.

Studies have indicated that migration of radioisotopes has occurred from the "seepage" pits and trenches even though the absorption capacity of Conasauga shale is very high. (Me78) Some of the factors which influence mobilization are: high annual rainfall, shallow groundwater levels and high-density surface drainage network, rock fractures, complexing agents used in decontamination operations, and natural organic acids. (Ta80) Means (Me78) has suggested that ethylenediamine-tetraacetic acid (EDTA), an extremely strong complexing agent used in decontamination operations, may cause low-level migration of ^{60}Co and also contribute to the mobilization of trace levels of Pa, Am, Cm, Th, and Ra.

Moisture and material transport models have been developed for the waste pit and trench areas. These models have been applied to Chemical Waste Pit 4. To augment calibration and verification, water table measurements were taken bimonthly at five locations, and groundwater samples were collected in both the saturated and unsaturated zones through seven monitoring wells and five vacuum-pressure suction lysimeters. Results suggest that the chemical character of the solution has favored retention of radionuclides. (Ta80) Currently, a ground water transport model is being developed for trench 7. (personal communication, Nancy Vaughan, ORNL, Dec. 1981)

Monitoring at the shale fracturing facility is achieved by a network of wells. These wells are observation wells to determine the orientation of the grout sheet, and rock-cover monitoring wells for verification of the continued impermeability of the shale above the grout sheets. The small-diameter cased observation wells extend below the deepest fracture. Both types of wells are logged with a gamma-sensitive probe after each disposal operation; new peaks of activity show where the latest injection has intersected each of these wells. (ORNL70) Core drillings have also

been used to confirm logging information and to obtain samples of the grout sheet. The rock cover integrity is tested by pumping water down uncased wells, a little above the depth of the shallowest fracture. Any marked increase in the volume of water injected in this manner would indicate an increase in permeability of the rock cover. Injection pressure and radiation exposure of the operating crew is regularly monitored during each injection, and after several injections have been completed, the surface uplift around the injection is determined. (Wee80a)

VI. WASTES REQUIRING SPECIAL HANDLING

The transuranic (TRU) wastes require special handling and storage because of their generally long half-lives, their high linear energy transfer, and their potential for criticality. The high-level wastes (HLW) present problems due to their high radiation exposure rates.

A. Disposal and Storage of TRU Radioactive Wastes

TRU materials at ORNL are defined as the isotopes of plutonium and the elements heavier than plutonium. Waste materials contaminated with U-233 are included in this category even though U-233 is not a TRU nuclide. (GC81)

TRU materials were strictly conserved during the early operating years of Oak Ridge National Laboratory. TRU contaminated waste and other radioactive waste were buried in shallow trenches since it was the least expensive option, ample land was available, and soil conditions were acceptable. (NAS76)

1. Disposal Methods

a. Waste Generation

All volumes of waste generated during the early years of ORNL were kept to a minimum due to the relative scarcity and uniqueness of the radionuclides used at ORNL. Various recovery operations were used for reclamation of radioactive materials to minimize waste volumes. (NAS76, Brow59)

b. Waste Disposal Methods

Prior to 1956, during the operational years of SWSAs 1-4, alpha-contaminated wastes were generally placed into holes approximately 4.6 meters (15 ft) in diameter and 4.6 meters (15 ft) in depth that were backfilled with 30 cm (12 in) of soil, 45 cm (18 in) of concrete, and again by 60 cm (24 in) or more of soil to reach the surface level. The purpose of the concrete layer was to prevent inadvertent disturbance of the plutonium-contaminated waste (Stra64). This practice was abandoned during

the latter portion of the operation of SWSA 5 when segregation of wastes was initiated at ORNL and retrievable storage was begun. (We76)

SWSA 2, which was operated between 1943 and 1946, received plutonium-contaminated liquid waste in stainless steel drums which were buried in trenches or stored in a natural ravine. Waste generated off-site was buried near the present location of the transformer station and covered with concrete; the use of concrete covers could indicate alpha contamination. The liquid plutonium waste and the other waste material in this burial ground was exhumed and re-buried in SWSA 3. Alpha wastes removed from SWSA 2 were placed in concrete lined trenches in the northeast end of SWSA 3. Later, alpha wastes were placed directly into unlined trenches in SWSA 3 and covered with concrete as burials extended to the west. (We76)

The practice of capping trenches containing alpha wastes with 45 cm (18 inches) of concrete was continued in parts of SWSA 4. "Higher level wastes and some special high-level wastes" were placed in auger holes 0.3 to 0.7 meters (1 to 2 ft) in diameter and 4.6 meters (15 ft) deep. There are about 50 of these holes along the Lagoon Road side of SWSA 4. (We76)

Attempts were made at SWSAs 3, (personal communication, D. Webster, USGS, Dec. 1981) 4 and 5 to segregate the beta-gamma wastes from the alpha contaminated wastes. (NAS76, 1977 Intralaboratory Correspondence from J.O. Duguid et al. to Distribution) In some cases, alpha emitters were covered with concrete prior to backfilling with dirt in SWSA 5. (NAS76) Some "highly radioactive waste materials" were disposed of in auger holes 4.6 meters (15 ft) deep and 31 cm (12 in) in diameter in SWSA 5. (Stra64, We76)

No accurate records are available showing the kind or quantity of waste buried during the early operation of the trenches. (1977 Intralaboratory correspondence from J.O. Duguid, et al. to Distribution) Table VI-1 lists estimates of the quantities of solid radioactive waste buried at various DOE sites in comparison to ORNL. (Di77) The volumes of solid radioactive waste buried at ORNL is approximately equal to that at other DOE burial sites. However, the activity at the time of burial of the wastes and the quantities of uranium and TRU wastes buried are substantially smaller. The levels of radioactive material disposed are

Table VI-1

Solid Radioactive Wastes Buried at DOE Sites
as of 10/1/76 (Di77)

Site	Volume (m^3)	Activity at Burial (kCi)	Uranium (kg)	TRU (kg)
Oak Ridge National Laboratory	180,000	100	100	13
Hanford	170,000	2,000	600,000	370
Savannah River Plant	260,000	8,200	84,000	7
Idaho National Engineering Laboratory	150,000	6,100	310,000	360
Los Alamos Scientific Laboratory	240,000	300	200,000	13

believed to be small due to the close accountability exercised with fission products and the extremely high value placed on radioactive materials. In addition, large curie sources of radioactive materials had limited availability and, therefore, the amount of radioactivity present in these burial grounds is assumed to be small. (1977 Intralaboratory correspondence from J.O. Duguid, et al. to Distribution, NAS76)

2. Storage Methods

On April 30, 1970, ORNL began segregating TRU waste from other classes of waste and started storing it in a manner that would allow retrievability for a 20 year period (1970 Intralaboratory Correspondence from R.E. Blanco to D.E. Ferguson). On September 12, 1974, the Atomic Energy Commission (AEC) proposed a ban on the soil burial of wastes containing more than 10 nCi/gram of TRU and required AEC approved storage for retrievability for 20 years. Table VI-2 lists the quantities of solid radioactive wastes retrievably stored at various DOE contractor sites. (Di77) A section of SWSA 5 has been designated for retrievable waste storage.

a. Waste Generation

TRU wastes requiring retrievable storage are generated primarily in research operations. In 1970, the major sources of contaminated solid waste were the TRU Facility (Building 7920), the Transuranium Research Building (Building 3508), the Pilot Plant (Building 3019), and the Hot Cell Building (Building 4507). (1970 Intralaboratory Correspondence from R.E. Blanco and J.P. Nichols to D.E. Ferguson) In early 1981 most of the TRU solid waste at ORNL was generated in the following facilities: Building 3019, Building 3508, Building 7920, the Radioisotope Production Laboratory A (Building 3028), the TRU Research Laboratory (Building 5505), the High Flux Isotopes Reactor (Building 7900), and the Thorium-Uranium Recycle Facility (Building 7930). (GC81)

b. Waste Disposal Methods

Since October, 1970, when segregation of waste started, three retrievable storage methods have been used at ORNL. These are: a) stored

Table VI-2

Solid Radioactive Waste Retrievably Stored at DOE Sites
as of 10/1/76 (Di77)

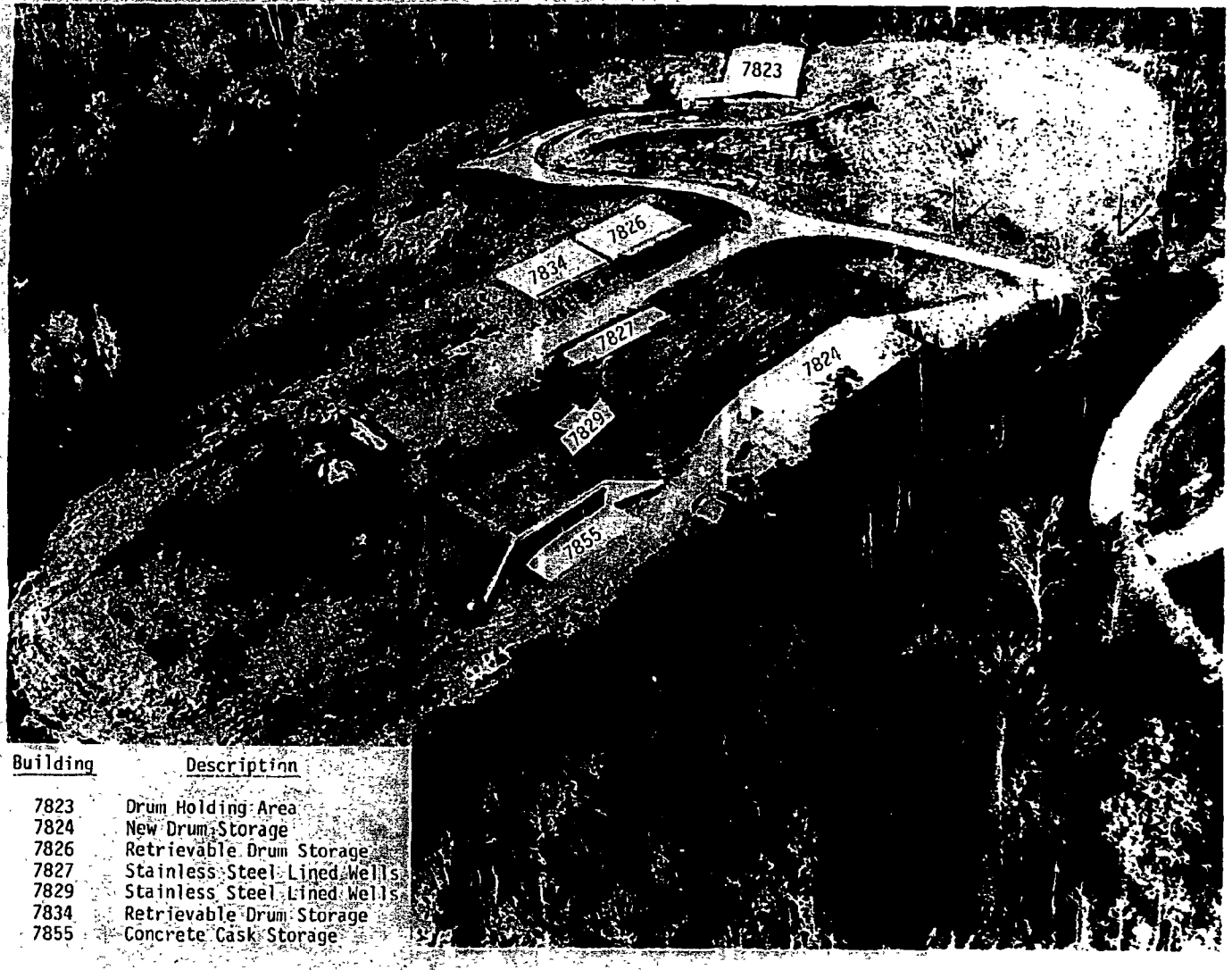
Site	Volume (m^3)	Pu (kg)	Other TRU (kg)
Oak Ridge National Laboratory	1,200	1	15
Hanford	6,600	53	--
Savannah River Plant	1,400	44	5
Idaho National Engineering Laboratory	32,000	170	64
Los Alamos Scientific Laboratory	1,200	17	5

drums; b) stainless steel lined wells; and c) concrete casks. The facilities described in this section for retrievable storage of wastes are shown in Figure VI-1.

Solid TRU wastes with low external gamma exposure rates (<200 mR/hr) were first stored in 114 or 220 liter (30 or 55 gallon) stainless steel drums in Building 7823, as shown in Figure VI-2. (1977 Intralaboratory Correspondence from J.O. Duguid et al. to Distribution) The drums are sealed with a neoprene gasket and a closure ring. (GC81) Building 7823 (now used as a temporary holding area) is 15 meters (48 ft) wide, 24 meters (78 ft) long and 2/3 below grade; it has a crushed rock floor, metal roof and walls, and ceiling of chain link fence fabric. Once a sufficient number of drums have accumulated, a cell of the Retrievable Waste Storage Facility, Building 7826, is opened and the waste drums emplaced for storage. Building 7826, which was constructed in 1976, is a one-story reinforced concrete and concrete block structure measuring 12 meters (39 ft) by 17 meters (55 ft) and 4 meters (13 ft) in height with 85% of the structure below grade. There are 24 cells which hold 220-liter drums with 64 drums/cell, 16 drums/layer and 4 layers/cell. (1977, Intralaboratory Correspondence from J.O. Duguid et al. to Distribution) Figure VI-3 is a photograph of Building 7826 with the cover removed and drums being loaded into a cell. A second storage facility (Building 7834) with a larger holding capacity was completed in 1980. It has removable concrete plugs rather than metal roofing and has space for an additional layer of drums in each cell. (GC81) About 85% of the structure is below grade. (1977 Intralaboratory Correspondence from J.O. Duguid et.al. to Distribution)

Prior to completion of Building 7826, the TRU wastes were stored in mild steel boxes, black iron drums, or stainless steel drums in Building 7823. (NAS76) Use of the black iron drums was discontinued because they were subject to deterioration. The drums are periodically inspected for leakage and are routinely maintained. (GC81) Criticality control is maintained by limiting the quantity of fissionable material to 20 grams in each 114 liter (30 gallon) drum. (1977 Intralaboratory Correspondence from J.O. Duguid et.al. to Distribution) The quantity of fissionable material

ORNL PHOTO 8039-81



Building	Description
7823	Drum Holding Area
7824	New Drum Storage
7826	Retrievable Drum Storage
7827	Stainless Steel Lined Wells
7829	Stainless Steel Lined Wells
7834	Retrievable Drum Storage
7855	Concrete Cask Storage

Fig. VI-1. Aerial view of TRU waste storage area.

ORNL PHOTO 2806-73

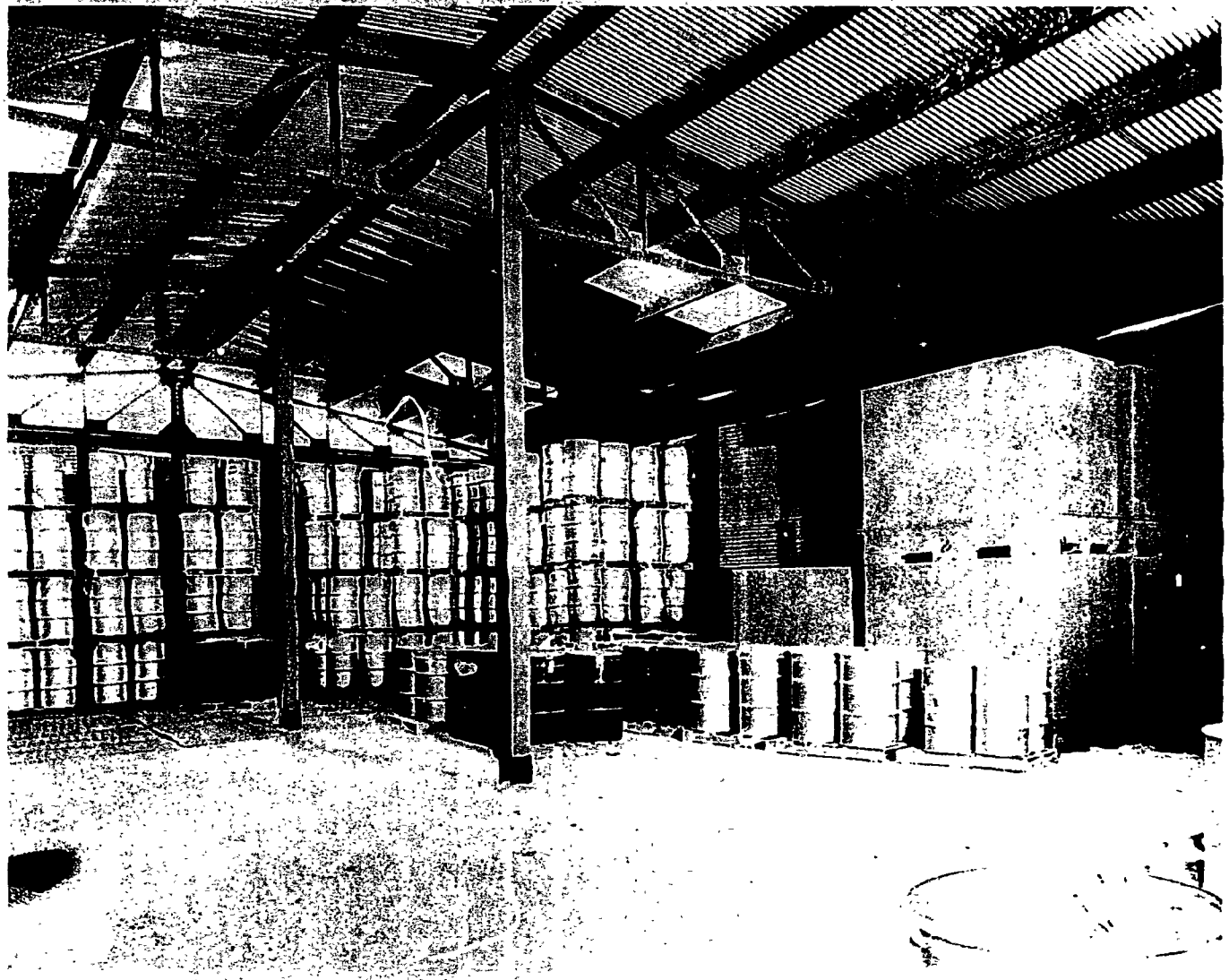
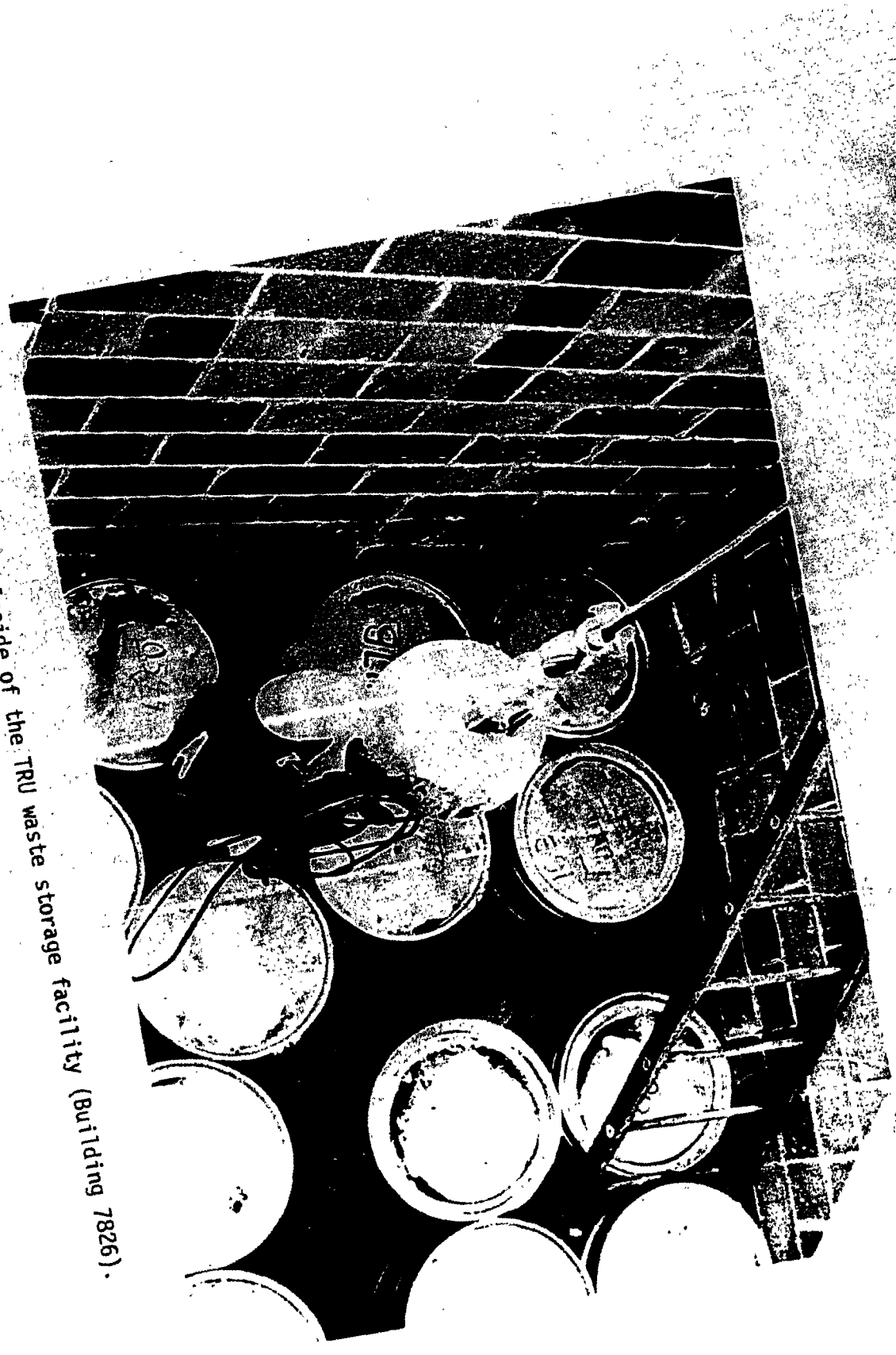


Fig. VI-2. Inside of TRU drum holding area (Building 7823).



ORNL PHOTO 5206-76

Fig. VI-3. Inside of the TRU waste storage facility (Building 7826).

allowed in each 220 liter (55 gallon) drum is 36 grams. (1979 ORNL Radioactive Solid Waste Operations Manual)

The total storage capacity of Buildings 7826 and 7834 is 3456 drums. At the end of 1979, approximately 1600 drums were in storage; 1300 stainless steel drums and 300 black iron drums. (GC81)

TRU waste with high external gamma exposure rates (>200 mR/hr) or having high neutron emission levels are sealed in reinforced concrete casks at the point of origin. (1977, Intralaboratory Correspondence from J.O. Duguid, et al. to Distribution) The majority of the waste placed into concrete casks has been generated in Building 7920. (GC81) Currently concrete casks with three different wall thicknesses (thin, intermediate, and thick) are available for waste burial. Internal diameters range from 65 to 100 cm (27 to 42 in) and the lengths range from 150 to 190 cm (58 to 73 in). (1979, ORNL Radioactive Solid Waste Operations Manaual) The wall thicknesses of available casks range from 11 to 30 cm (5 to 12 in), depending on the shielding requirements, and the casks are 2.5 meters (8 ft) in height. (GC81) Once the casks are filled and sealed, they are transported by tractor-trailer units and unloaded by mobile crane into a 3 meter (10 ft) deep trench, as shown in Figure VI-4. The trench is backfilled with soil when loaded to capacity. (NAS76, 1977 Int'laboratory Correspondence from J.O. Duguid et al. to Distribution) Use of the 11 cm casks was discontinued in the late 1970's. (GC81) Criticality control is maintained by limiting the fissionable material to 200 grams per cask. (Procedures and Practices for Radiation Protection, Health Physics Manual, Oak Ridge National Laboratory, 1980)

The practice of burial in trenches in the northern section of SWSA 5 (TRU Area) was discontinued in 1979 and storage was initiated in a cave-like facility (Building 7855) in the side of a knoll (Fig. VI-5) (GC81) Building 7855 is a one-story, four bay concrete block structure with a reinforced concrete slab base and roof. The casks are loaded into the cave using a forklift. At the end of 1979, 190 casks had been buried in trenches; cave storage began in 1980. (GC81)

Small TRU-contaminated waste packages with high external gamma exposure rates have been placed in stainless steel (or in some cases, brass) capsules and sealed with a metal gasket and bolt closure assembly

ORNL PHOTO 1647-71

Fig. VI-4. Concrete casks used for TRU wastes with high external gamma exposure rates.

ORNL PHOTO 3464-80

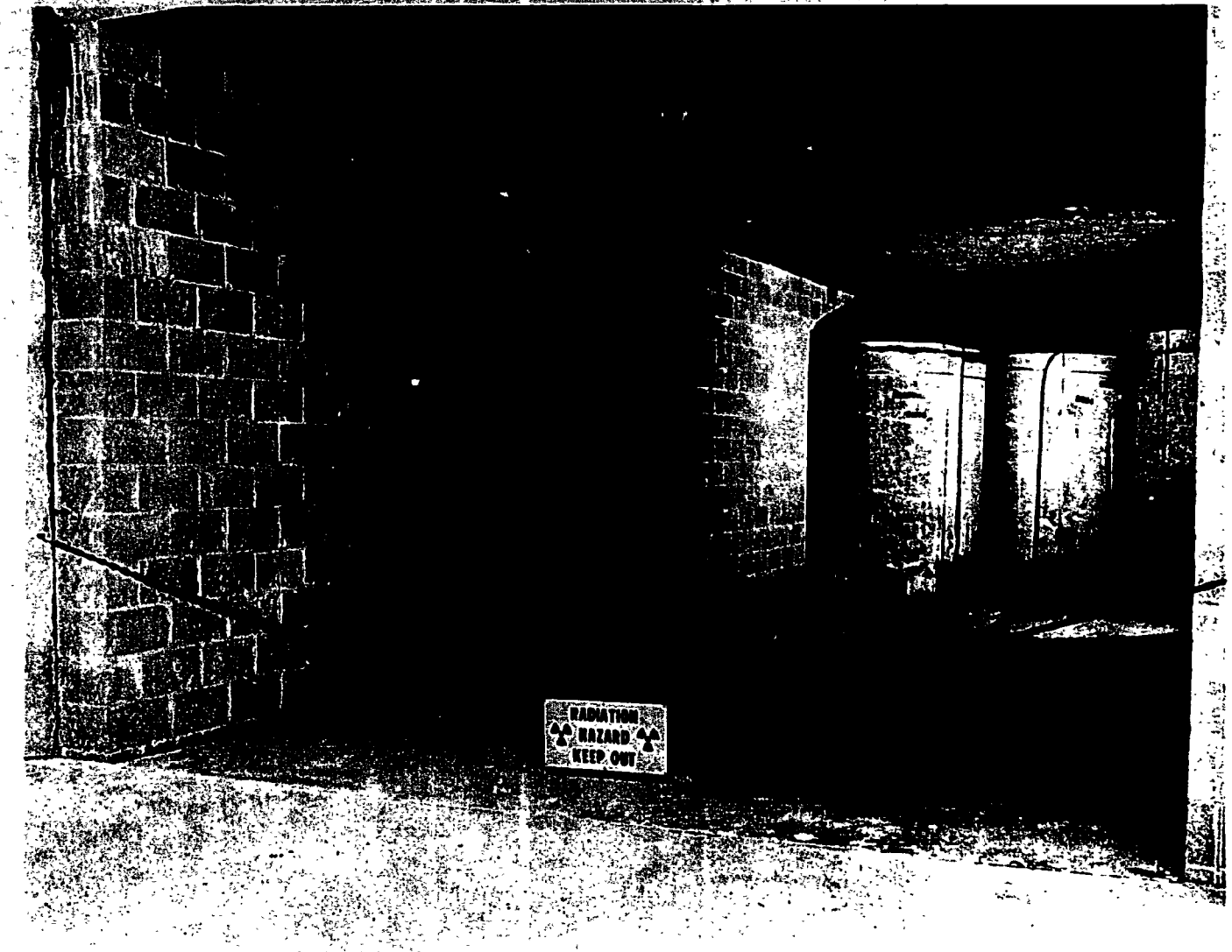


Fig. VI-5. Cave-like facility for storing TRU waste with high external gamma exposure rates or having high neutron emission levels.

for storage. The first capsules were stored in individual auger holes, each lined with stainless steel and closed with a stepped concrete plug (Fig. VI-6). The auger holes are 2.75 meters (9 ft) deep and have a 24 cm (9 in) outer layer of concrete placed around the stainless steel liner to prevent flotation. The auger hole itself is 20 to 75 cm (8 to 30 in) internal diameter and the concrete plugs are 46 cm (18 in) thick. One meter spacing was maintained between the eight auger holes. (1977, Intralaboratory Correspondence from J.O. Duguid et al. to Distribution)

Buildings 7827 and 7829, built after the first eight auger holes (Fig. VI-6) are an improved extension of ORNL facilities for storing TRU wastes with high external gamma exposure rates. Currently, building 7827 has 30 wells; 15 wells are 4.6 meters (15 ft) deep and the remaining wells are 3.1 meters (10 ft) deep. Each group is comprised of an equal number of 20 cm (8 in), 40 cm (16 in) and 76 cm (30 in) diameter holes lined with stainless steel and capped with stepped concrete plugs. Building 7829 contains 10 wells 30 cm (12 in) in diameter by 4.6 meters (15 ft) deep. (personal communication, E. M. King, ORNL, Dec. 1981) The waste containers are held by a cable and lowered into the wells from a shielded carrier. (GC81) Spacing between wells is maintained in such a manner that noncriticality is assured. (1979 ORNL Radioactive Solid Waste Operations Manual)

Oil wastes which contain radioactivity are shipped to the ORNL burial grounds following proper approval and are held for storage. These liquid wastes will be disposed by hydrofracturing in the future. (0a79b, personal communication, T. Grizzard, ORNL, Dec. 1981)

The volumes and quantities of solid radioactive waste retrievably stored at DOE sites is shown in Table VI-2. ORNL has a relatively small volume of TRU wastes stored in retrievable form in comparison to other DOE sites. The quantity of plutonium stored at ORNL is signficantly less than other DOE sites, yet the quantities of other TRU nuclides stored at ORNL are surpassed only by those at the Idaho National Engineering Laboratory.

ORNL PHOTO 1646-71

Fig. VI-6. The above ground portion of a stainless steel lined auger hole.

B. ^{235}U Wastes

Fissile non-alpha wastes are the solid wastes which by definition contain more than one gram of ^{235}U regardless of the concentration, or more than 35.7 grams/m^3, regardless of quantity. (NAS76)

1. Disposal Methods

a. Waste Generation

Sources of ^{235}U waste at ORNL include various metallurgical operations, residues from instrument applications, hot cell operations, and various research and analytical activities. (1977 Intralaboratory Correspondence from J.O. Duguid et al. to Distribution) The major concern with these wastes is not exposure, but criticality. (NAS76)

b. Waste Disposal Methods

The ^{235}U wastes containing greater than 36 gm/m^3 (1 gm/ft^3) of fissionable isotopes are normally buried in unlined auger holes of various diameters ranging from 60 cm (2 ft) to 110 cm (3.5 ft) and 6.2 meters (20 ft) deep which are drilled in the Conasauga shale of the burial areas. The depth is determined by prevailing hydrologic conditions. (1977 Intralaboratory Correspondence from J.O. Duguid et al. to Distribution, GC80) The holes are one meter apart (edge-to-edge) and a 200 gram fissionable product limit per auger hole is used for criticality control. The unlined auger holes are closed with backfill and a 15 to 20 cm (6 to 8 in) layer of concrete is poured about 15 to 31 cm (6 to 12 in) below the surface. The area is then planted in grass. (personal communication, E.M. King, ORNL, Dec. 1981)

When unpackaged bulk material has less than 36 gm/m^3 (1 gm/ft^3) of fissionable isotopes, it is placed in unlined trenches. These trenches are filled to a level 0.9 meters (3 ft) from the surface and then backfilled with soil. Periodically, after an area of about an acre has been filled with closed trenches, 0.6 meters (2 ft) of soil is removed from over the trenches and 4 lb/ft^2 of bentonite clay are disked into the soil. The 0.6 meters (2 ft) of soil is then replaced over the trenches and the

surface is planted in grass. (personal communication, E.M. King, ORNL, Dec. 1981) The bentonite layer impedes infiltration of rainfall into the waste. SWSA 5 was abandoned as a ^{235}U disposal area due to excessive limestone in the disposal area. (1979 ORNL Radioactive Solid Waste Operations Manual) All ^{235}U waste currently generated is stored in SWSA 6.

C. Liquid Waste

1. TRU Liquid Wastes

a. Waste Generation

The TRU processing area has been the major source of TRU liquid waste at ORNL since the late 1960's. Quantities of wastes generated varied from 2700 to 15000 liters/year (730 to 4100 gallons/year). (GC80)

b. Waste Disposal Methods

Prior to July 1970, wastes from the transuranium processing facility were diluted, neutralized with caustic and pumped via underground pipes to storage tank W-6 in Bethel Valley where it was mixed with and treated as intermediate level waste. (1972 Intralaboratory Correspondence from W.D. Burch, et al. to Distribution, GC80) The concentrations normally did not exceed 1.3 Ci/liter (5 Ci/gallon) even though originally the maximum operating level was anticipated to be 2.7 Ci/liter (10 Ci/gallon). Solutions containing I-131 were stored for 90 days prior to transfer to tank W-6. A significant increase in the rate of generation of TRU liquid wastes occurred due to the processing of some Savannah River fuel slugs and target tubes at the TRU facility. The increased rate of liquid waste generation and leaks in the pipeline to Bethel Valley resulted in a decision to truck the liquid wastes to the storage tanks in Bethel Valley. New piping was laid in 1971-72 and transfer of wastes by pipeline to storage tank W-6 was resumed in mid-1972. Plans were made in 1972 for neutralization and combination of these wastes with ILW in tank W-6, evaporation of the supernatant liquid, and transfer of the concentrated liquid to the hydrofracture unit.

Until mid-1980, TRU liquid wastes were collected in the intermediate-level wastes tanks T1 and T2 located in the Melton Valley area and transported to the W-5 tank area. Tanks T1 and T2 each have 56,000 liter (15000 gallon) capacities and serve the 7900 area. TRU contaminated waste from the Transuranium Processing Facility, Building 7920, are transferred into a stainless steel, [illegible]ly contained tank installed in late 1980. TRU wastes are now pumped into the OR-ILW evaporator service tanks W21 and W22 unless the activity levels exceed 5.3 Ci/liter (20 Ci/gallon). The wastes will then be mixed with and treated as intermediate-level waste. (GC80)

2. High-Level Liquid Waste

a. Waste Generation

In earlier papers, the term "highly radioactive" liquid waste was used not to identify high-level waste but to identify intermediate-level waste. (Brow59) High-level liquid radioactive waste (HLW) at ORNL is defined as those wastes with a concentration greater than 5 Ci/gallon. (personal communication, L. Lasher, ORNL, Oct. 1981) During the time span from 1964 to 1980 small quantities of high-level radioactive liquid wastes were generated, primarily by the following facilities (GC80):

Building 3019 - Pilot Plant

Building 3517 - Fission Product Development Laboratory

Building 7920 - Transuranium Processing Facility

b. Waste Disposal Methods

Equipment has been installed for the collection of large quantities of HLW even though no significant amounts of HLW are currently generated at ORNL. (GC80) In 1965, two stainless steel 190,000 liter (50,000 gallon) tanks, designated C-1 and C-2 measuring 19 meters (62 ft) long and 3.6 meters (12 ft) in diameter, and an evaporator were installed for the collection of hot, acidic HLW with concentrations up to 750 Ci/liter (2800 Ci/gallon). (Bi79, GC80) The tanks are located in an

underground reinforced concrete vault north of the Evaporator Building (Building 2531). (Bi79) Tank C-2 is used for primary collection and currently holds about 7500 liters (2000 gallons) of TRU Facility HLW which was transported there by a carrier. (Bi79, GC80) Tank C-1 is used as a standby collection tank for overflow from C-2. (GC80) In 1979, 30 cm (12 in) stainless steel lines were installed in concrete conduit for transfer of HLW from the Pilot Plant (Building 3019) and the Fission Product Development Laboratory (Building 3517) but have not been connected to the tanks as of December 1981. The small quantities of HLW generated at these facilities has been stored locally by the laboratories generating the wastes. (Bi79)

The HLW is diluted with intermediate-level waste and either treated in the ILW evaporator and sent to the hydrofracture facility or it is sent directly to the hydrofracture facility. (GC80)

c. Monitoring

Circulated air from tanks C-1 and C-2 is vented through the off-gas connection on each tank. The tanks and the vaults are vented through the ORNL Gaseous Waste Disposal System. Continuous recording of the liquid level, temperature and specific gravity of tank contents is possible via instrumentation on each tank. Alarms for indicators of overfilling or excessive temperatures are available in the Evaporator Control room. (Bi79)

VII. OFF-SITE RELEASES OF RADIONUCLIDES AND MONITORING

Natural levels of activity and concentration of dissolved substances in water from White Oak Creek were measured in 1943 before the first discharge of effluent. The water discharged from White Oak Dam (WOD) has been monitored since 1944. The methods and frequency of sampling have changed over the years. Until 1958, "grab samples" were taken. In 1958 a sampling device was installed which pumped water continuously from the creek into a collection drum. This was replaced in 1960 with a continuous and proportional flow monitor that took samples in proportion to discharge. (We76) These samples are collected weekly and analyzed as a control measure for gross beta activity to evaluate the gross concentration of radioactivity entering the Clinch River. These samples are also analyzed for the transuranic alpha emitters, total strontium and ^{131}I. Monthly composites, made from portions of the weekly samples, are analyzed for gross beta, ^{90}Sr, ^{131}I, ^{137}Cs, ^{106}Ru, ^{60}Co, tritium, and transuranic radionuclides. Table VII-1. shows the annual discharges of ^{137}Cs, ^{106}Ru, ^{90}Sr, ^{3}H, and TRU to the Clinch River for the period of 1949-1979. (Oa79c)

Prior to 1957 the majority of radionuclides entering the Clinch and Tennessee Rivers were from process waste. Other sources were seepage from chemical waste pits (primarily ^{60}Co and ^{106}Ru from Pits 2, 3, and 4), and erosion and leaching of sediments contained in the beds of the previously used intermediate pond and White Oak Lake. Another source of radioactivity was the fallout from weapons tests, especially high in 1961-62. During this period, 16% of the total ^{90}Sr and measurable quantities of ^{137}Cs and ^{106}Ru in the Clinch River came from fallout. (Stru67) The principal radionuclides with long half-lives released to the Clinch River were ^{144}Ce and other rare earths, ^{60}Co, ^{137}Cs, ^{90}Sr, and ^{106}Ru. Some low-level activity was released from the process treatment plants, settling basin and laundry facilities.

Several surveys have been conducted at ORNL to determine the radiological condition of sediment in White Oak Creek below the dam. The earliest survey on record was in 1945 and 1946. Total activity in the sediment was calculated to be 0.3 Ci in 1945 and 0.9 Ci in 1946. (Mor47)

Table VII-1. (0a79a)

Annual Discharges of Selected Radionuclides to the Clinch River (Curies)

Year	^{137}Cs	^{106}Ru	^{90}Sr	^{3}H	TRU
1949	77	110	150	NA[a]	0.009
1950	19	23	38		0.04
1951	20	18	29		0.08
1952	10	15	72		0.03
1953	6	26	130		0.08
1954	22	11	140		0.07
1955	63	31	93		0.25
1956	170	29	100		0.28
1957	89	60	83		0.15
1958	55	42	150		0.08
1959	76	520	60		0.68
1960	31	1900	28		0.19
1961	15	2000	22		0.07
1962	6	1400	9		0.06
1963	4	430	8		0.17
1964	6	191	7	1929	0.08
1965	2	69	3	1161	0.50
1966	2	29	3	3090	0.16
1967	3	17	5	13273	1.03
1968	1	5	3	9685	0.04
1969	1	2	3	12247	0.20
1970	2	1	4	9473	0.40
1971	1	0.5	3	8945	0.05
1972	2	0.5	6	10600	0.07
1973	2	0.7	7	15000	0.08
1974	1	0.2	6	8633	0.02
1975	0.6	0.3	7	11061	0.02
1976	0.2	0.2	5	7422	0.01
1977	0.2	0.2	3	6249	0.03
1978	0.3	0.2	2	6292	0.03
1979	0.2	0.1	2	7700	0.03
1980	0.6	0	2	4554	0.04

[a]No analysis performed.

A survey of gamma activity in the Clinch and Tennessee Rivers bottom deposits was undertaken in 1951 and repeated in 1952. The survey covered 627 miles of the Tennessee River, about 60 miles of the Clinch River, and portions of the major streams feeding these rivers. The activity below Chickamauga Reservoir was found to be fairly uniform. The activity above this point increased as the mouth of the Clinch River was approached and reached a maximum at Clinch River mile 13. The beta-gamma ratio increased as the activity of the mud decreased. (Mo53a) The 1952 survey indicated a trend toward increasing accumulations of radioactive materials in bottom sediments with time. (Mo53b)

Several organizations were involved in a study of the Clinch River downstream from ORNL which began in 1959 and continued until 1965. One objective of the study was to determine the fate of radioactivity which had been released into the Clinch River and to see how the radionuclides were dispersed in the river and sediment. (Stru67)

As part of the study, water-sampling stations were constructed on the Clinch and Tennessee Rivers in November 1960. Two of the stations (one on the Clinch and one on the Tennessee River) were placed upstream from the point of radionuclide entry into the Clinch River so that background levels could be determined. The other two stations on the Clinch River were at Clinch River mile 5.5 (Centers Ferry in Kingston) and Clinch River mile 14.4 (ORGDP Water Plant). On the Tennessee River, the two sampling stations were at Tennessee River mile 471.0 (Chickamauga Dam at Chattanooga) and Tennessee River mile 529.9 (Watts Bar Dam near Spring City). In addition, grab samples were taken from streams near the Oak Ridge area and the Tennessee River. ORNL and the United States Public Health Service both analyzed the water samples from the water-sampling station at White Oak Dam as a test of analytical procedures. (Stru67) Table VII-2. shows the average and range of concentrations for the period November 1, 1960 to February 18, 1961. (Car61)

Results from this continuing study in 1962 indicated that no ^{106}Ru and very small quantities of ^{90}Sr were sorbed by the bottom sediments of the Clinch River between the mouth of White Oak Creek and Centers Ferry.

Fifteen cores were taken from the Clinch River in the summer of 1962. The vertical distribution of selected radionuclides was determined, and

Table VII-2

Summary of Radiochemical Analyses[a] (Car61)

Radionuclide	Average Concentration (μμc/liter)	Range in Concentration (μμc/liter)
Clinch River at Oak Ridge Water Plant		
Ruthenium 106	48	b-210
Cobalt 60	b	
White Oak Creek at White Oak Dam		
Ruthenium 106	177,000	116,000-274,000
Cobalt 60	4,240	2,500-7,700
Clinch River at Oak Ridge Gaseous Diffusion Plant Water Plant		
Ruthenium 106	246	76-383
Cobalt 60	b	Tr[c]
Strontium 90	23.3	4.5-70
Cesium 137	11.9	b-32
Clinch River at Centers Ferry		
Ruthenium 106	381	b-1,500
Cobalt 60	9.9	b-33
Tennessee River at Watts Bar Dam		
Ruthenium 106	78	8-139
Cobalt 60	b	
Tennessee River Chickamauga Dam		
Ruthenium 106	95	b-290
Cobalt 60	b	

[a]Results of radioactive chemical analyses furnished by U.S. Public Health Service for all stations except Clinch River at Oak Ridge Gaseous Diffusion Plant Water Plant.

[b]Concentration is too low for detection.

[c]Cobalt 60 detected in suspended sediment of one sample.

then each core was dissected and analyzed to determine the total radionuclide content. It was shown that ^{137}Cs, ^{106}Ru, TRE (except ^{144}Ce), ^{90}Y and ^{60}Co are displaced longitudinally with the concentration of these radionuclides decreasing with distance downstream from White Oak Creek. (Car63)

An estimate was made of the inventory of radionuclides in bottom sediments in Clinch River for a total distance of 21 miles, from the mouth of White Oak Creek to the mouth of the Clinch River. The quantities of these radionuclides in bottom sediments were 155 Ci of ^{137}Cs, 18 Ci of ^{60}Co, 16 Ci of ^{106}Ru, 3 Ci of ^{90}Sr, and 10 Ci of the rare earths; the total activity was about 200 Ci Fifty percent or more of these radionuclides were downstream from Clinch River mile 8.7. Ratios of the quantities of these radionuclides in the sediments to quantities that were discharged through White Oak Dam were calculated, with correction for decay, in order to see how much activity was retained in the sediments. The highest retention was for ^{137}Cs, 21%; followed by ^{60}Co, 9%; ^{106}Ru, about 0.4%; and ^{90}Sr about 0.2%. Multiple half-lives and inadequate data made the estimate difficult for rare earths; however, it was estimated that they were retained to the extent of about 25% or greater. (Car65) Samples of sediment from the mouth of White Oak Creek entering the Clinch River were collected in 1970. The ^{137}Cs concentration in the sediment was 5.8 pCi/g. This concentration was higher than the concentration of cesium found in the sediment from the White Oak lake bed, which was 1.9 pCi/g. (Ta70)

In 1979, T.W. Oakes made new estimates of the inventory of radionuclides in sediments of the Clinch River. These calculations were based on the previous inventory accounting for decay, and the total release of tritium from White Oak Lake since 1964 of 132,000 Ci. The new values were 108 Ci for ^{137}Cs, 5 Ci for ^{60}Co, 2 Ci for ^{90}Sr, and 5 Ci for total transuranics. The total approximate inventory was 120 Ci. (Oa79a)

In addition to surveys and studies to determine the radiological conditions of the Clinch and Tennessee Rivers as a result of off-site releases, studies were also conducted to determine exposure levels from and around Oak Ridge. Surveys have been made of the Oak Ridge Reservation and the surrounding area utilizing the Aerial Radiological Measuring System (ARMS). These surveys consisted of airborne gamma radiation measurements

from both natural- and man-made isotopes on or in the terrain surface. The purpose was to identify radioactive contaminants, including their concentrations and spatial distribution, attributable to ERDA operations. Airborne radiological surveys were conducted in 1959, 1973, 1974 and 1981. The 1959 and 1973 data were collected by fixed-wing surveys. The 1974 survey was made by helicopter in order to survey at lower altitudes and slower speeds. (Bu76) Results of the 1981 survey have not yet been published. Measurable exposure levels were identified at and near SWSA 3, with ^{60}Co and ^{137}Cs being the dominant gamma-producing isotopes. The main source over the laboratory proper was from the equalization basin at the Process Waste Treatment plant, which also showed exposure from ^{60}Co and ^{137}Cs. These exposure levels were as high as 800 uR/hr. An exposure rate of 50-100 uR/h (1 m above ground, 400 m diameter)* was detected at the inactive Chemical Waste Pit 1, west of SWSA 4. Elevated exposure rates (50-100 uR/hr) were also found at White Oak Lake and surrounding area. Gamma exposure rates for the Clinch River near the mouth of White Oak Creek ranged from 0.8 to 6 uR/h. An exposure rate of 100 uR/hr was measured at about 400 m downstream from the mouth of the creek. (Bu76)

The closest public water supply is located at Kingston, Tennessee on the Tennessee River, approximately one-half mile upstream from the confluence of the Clinch and Tennessee Rivers. Under normal conditions of power generation only Tennessee River water is used for the public water supply. However, under backflow conditions Clinch River water may move upstream and contribute to the water source for the filtration plant. It is estimated that backflow conditions would prevail a maximum of 20% of the time. Measurements were made of untreated river water samples at Kingston to indicate the maximum dose commitment resulting from ingesting 400 ml/day (20% of the daily adult requirement) correcting for background concentrations. The maximum dose commitment in 1980 was 6.6 mrem to the bone and 1.5 mrem to the total body. (Aux81) These doses are 0.4% and 0.3% respectively, of the allowable annual standard of DOE Manual Chapter 0524.

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*Radiation exposure rates 1 meter above ground are inferred from helicopter surveys at 75 meter altitudes.

Numerous studies have been made of radioactivity in fish (starting in 1948) in White Oak Lake and the Clinch River.

Estimates have been made of the 50-year dose commitment to an adult consuming 16.8 kg (37 lbs) of fish per year from the Clinch River. The maximum dose commitment to an individual was calculated on the basis of analysis of edible parts of the fish examined. The maximum organ dose commitment to man in 1980 was estimated to be 72 mrem to the bone from ^{90}Sr and 1.4 mrem maximum total body dose. These doses are 5% and 0.3%, respectively, of the allowable annual standard of DOE Manual Chapter 0524.

The point of maximum potential external radiation exposure is located on the site boundary along the bank of the Clinch River adjacent to a cesium field experimental plot. This area is considered remote since its only access is by boat. Assuming that an individual remained at this point for 24 hours/day for a year the potential whole body dose was calculated to be 240 mrem/year. A more realistic residence time of 240 hours/year was calculated to be 6.6 mrem/yr. The latter calculated dose represents what is considered to be the probable upper limit of exposure. Table VII-3 shows a summary of the estimated radiation dose to an adult during 1980 at locations of maximum exposure. (Aux81)

In summary, the maximum potential radiation dose calculated for individuals and population groups in uncontrolled areas is well within the guidelines of DOE Manual Chapter 0524 on radiation protection standards for external and internal exposure.

Table VII-3. Summary of the Estimated Radiation Dose to An Adult Individual During 1980 at Locations of Maximum Exposure (Aux81)

Pathway	Location	millirem	
		Total Body	Critical Organ
Liquid Effluents			
Aquatic food chains	Clinch-Tennessee River System (^{90}Sr)	1.1	53 bone
Drinking water[a]	Kingston, TN (^{90}Sr)	0.15	6.6 bone
Direct radiation along water, shores, and mud flats[b]	Downstream from White Oak Creek near experimental CS field plots	6.2	6.2 total body

[a]Based on the analysis of raw (unprocessed) water.

[b]Assuming a residence time of 240 hr/yr.

NOTE: Average background total body dose in the U.S. is 106 mrem/yr.

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