ornl

OAK RIDGE
NATIONAL
LABORATORY

MARTIN MARIETTA

ORNL/RAP/LTR-89/7

Results of Outdoor Radiological Walkover Surveys at the Tritium Target Fabrication Facility (7025), Thorium Storage Facility (7019), Closed Contractors' Landfill (7658), and Process Waste Basin (7711) Sites

J. K. Williams
M. S. Uziel
J. L. Quillen

CAUTION

This document has not been given final patent clearance and is for internal use only. If this document is to be given public release, it must be cleared through the site Technical Information Office which will see that the proper patent and technical information reviews are completed in accordance with Energy Systems Policy.

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

ORNL/RAP/LTR-89/7

Health and Safety Research Division

Remedial Action Program
Environmental Compliance Program
(Activity No. KG 02 00 00 0)

RESULTS OF OUTDOOR RADIOLOGICAL WALKOVER SURVEYS AT THE TRITIUM TARGET FABRICATION FACILITY (7025), THORIUM STORAGE FACILITY (7019), CLOSED CONTRACTORS' LANDFILL (7658), AND PROCESS WASTE BASIN (7711) SITES

J. K. Williams, M. S. Uziel, and J. L. Quillen

Date Published – September 1989

Investigation Team

R. E. Swaja – Measurement Applications and Development Manager
J. L. Quillen – Field Survey Supervisor

Survey Team Members

J. L. Quillen
J. K. Williams

Work performed by the
Measurement Applications and Development Group

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6285
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400

CONTENTS

LIST OF FIGURES v

LIST OF TABLES vii

ACKNOWLEDGMENTS ix

ABSTRACT xi

INTRODUCTION 1

SURVEY METHODS 1

SURVEY SITES 3

TRITIUM TARGET FABRICATION FACILITY (7025) 3

History of the Site 3

Discussion of Survey Results 5

THORIUM STORAGE FACILITY (7019) 10

History of the Site 10

Discussion of Survey Results 10

CLOSED CONTRACTORS' LANDFILL (7658) 15

History of the Site 15

Discussion of Survey Results 17

PROCESS WASTE BASIN (7711) 19

History of the Site 19

Discussion of Survey Results 20

RECOMMENDATIONS 22

REFERENCES 23

APPENDIX: WAG 12 GROUNDWATER MONITORING DATA (1988) 25

FIGURES

1 View looking east at the Tritium Target Fabrication Facility (7025) (December 1988) 3

2 View looking north at the Tritium Target Fabrication Facility (7025) (December 1988) 4

3 Diagram showing results of outdoor gamma exposure rate measurements and locations of soil samples taken at the Tritium Target Fabrication Facility site 6

4 Diagram showing locations of outdoor alpha measurements and beta-gamma dose rates at the Tritium Target Fabrication Facility site 8

5 View looking east at the Thorium Storage Facility (7019) site (September 1989) 11

6 Dry storage wells at the Throium Storage Facility site (September 1989) 11

7 A dry storage well at the Thorium Storage Facility site (September 1989) 12

8 Diagram showing results of outdoor gamma exposure rate measurements and locations of soil samples taken at the Thorium Storage Facility site 13

9 View looking northeast at the Closed Contractors' Landfill (7658) (December 1988) 15

10 View looking west at the Closed Contractors' Landfill (7658) (December 1988) 16

11 Diagram showing results of gamma exposure rate measurements taken at the Closed Contractors' Landfill—WAG 12 area 18

12 View looking northwest at the Process Waste Basin (7711) (December 1988) 19

13 View of the north corner of the Process Waste Basin (7711) and Health Physics Research Reactor area (December 1988) 20

14 Results of gamma exposure rate measurements (μR/h) are shown on the drawing of the Process Waste Basin (7711) 21

TABLES

1 Survey sites with respective WAG and SWMU identification numbers 2

2 Concentrations of ^{60}Co, ^{137}Cs, gross alpha, gross beta, and tritium in surface soil taken from the Tritium Target Fabrication Facility (7025) site 9

3 Concentrations of ^{238}U, ^{232}Th, and ^{226}Ra in soil samples taken from the Thorium Storage Facility (7019) site 14

4 Gamma exposure rates and alpha and beta-gamma activity levels measured on the interior surfaces of the storage wells at the Thorium Storage Facility (7019) site 14

A.1 Concentrations of gross alpha, gross beta, ^{60}Co, and ^{137}Cs in groundwater samples collected December 13, 1988, from piezometer wells at WAG 12 27

A.2 Concentrations of mercury in groundwater samples collected December 13, 1988, from piezometer wells at WAG 12 28

A.3 Results of analyses for volatile organics in groundwater samples collected December 13, 1988, from piezometer wells at WAG 12 29

A.4 Results of analyses for base/neutral/acid extractable organics in groundwater samples collected December 13, 1988, from piezometer wells at WAG 12 30

ACKNOWLEDGMENTS

This project was sponsored by the Environmental Sciences Division at Oak Ridge National Laboratory (ORNL) in support of the Remedial Action Program (RAP). The authors wish to acknowledge the support of L. D. Bates, RAP manager; T. W. Burwinkle, Facility Management Programs; H. R. Gaddis, Facility Management Implementation; D. F. Hall, Site Corrective Measures Program (SCMP) manager; and members of their staffs. We also wish to express our appreciation to J. R. Trabalka of the Environmental Sciences Division. We also thank the following reviewers for providing detailed suggestions concerning the draft manuscript: W. S. Aaron, J. A. Aebischer, T. L. Ashwood, E. G. Bailiff, W. J. Boegly, Jr., T. W. Burwinkle, H. M. Butler, Jr., R. F. Carrier, J. T. Ensminger, D. F. Hall, S. W. Hawthorne, L. J. Jeffers, A. King, C. E. Nix, J. E. Nyquist, P. T. Owen, R. E. Swaja, J. R. Trabalka, and J. W. Wade. In addition, we gratefully appreciate C. T. Garten, Jr. of the Environmental Sciences Division for providing valuable data and thoughtful suggestions concerning this report. We also wish to acknowledge the graphics contributions by T. R. Stewart, R. L. Coleman (subcontract employee of Don Stone and Associates, Inc.), D. D. Folse (student), J. M. Fielden, and R. C. Phillips of the Health and Safety Research Division (HASRD).

ABSTRACT

Surface radiological walkover surveys were conducted at the Tritium Target Fabrication Facility (7025), Thorium Storage Facility (7019), Closed Contractors' Landfill (7658), and Process Waste Basin (7711) during January and May of 1989. The surveys were completed by the Measurement Applications and Development Group of the Health and Safety Research Division (HASRD) of the Oak Ridge National Laboratory (ORNL). The purpose of the surveys was to identify surface contamination by on-site radiation measurements and analyses of soil samples.

Survey results showed no evidence of detectable surface radioactivity above typical Oak Ridge Reservation background levels at the Closed Contractors' Landfill and the Process Waste Basin. At the Tritium Target Fabrication Facility site, soil samples contained 20 to 130 times the amount of tritium found in background samples from the Walker Branch Watershed. At the Thorium Storage Facility site, one small (<1 m^2) area had gamma levels of 400 μR/h and ^{232}Th concentrations of 950 pCi/g at soil depths of 0 to 15 cm. Recommendations are included.

RESULTS OF OUTDOOR RADIOLOGICAL WALKOVER SURVEYS AT THE TRITIUM TARGET FABRICATION FACILITY (7025), THORIUM STORAGE FACILITY (7019), CLOSED CONTRACTORS' LANDFILL (7658), AND PROCESS WASTE BASIN (7711) SITES

INTRODUCTION

Surface radiological walkover* surveys of the Tritium Target Fabrication Facility (7025), Thorium Storage Facility (7019), Closed Contractors' Landfill (7658), and Process Waste Basin (7711) were conducted in January and May of 1989 by the Measurement Applications and Development Group of the Health and Safety Research Division (HASRD) of the Oak Ridge National Laboratory (ORNL) at the request of the Remedial Action Program (RAP) of ORNL. The purpose of this cursory survey was to identify surface contamination as determined from on-site radiation measurements and analysis of soil samples. Furthermore, results of this survey may play a role in determining whether these sites should be excluded from some regulatory requirements, e.g., remedial investigations.

Two of the four survey sites (Table 1) have been assigned a Solid Waste Management Unit (SWMU) identification number by the ORNL RAP and also fall under a Waste Area Group (WAG) designation.[1]

SURVEY METHODS

A portable survey meter with a sodium iodide (NaI) scintillation probe was used to detect gamma radiation. The scintillation probe was connected to a Victoreen Model 490 Thyac III® ratemeter. Because NaI gamma scintillation instruments are energy dependent, measurements of gamma radiation levels made with this instrument must be normalized to pressurized ionization chamber (PIC) measurements to estimate gamma exposure rates (the PIC is calibrated by the National Institute of Standards and Technology). The function developed for these conversions is:

$$y = x/\mathrm{CF}$$

*A "walkover" differs from the usual scoping survey in that the measurements are not recorded at predetermined, evenly spaced grid locations. A cursory radiological scan of the ground surface is performed, and, where warranted, soil samples are collected and analyzed for the presence of radionuclides that are not detectable with survey instruments.

Table 1. Survey sites with respective WAG and SWMU identification numbers

Survey site	Waste Area Group WAG	Solid Waste Management Unit SWMU
Tritium Target Fabrication Facility (7025)	a	b
Thorium Storage Facility (7019)	a	b
Closed Contractors' Landfill (7658)	12.0	12.1
Process Waste Basin (7711)	16.0	16.2

[a]Site located east of the WAG 17 (ORNL Services Area) boundary.
[b]Not assigned.

where

y = the exposure rate in microroentgens per hour (μR/h),

x = the scintillometer measurements in counts per minute (cpm),

CF = the conversion factor determined in the field through a direct correlation between a selected number of PIC measurements and scintillometer measurements in cpm/(μR/h).

For these sites, CF = 420 cpm/(μR/h).

Alpha radiation was measured with an ORNL alpha survey meter connected to a zinc sulfide scintillation probe. Beta-gamma and gamma energy levels were detected with a portable Bicron® ratemeter with an HP-260 pancake detector (<2 mg/cm^2 window thickness). The instrument was set in the open configuration to detect beta-gamma and in the closed configuration to detect gamma. After calibration of the HP-260 detector to a known strontium source at the ORNL Radiation Calibration Laboratory (RADCAL), beta radiation activity levels in cpm were converted to dose rates in mrad/h using the following relationship:

$$2800 \text{ cpm} = 1 \text{ mrad/h or (mrad/h)/cpm} = 0.00036 .$$

Gamma radiation levels measured with the portable Bicron® ratemeter were converted to dose rates by using the instrument-specific conversion factor based on ^{226}Ra:

$$4500 \text{ cpm} = 1 \text{ mrad/h} .$$

A comprehensive description of the survey methods and instrumentation is presented in *Procedures Manual for the ORNL Radiological Survey Activities (RASA) Program*, Oak Ridge National Laboratory, ORNL/TM-8600 (April 1987).[2] With the exception of measurements of transferable activity, which are reported as net disintegration rates, all

direct measurements presented in this report are gross readings; background radiation levels have not been subtracted. Similarly, background concentrations have not been subtracted from radionuclide concentrations in soil samples.

SURVEY SITES

TRITIUM TARGET FABRICATION FACILITY (7025)

History of the Site

The Tritium Target Fabrication Facility (TTFF) is operated by Isotope Research Materials Laboratory (IRML) personnel of the ORNL Chemical Technology Division. The facility is located approximately 150 m (490 ft) east of the 7000 area near the end of White Oak Avenue in Building 7025.[3] Two views of the surveyed site are shown in Figs. 1 and 2.

The building is designed primarily for the purpose of producing tritium-containing accelerator targets as well as loading tritium by absorption into other types of metal specimens. The accelerator targets are used by other laboratories to produce neutrons for

ORNL-PHOTO 11200-88

Fig. 1. View looking east at the Tritium Target Fabrication Facility (7025) (December 1988).

ORNL-PHOTO 11202-88

Fig. 2. View looking north at the Tritium Target Fabrication Facility (7025) (December 1988).

experimental purposes.[4] Future plans include the addition of a manifold to the existing tritium system in order to salvage tritium from outdated prototype glass tubes that are generated by the Radioluminescent Light Program at ORNL.[5] The TTFF also contains a vacuum evaporation system for vaporizing and depositing UO_2 and ThO_2 onto substrates for use as targets in accelerator and reactor experiments.[4] Only tritium or the alpha-emitting materials ^{235}U, ^{238}U, and ^{232}Th are processed or stored in this facility.[3]

Building 7025 was erected in 1968 on a concrete pad. The building is a prefabricated steel structure with a total floor area of 55 m^2 and a total free space volume of about 170 m^3. A single door is located on the north side of the building. Fencing and a locked gate prevent unauthorized entrance. In 1983, the perimeter security fence that ended at the east boundary of the 7000 area was extended to completely enclose Building 7025 and other buildings within the ORNL security area.[3]

A forced-air exhaust system is located at the rear of the building, and a forced-air input system for heating and cooling is on the opposite side of the building. The result is a high-velocity air stream blanketing the tritium-handling equipment, thus virtually eliminating the escape of tritium gas or tritium-contaminated water vapor into the personnel area of the building.[3]

The tritium equipment is housed in an 8 × 1.5 m (26 × 5 ft) stainless steel hood that is exhausted by a 0.94-m^3/s fan. The fan forces air up a 4-m stainless steel stack. The

effective stack height is 9.1 m (30 ft) with an air velocity of 12.9 m/s.[6] Air vented to the atmosphere from the hood exhaust fan and stack is continuously sampled and analyzed by scintillation counting to provide a measure of tritium release. This system has proved effective in limiting personnel exposure to tritium either by inhalation or by absorption through the skin. In over 16 years of operation of this facility, approximately 1 million Ci of tritium have been successfully handled and hundreds of targets have been prepared and shipped.[3]

Another forced-air system exhausts the hood surrounding the uranium and thorium vacuum deposition system. This ventilation system controls the spread of particulate contamination of actinide oxides used in the evaporation-condensation system. Reportedly, the small quantities (<50 g or <100 μCi) and very low specific activities of these materials cause these isotopes to be of minimal consequence with regard to personnel exposure.[3]

Tritium process waste is handled in gaseous, liquid, and solid forms. Gaseous waste, which is discharged to the atmosphere through the hood exhaust system, averages far less than 100 Ci per month. Solid waste consists of gloves, wipes, shoe covers, contaminated glass, and some contaminated equipment. Solid waste is bagged and treated in accordance with division and laboratory solid waste disposal procedures. Liquid waste is rarely generated, but its disposal is provided for by a stainless steel sink with a drain inside the east end of the hood. The sink drain is connected to a 1500-L (400-gal) stainless steel tank buried in the ground outside the east wall of the building. When the full operating level of the waste tank is reached, an electronic liquid-level gage is activated and a visual signal is delivered inside the building. The tank contents can then be pumped into a liquid waste disposal truck for disposal by ORNL Waste Operations. Over the 16 years of facility operations, the holding tank has been pumped for disposal only once.[3]

Shoe covers are routinely worn inside the building. Operations that require opening a hood door are performed by personnel wearing shoe covers, gloves, and white coveralls. For hood maintenance, personnel are required to wear gloves, shoe covers, coveralls, and air-line masks. A tritium monitor located at the middle-top of the hood is used to detect airborne tritium. Using a flexible hose, the air-sampling input to the monitor can be localized to the vicinity of personnel activity. An audible alarm is sounded at a tritium concentration of about 7 μCi/m^3, which is considerably below the maximum permissible concentration for elemental tritium for a 40-hr week.[3] A second tritium monitor centrally located in the room monitors the general work area and alarms at 7 μCi/m^3.[5] In addition, health physics personnel routinely sample body fluids from Building 7025 operating personnel.[3]

According to ORNL Environmental Monitoring and Compliance Section measurements, total tritium releases from the 7025 stack for August 1 through December 28, 1988 were 140 Ci. Total releases from January 3 through June 27, 1989 were 316 Ci.[5]

Discussion of Survey Results

The results of gamma exposure rate measurements external to the building are shown in Fig. 3. Generally, the surface scan revealed gamma levels ranging from 7 to 360 μR/h. For comparison, typical Oak Ridge Reservation (ORR) background levels at the ground surface averaged 13 μR/h. Determination of outdoor gamma exposure rates was significantly confounded by radiation emanating from a thorium source stored inside an

ORNL-DWG 89-6912

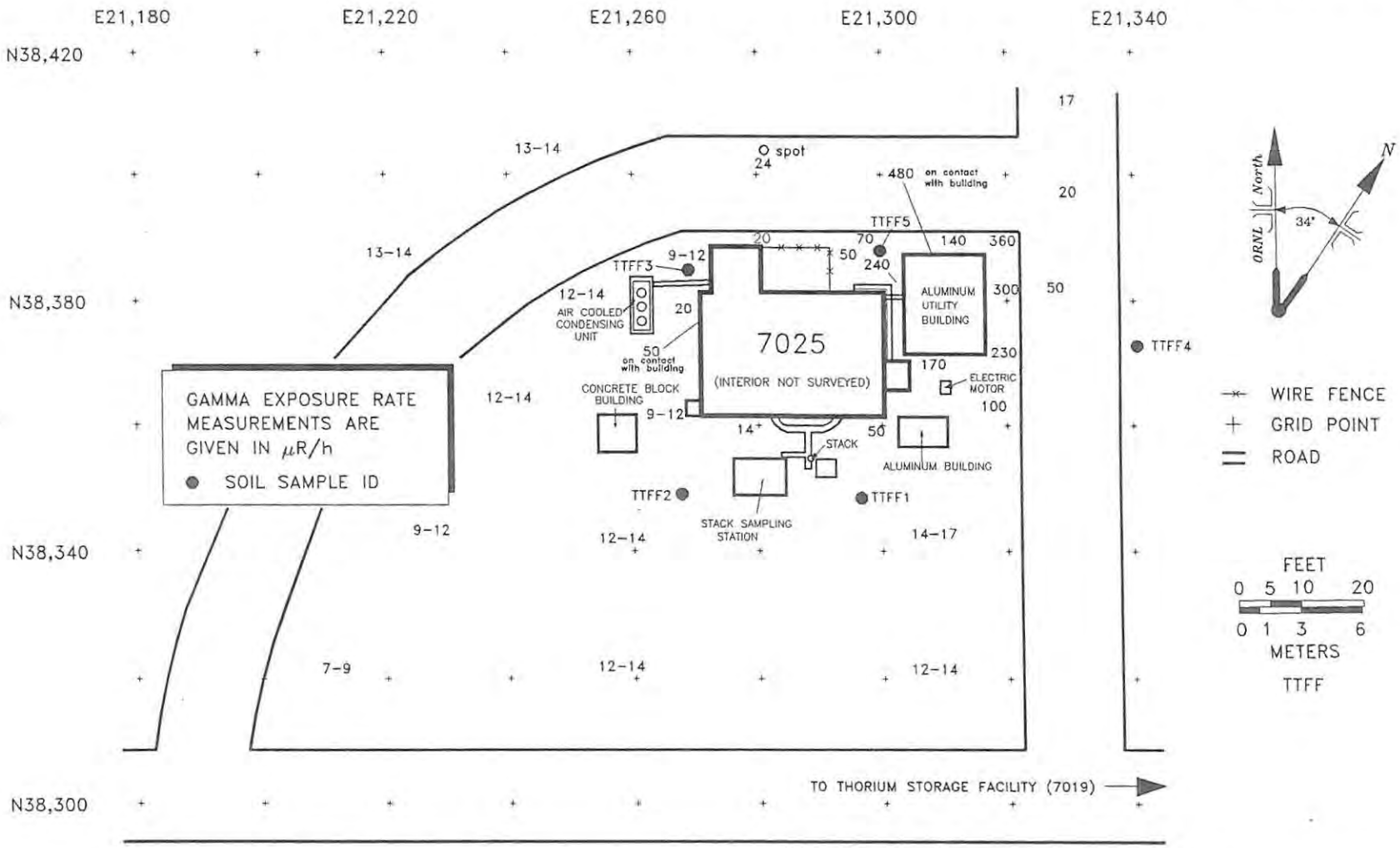


Fig. 3. Diagram showing results of outdoor gamma exposure rate measurements and locations of soil samples taken at the Tritium Target Fabrication Facility site.

aluminum utility building located immediately north of Building 7025. Highest outdoor ground-surface gamma levels (360 μR/h) were found at the northernmost corner of the aluminum utility building. Gamma levels up to 480 μR/h were measured on contact with the northeast side of the building. A metal lock secured access into the utility building. Currently, Building 7025 is designated as a "Regulated Zone" with specific access restrictions posted on the entrance door of the building. The aluminum utility building containing the radiation source is placarded with "Radiation Zone" signs. Based on the results of the gamma scan and on guidelines outlined in the ORNL Health Physics Procedure Manual,[7] radiation control measures currently in place at the Building 7025 site are deemed appropriate. However, the storage location of the thorium source inside the aluminum building may result in elevating the outdoor gamma levels and, subsequently, warrant an extension of the radiation zone boundary. Signs and storage methods are all in accordance with procedures.[5] Building 7025 is the most remote and least inhabited area available for storage of the thorium source.[5] A request to store the material in the main nuclear materials vault where radiation and access would be further reduced was denied.[5]

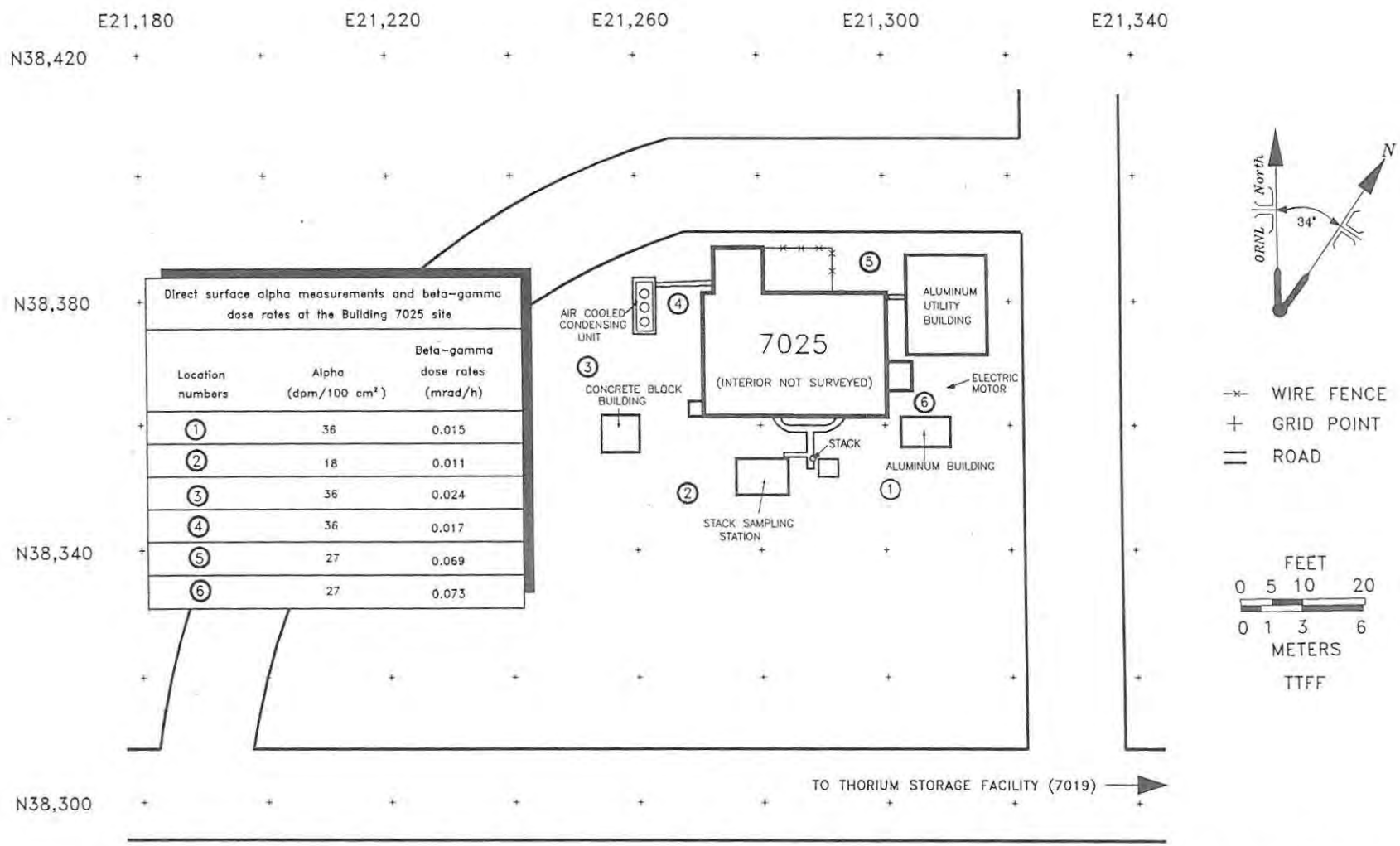
Directly measured alpha activity levels and beta-gamma dose rates were determined at six locations, as shown on Fig. 4. Direct alpha activities ranged from 18 to 36 disintegrations per minute (dpm) per 100 cm^2 and averaged 30 dpm/100 cm^2. The maximum measurement, 36 dpm/100 cm^2, was obtained at Locations 1, 3, and 4. This value represents typical ORR background levels. For comparative purposes, 30 dpm/100 cm^2 is well below the ORNL health physics guideline[7] of 300 dpm/100 cm^2 for establishing a Contamination Area.

Beta-gamma dose rates (Fig. 4) ranged from 0.011 to 0.073 mrad/h, which represents approximately 4 to 29% of the beta-gamma direct surface contamination level (0.25 mrad/h)[7] used in establishing a contamination area. The ratio of beta to gamma radioactivity, determined by taking the difference between the open- and closed-window readings (beta) and comparing this to the closed-window reading (gamma), indicates primarily gamma radiation.

Five surface soil samples collected at depths of 0 to 15 cm (0 to 6 in.) were taken at the site. Locations of soil sample hole numbers are shown in Fig. 3, and results of laboratory analyses (wet wt) are presented in Table 2. All ^{60}Co concentrations were below the lower detection limit of the analytical procedure (0.1 pCi/g).[8] Cesium-137 was detected in samples TTFF2, TTFF3, and TTFF4.[8] In addition, sample TTFF3 contained gross alpha and gross beta in concentrations higher than normal for uncontaminated soil in the Oak Ridge area.[8] Tritium concentrations ranged from 5.9 to 30 pCi/g with highest concentrations found at sample location TTFF1, located about 3.6 m (12 ft) east of the 7025 stack. Soil sample TTFF4, collected approximately 16 m (52 ft) northeast of the stack, contained 25 pCi/g tritium. Samples collected southwest, west, and northwest of the stack contained 10, 12, and 5.9 pCi/g tritium, respectively.

Tritium concentrations that are probably representative of those found in uncontaminated areas on the ORR were measured in rainfall, surface water, and groundwater collected from the Walker Branch Watershed (WBW) during November and December of 1988.[9] These data, part of another study, are presented here for comparison with tritium concentrations in surface soil presented in Table 2 (note footnote e). Ordinarily, tritium in soil water should be approximately equal to tritium in rainfall if there are no other sources of tritium contamination to the soil.[9]

ORNL-DWG 89-6913



Direct surface alpha measurements and beta-gamma dose rates at the Building 7025 site		
Location numbers	Alpha (dpm/100 cm²)	Beta-gamma dose rates (mrad/h)
1	36	0.015
2	18	0.011
3	36	0.024
4	36	0.017
5	27	0.069
6	27	0.073

Fig. 4. Diagram showing locations of outdoor alpha measurements and beta-gamma dose rates at the Tritium Target Fabrication Facility site. Results are shown in the inset.

Table 2. Concentrations of ^{60}Co, ^{137}Cs, gross alpha, gross beta, and tritium in surface soil taken from the Tritium Target Fabrication Facility (7025) site[a]

Sample ID[b]	Concentrations in pCi/g (Bq/kg) wet wt				
	^{60}Co[c]	^{137}Cs[c]	Gross alpha[d]	Gross beta[d]	Tritium[e]
TTFF1	<0.054 (<2)	<0.027 (<1)	19 ± 20 (690 ± 800)	14 ± 20 (530 ± 600)	30 ± 3 (1100 ± 100)
TTFF2	<0.027 (<1)	0.11 ± 0.04 (4.1 ± 1)	6.5 ± 10 (240 ± 500)	20 ± 20 (750 ± 800)	10 ± 1 (370 ± 50)
TTFF3	<0.054 (<2)	0.43 ± 0.05 (16 ± 2)	22 ± 20 (810 ± 600)	32 ± 20 (1200 ± 600)	12 ± 1 (450 ± 50)
TTFF4	<0.054 (<2)	0.17 ± 0.04 (6.2 ± 2)	40 ± 40 (1500 ± 1000)	0 ± 10 (0 ± 400)	25 ± 2 (910 ± 70)
TTFF5	<0.11 (<4)	<0.11 (<4)	40 ± 50 (1500 ± 2000)	81 ± 50 (3000 ± 2000)	5.9 ± 1 (220 ± 50)

[a]Surface soil samples were collected at depths of 0-15 cm.

[b]Locations of soil sample hole numbers are shown on Fig. 3.

[c]Cobalt-60 and ^{137}Cs analyses were performed in accordance with U.S. Environmental Protection Agency (EPA) procedure 901.1 (see ref. 8).

[d]Uncontaminated soil in the ORNL area usually contains 5-20 pCi/g (200-800 Bq/kg) gross alpha and 10-40 pCi/g (500-1500 Bq/kg) gross beta (dry wt) (see ref. 8).

[e]Tritium analyses were performed in accordance with U.S. EPA procedure 906.0. Because equal amounts of soil and distilled water leachate were mixed together before tritium was measured in the water leachate, results in pCi/mL (Bq/L) of water are equivalent to pCi/g (Bq/kg) of soil (see ref. 8).

During the measurement period, tritium concentrations in rainfall on WBW varied from <0.025 pCi/mL to 0.22 pCi/mL with three rainfalls in the range of 0.2 pCi/mL, two in the range of 0.1 pCi/mL, and three <0.02 pCi/mL. Tritium concentrations at a surface weir, which probably represents a mixture of surface runoff and groundwater, were 0.26 pCi/mL. Tritium concentrations in groundwater collected from a subsurface weir, a small underground cavelike facility with groundwater collecting pans installed at soil depths of about 2 and 3 m, ranged from 0.23 to 0.27 pCi/mL.[9]

When tritium concentrations in groundwater from WBW are compared to tritium concentrations in soil samples from the TTFF (Table 2), the TTFF soil samples appear to contain 20 to 130 times as much tritium. This comparison, however, needs further clarification. All analyses were made using U.S. Environmental Protection Agency (EPA) procedure 906.0, which is a standard method for measuring tritium in drinking water. The detection limit of this procedure is approximately 0.3 pCi/mL, and all WBW measurements fall below this detection limit. With this in mind, it is more accurate to state that the TTFF soil sample tritium levels were 20 to 100 times the detection limits of the analytical procedure while all WBW (background) samples were below the detection limits.

Since the TTFF is an active, operational facility, on-site tritium concentrations (i.e., atmospheric, soil, soil water) are subject to significant fluctuations. Therefore, the survey data presented in this report represent a "snapshot" assessment on the date of the survey.

THORIUM STORAGE FACILITY (7019)

History of the Site

The Thorium Storage Facility (7019) was constructed in the early 1960s[10] for storage of normal uranium, depleted uranium, ^{6}Li, ^{232}Th, and other source materials with exposure rates less than 10 mR/h.[11] The facility retains its original name although all stored nuclear materials were removed from the building in August 1984.[11] Currently, the building contains shipping containers for radioactive material and equipment, such as a drum handler and a hydraulic lift, to move the containers. The building also houses discarded security cabinets, radioisotope vaults, filing cabinets, and other former storage containers that no longer meet General Services Administration (GSA) approval standards for classified material storage.[11]

The building has metal sides and a steel frame and sits on a concrete slab (Fig. 5). Gross floor area is about 89 m^2 (960 ft^2).[12] The building was never environmentally controlled. Around 1980, the bottom of a storage drum rotted and contamination spilled in a small spot on the concrete floor. After cleanup, the area was painted to cover residual contamination.[11] Elevated exposure rates are still evident at this spot.

The building is surrounded by a fence with a locked gate; the entrance door to the building is also locked. Keys controlled by Laboratory Protection Division personnel and Plant and Equipment Division personnel strictly limit access to the area.[11]

Ten dry storage wells (Fig. 6) east of the Thorium Storage Facility were constructed in the mid-1960s to provide safe storage for zirconium sponge belonging to the Y-12 plant. The porous zirconium was a potential explosive if it got wet or overheated. At that time, wells were sometimes used as a means of minimizing the danger of storing explosives, since presumably, the explosion could only go up and would cause less horizontal damage. Later, the wells were also used to store thorium. The wells were taken out of service in the mid-1970s.[10]

The cylindrical wells are about 0.9 m (3 ft) in diameter by 3 m (10 ft) deep with heavy-gage, corrugated culvert metal on the outside and an inner metal lining. They are covered with heavy metal lids (Fig. 7). Some of these lids are fastened with security seals and others can be opened. The wells are outside the locked fence that surrounds the Thorium Storage Facility.

Discussion of Survey Results

Outdoor surface gamma exposure rate measurements at the Thorium Storage Facility site are shown in Fig. 8. With the exception of one contaminated "hot" spot, surface gamma levels are representative of typical background values ranging from 6 to 12 μR/h. The highest outdoor gamma level (400 μR/h) was identified at a small spot (<1 m^2) on the ground at a metal fence post ~35 ft east of Building 7019.

ORNL-PHOTO 4608-89

Fig. 5. View looking east at the Thorium Storage Facility (7019) site (September 1989).

ORNL-PHOTO 3039-89

Fig. 6. Dry storage wells at the Thorium Storage Facility site (September 1989).

ORNL-PHOTO 3040-89

Fig. 7. A dry storage well at the Thorium Storage Facility site (September 1989).

Results of radionuclide analysis of two soil samples taken at the spot show ^{232}Th concentrations of 950 and 390 pCi/g in surface (0-15 cm) and subsurface (15-30 cm) samples, respectively (see Table 3). This residual contamination may be the result of improper disposal of rinsate used in the decontamination process of a previously reported ^{232}Th spill in Building 7019. If DOE "hot spot" guidelines[13] were applicable for this site, the maximum surface ^{232}Th concentration (950 pCi/g) would exceed the guideline value (50 pCi/g) for "hot spots" <1 m^2 by a factor of 19.

Gamma exposure rate measurements taken inside each well ranged from 4 to 10 μR/h (see Table 4). Smears were also obtained from selected locations inside the wells and analyzed for removable alpha and/or beta-gamma contamination. In general, the wells were found to be free of significant alpha contamination. Only one well was found to have removable beta-gamma activity levels in excess of the ORNL health physics guideline limit of 1000 dpm/100 cm^2 for establishing a Contamination Area. Analysis of smears disclosed transferable beta-gamma activities of 1200 dpm/100 cm^2 in Storage Well 5.

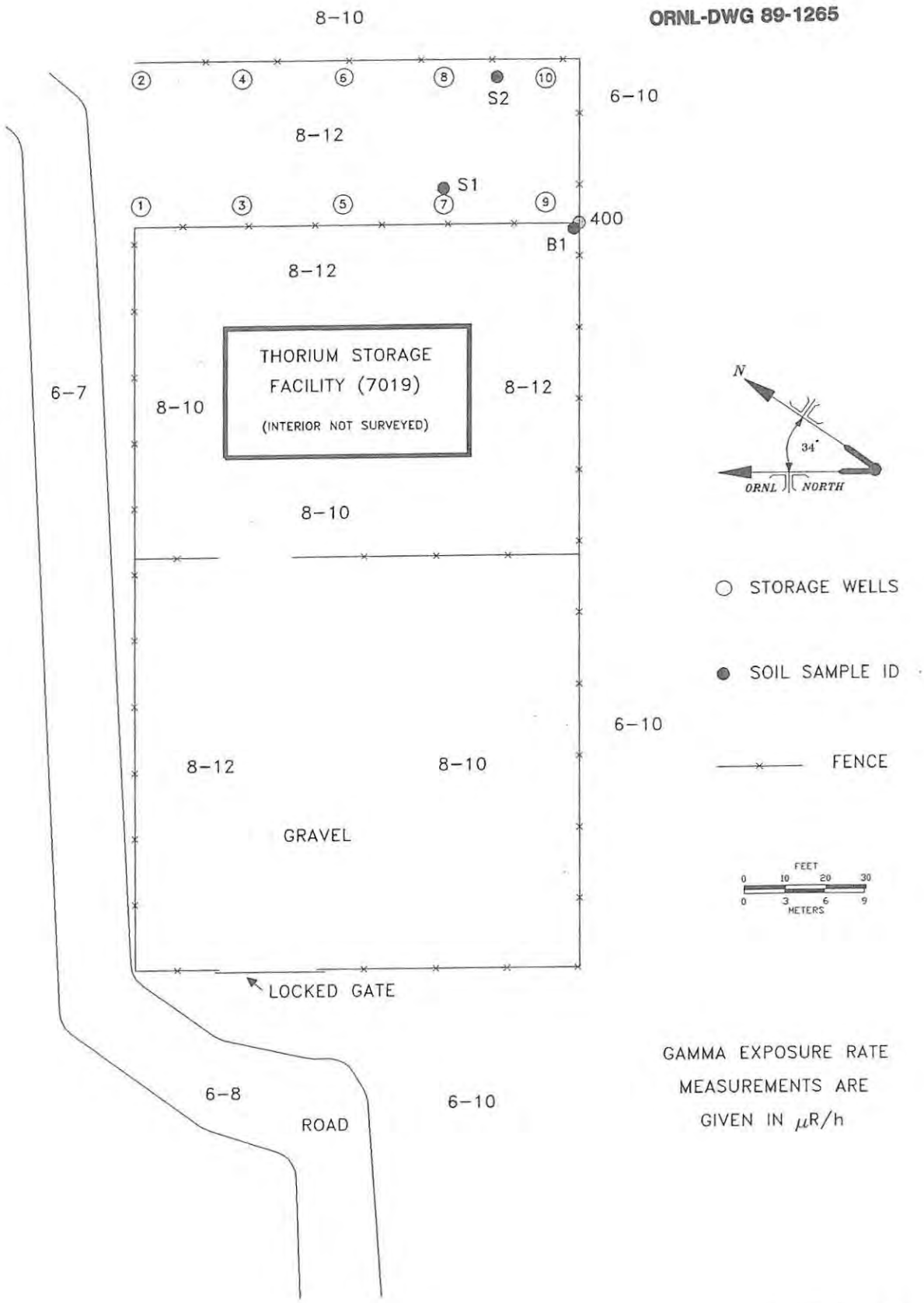


Fig. 8. Diagram showing results of outdoor gamma exposure rate measurements and locations of soil samples taken at the Thorium Storage Facility site. The dry storage wells located east of Building 7019 are numbered 1 to 10.

Table 3. Concentrations of ^{238}U, ^{232}Th, and ^{226}Ra in soil samples taken from the Thorium Storage Facility (7019) site

Sample ID[a]	Depth (cm)	Radionuclide concentration in pCi/g (dry wt)		
		^{238}U[b]	^{232}Th	^{226}Ra
B1A	0-15	<57.00	950.00 ± 5.0	2.70 ± 1.0
B1B	15-30	<24.00	390.00 ± 2.0	1.70 ± 0.3
S1	0-15	<0.77	0.32 ± 0.02	0.35 ± 0.02
S2	0-15	1.40 ± 1.0	1.30 ± 0.07	1.00 ± 0.03

[a]Locations of soil sample hole numbers are shown on Fig. 8.
[b]Background levels of ^{238}U in the main ORNL complex usually range from 0.027 to 0.54 pCi/g (dry wt) (see ref. 8).

Table 4. Gamma exposure rates and alpha and beta-gamma activity levels measured on the interior surfaces of the storage wells at the Thorium Storage Facility (7019) site

Well number[b]	Gamma exposure rates[a] (μR/h)	Transferable contamination	
		Alpha (dpm/100 cm^2)[c]	Beta-gamma (dpm/100 cm^2)[c]
1	4-10	d	d
2	4-8	6	d
3	4-8	d	d
4	4-8	d	d
5	4-8	6	1200
6	4-7	d	d
7	4-6	15	170
8	4-8	15	d
9	4-7	6	d
10	4-6	6	d

[a]Gamma radiation was measured with a NaI scintillation probe connected to a portable scaler.
[b]Locations of well numbers are shown on Fig. 8.
[c]Disintegrations per minute per 100 cm^2.
[d]Background.

CLOSED CONTRACTORS' LANDFILL (7658)

History of the Site

The Closed Contractors' Landfill was used to bury general construction debris and demolition waste generated by contractors working at ORNL. It is located about 2.3 km (1.4 miles) east-southeast of the main plant area and about 152 m (500 ft) east-northeast of the intersection of Melton Valley Access Road and Ramsey Drive. ORNL grid coordinates (measured in feet) are North 18,650 and East 37,500.[1] Two views of the surveyed site are shown in Figs. 9 and 10.

The landfill is approximately 154 m (500 ft) long in the east-west direction and 79 m (260 ft) wide in the north-south direction. The approximate area is about 1.2 ha (3 acres). The original land surface sloped from north to south so that the depth of fill probably ranges from less than 1.8 m (6 ft) on the north side to about 9 m (30 ft) on the south. Estimates of the amount of material buried range from 30,000 to 50,000 m^3 depending on the depth of excavation, the existence of natural depressions, and the degree of compaction of the waste.[1]

The road into this area was built in the early 1960s, and the landfill area at the top of the hill (north) was opened at this time. In the mid-1960s, the area on top of the hill was closed and the landfill area at the bottom of the hill was opened.[14] In 1975[15] when another

ORNL-PHOTO 11195-88

Fig. 9. View looking northeast at the Closed Contractors' Landfill (7658) (December 1988).

ORNL-PHOTO 11197-88

Fig. 10. View looking west at the Closed Contractors' Landfill (7658) (December 1988).

landfill (located southeast of the intersection of Bethel Valley Road and Highway 95)[16] was opened, the Contractors' Landfill was closed. The Contractors' Landfill was graded level and seeded with grass but not fenced.

Ramsey Drive, constructed in 1975, was originally built over outcroppings of the southernmost part of the landfill. When the pavement in these areas collapsed, the buried material was dug up, moved to the northern part of the site, and replaced by fill dirt to support the road. No materials are buried south of Ramsey Drive.[15]

No waste-specific records were kept on the landfill operation, and no administrative controls were maintained on the nature of the waste being buried. As a result, construction waste sent to the landfill probably included empty paint cans and other debris that could include small amounts of hazardous waste.[1]

Records indicate that the Closed Contractors' Landfill does not represent a source of release of radioactive or hazardous materials. Aerial radiation surveys and walkover radiation surveys [0.9 m (3 ft) above ground surface] have not detected radiation levels above background. No visible leakage or seeps have been observed or documented.[1]

In 1986, gravel and dark mud samples taken from the bed of a stream that drains the landfill area to the south contained near-background levels of ^{60}Co, ^{90}Sr, and ^{137}Cs. One

pol. noted

sample contained nickel concentrations about twice background and one contained 1200 μg/kg of di-*n*-butylphthalate, a common component of plastic materials often found in sediments.[1] When additional samples were collected and analyzed for semivolatile organic constituents, only phthalates were detected.[17]

In 1987, groundwater samples taken from three downgradient wells and one upgradient well had relatively high concentrations of Al, Ba, Fe, Mg, and Mn in one downgradient well and elevated levels of chromium in another. Volatile organics detected included methylene chloride and 1,2 dichloroethane at concentrations of 7 ppb and 5 ppb, respectively. The only semivolatile organic detected was di-*n*-butylphthalate at a level of 10 ppb.[17]

Based on survey results presented in the RCRA facility assessment, it did not appear that WAG 12 was a source of past releases. Therefore, ORNL recommended that WAG 12 be removed from further consideration as a Resource Conservation and Recovery Act (RCRA) Section 3004(u) site.[17]

Previously unreported WAG 12 groundwater monitoring data for 1988 are presented in the appendix of this report. Sampling well locations are shown on Fig. 11. Gross alpha, gross beta, ^{60}Co, and ^{137}Cs concentrations (Table A.1) were similar to those found in uncontaminated groundwater in the Oak Ridge area at all six wells. Also, Hg concentrations of <0.0001 μg/mL in all wells (Table A.2) were far below the maximum contaminant level for Hg (2 μg/mL). Results of analyses for 34 volatile organics (Table A.3) indicated that bromodichloromethane was present in two wells (912 and 916) at concentrations below the quantitation limit of the analytical system. Chloroform was present in well 916 and 917 at concentrations near and below the quantitation limit, respectively. All other volatile organics were not detected. Results of analyses for 65 base/neutral/acid extractable organics (Table A.4) indicated that bis(2-ethylhexyl)phthalate was present below the quantitation limit in well 913, 914, and 917. All other extractable organics were not detected.

Discussion of Survey Results

The results of gamma exposure rate measurements are shown in Fig. 11. Generally, the surface scan revealed gamma levels ranging from 7 to 14 μR/h. These values represent natural background levels for uncontaminated areas. Surface gamma levels were slightly elevated in the open field area south of Ramsey Drive. The NaI probe of the portable gamma scintillation survey meter was lowered into an excavated posthole ~40 cm (16 in.) deep. Gamma exposure rates at 0-15 cm (0-6 in.), 15-30 cm (6-12 in.), and 30-40 cm (12-16 in.) of depth were 19, 26, and 24 μR/h, respectively. (The excavated soil was subsequently placed back into the hole.) This increase in gamma levels is the result of natural radioactive materials inherent in pieces of shale scattered on the ground surface and in subsurface soil. Measurements taken inside two dilapidated brick-lined kilns showed elevated gamma exposure rate levels of up to 40 μR/h. These values are most likely due to natural radioactive materials inherent in the brick.

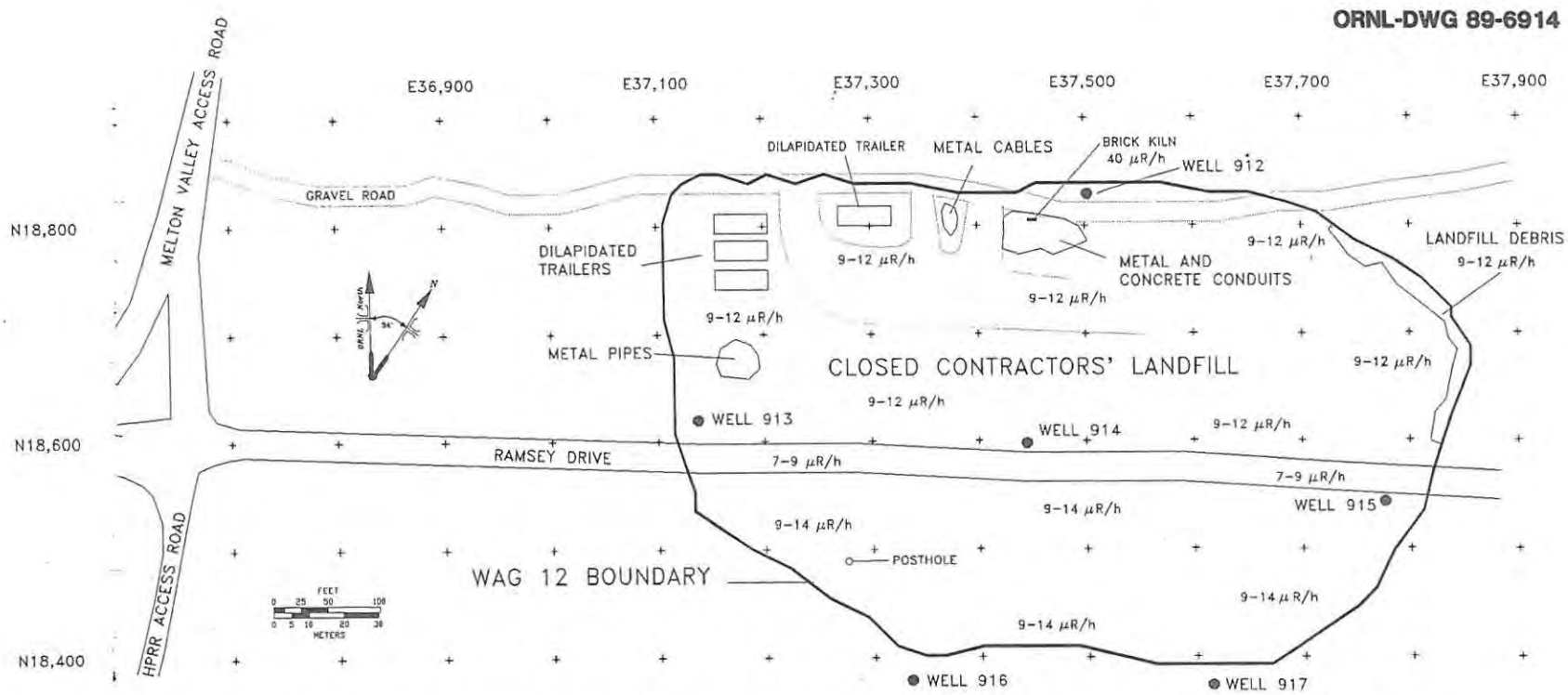


Fig. 11. Diagram showing results of gamma exposure rate measurements taken at the Closed Contractors' Landfill—WAG 12 area.

PROCESS WASTE BASIN (7711)

History of the Site

The Process Waste Basin (7711) is located just west of the Health Physics Research Reactor (HPRR) at ORNL grid coordinates North 12,260 and East 35,830.[1] Structures in the area are part of the Dosimetry Applications Research Facility (DOSAR), which is located about 3.3 km (2 miles) southeast of the main research area at ORNL. The surrounding hills provide natural shielding and prevent line-of-sight viewing from all directions. An exclusion fence surrounds the facility, and access is obtained only through a security guard station.[18] Two views of the surveyed site are shown in Figs. 12 and 13.

The Process Waste Basin, which is sometimes referred to as the retention pond[19] or retention basin,[1] was designed to receive water draining from the concrete-lined pits in the reactor building. The two pits are used to store the reactor core.[20] A 15-cm- (6-in.-)[19] diameter pipe with an untrapped drain connects the storage pits to the basin.[20] Ordinarily there is no water in the storage pits, but in the event that groundwater or water from some other source seeps into the pits, the water would drain into the Process Waste Basin. The basin would also receive water from a washdown of the reactor bay in the event of a criticality accident.[20] Every six months, fire department personnel make sure this drain system is free of obstruction by flushing water through the drain port of the storage pits to the Process Waste Basin.[20,21]

Reactor Bldg pits drain to basin

ORNL-PHOTO 11187-88

Fig. 12. View looking northwest at the Process Waste Basin (7711) (December 1988).

ORNL-PHOTO 11190-88

Fig. 13. View of the north corner of the Process Waste Basin (7711) and Health Physics Research Reactor area (December 1988).

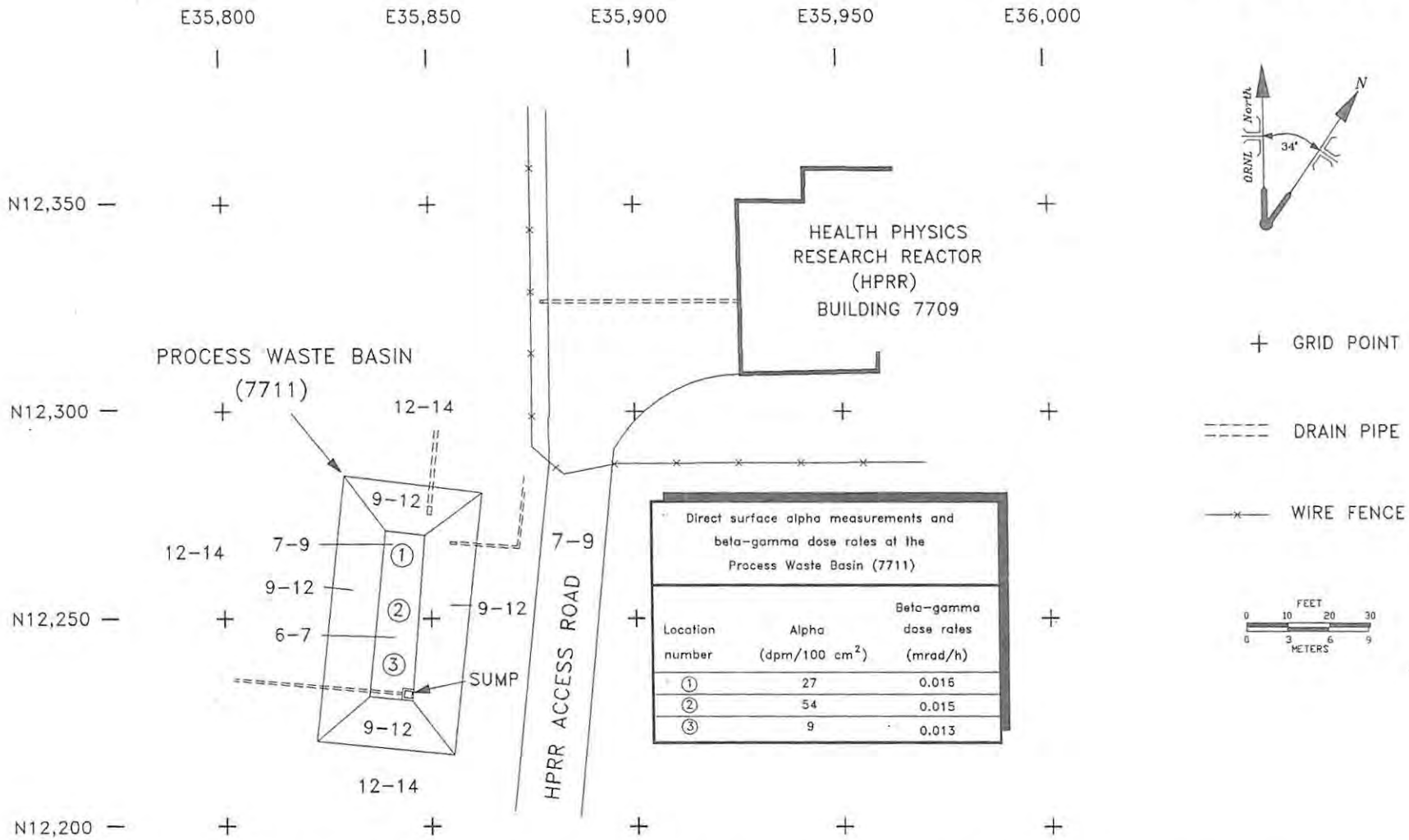
The basin, built in 1962,[20] is approximately 10 × 20 m (34 × 64 ft) at the top of the berm with sides sloping 4 m (12 ft) inward to a 2-m- (6-ft-) deep bottom that is 3 × 12 m (10 × 40 ft).[19] The basin is lined with a deteriorating Hydromat® asphalt liner. When filled to a depth of 1 m (3.75 ft), the basin holds approximately 95,000 L (25,000 gal).[22] The inlet pipe on the north bank of the basin leading from the two reactor storage pits[20] is covered with a 0.01-m (1/2-in.) mesh rodent screen.[22] Another inlet pipe is located on the east bank of the basin. A 0.6-m- (2-ft-) deep sump[22] in the southeast corner contains a valve that can release water from the basin to prevent overfilling.[20]

No wastes have ever been diverted to the basin. The only water entering the basin has come from the periodic checks for obstructions by the fire department or from precipitation.[1,19]

Discussion of Survey Results

The results of gamma exposure rate measurements are shown in Fig. 14. Generally, a surface scan of the waste basin revealed gamma levels ranging from 6 to 14 μR/h. These values represent natural background levels for uncontaminated areas. Directly measured alpha activity levels and beta-gamma dose rates were determined at three locations as

ORNL-DWG 89-6915



Direct surface alpha measurements and beta-gamma dose rates at the Process Waste Basin (7711)

Location number	Alpha (dpm/100 cm^2)	Beta-gamma dose rates (mrad/h)
①	27	0.016
②	54	0.015
③	9	0.013

Fig. 14. Results of gamma exposure rate measurements (μR/h) are shown on the drawing of the Process Waste Basin (7711). Alpha measurements and beta-gamma dose rates are given in the inset.

shown in Fig. 14. Direct alpha activities ranged from 9 to 54 dpm/100 cm^2 and averaged 30 dpm/100 cm^2. The maximum measurement, 54 dpm/100 cm^2, was obtained at Location 2. This value is within the range of typical ORR background levels. For comparative purposes, 30 dpm/100 cm^2 is well below the ORNL health physics guideline[7] of 300 dpm/100 cm^2 for establishing a Contamination Area. Additionally, beta-gamma dose rates ranged from 0.013 to 0.016 mrad/h, which is approximately 5 to 6% of the beta-gamma direct surface contamination level (0.25 mrad/h)[7] used in establishing a contamination area.

RECOMMENDATIONS

Analyses of outdoor radiological data from walkover surveys indicate no evidence of detectable surface radioactivity above typical ORR background levels at the Closed Contractors' Landfill (7658) and the Process Waste Basin (7711). There is the potential for subsurface soil and groundwater contamination from organic chemicals at the Closed Contractors' Landfill site because of the type and large volume of buried wastes (e.g., paint cans). Subsurface drilling in the fill material with subsequent RCRA Extraction Procedure Toxicity Characteristic tests and radiological analyses of core samples should be considered for a more thorough site assessment.

At the Tritium Target Fabrication Facility site, ^{137}Cs was detected in three surface soil samples and gross alpha and gross beta activities in one sample were above typical ORR background ranges. Additionally, soil tritium levels were found to be 20 to 100 times higher than the analytical detection limits while all WBW (background) samples taken on the ORR were below the detection limits. These data suggest significant levels of tritium in the soil. It is recommended that a more detailed soil profile and groundwater sampling survey be conducted to adequately characterize the radiological status of the TTFF site. One area of concern is the condition (including the level of liquid waste) of the buried stainless steel tank outside the east wall of the building.

Results of the outdoor walkover survey at the Thorium Storage Facility indicate one small (<1 m^2) hot spot of soil contamination that was subsequently attributed to ^{232}Th. Surface gamma exposure rates of up to 400 $\mu R/h$ were measured at this spot. Analytical results of soil samples collected from this spot demonstrate the presence of ^{232}Th (950 and 390 pCi/g in surface and subsurface samples, respectively). It is recommended that this hot spot be cleaned up. Only one storage well was found to have removable beta-gamma activity levels in excess of the ORNL health physics guideline limit of 1000 dpm/100 cm^2 for establishing a Contamination Area. Analysis of smears disclosed transferable beta-gamma activities of 1200 dpm/100 cm^2 in Storage Well 5. During the survey, a live snake and the remains of several small rodents were found in the bottom of the storage wells. It is recommended that all wells be sealed with metal locks. This action would minimize small animal intrusion.

The results of the walkover surveys at the Tritium Target Fabrication Facility (7025) and Thorium Storage Facility (7019) sites should be considered in the determination of (1) site inclusion in the WAG 17 (ORNL Services Area) or (2) site exclusion from further regulatory concerns. These data suggest that further radiological characterizations of each site would be required in this assessment.

REFERENCES

1. *RCRA Facilities Assessment (RFA)–Oak Ridge National Laboratory*, Oak Ridge National Laboratory, ORNL/RAP-12/VI (March 1987).
2. T. E. Myrick, B. A. Berven, W. D. Cottrell, W. A. Goldsmith, and F. F. Haywood, *Procedures Manual for the ORNL Radiological Survey Activities (RASA) Program*, Oak Ridge National Laboratory, ORNL/TM-8600 (April 1987).
3. *Safety Analysis Report for Building 7025*, Operations Division, Oak Ridge National Laboratory, ORNL/CF-84/318 Draft (May 6, 1985).
4. *Operational Safety Requirements for Building 7025*, Operations Division, Oak Ridge National Laboratory, ORNL/CF-82/56 Draft (March 1987).
5. Personal Communication, W. S. Aaron, Chemical Technology Division, Oak Ridge National Laboratory.
6. *Safety Analysis Report for Building 7025*, Operations Division, Oak Ridge National Laboratory, ORNL/CF-84/318 Draft (no date, assumed to be August 1987).
7. *Procedures and Practices for Radiation Protection Health Physics Manual*, Oak Ridge National Laboratory, Sect. 2.7, issued July 5, 1989.
8. Personal Communication, J. W. Wade, Analytical Chemistry Division, Oak Ridge National Laboratory.
9. Personal Communication, C. T. Garten, Environmental Sciences Division, Oak Ridge National Laboratory.
10. Personal Communication, J. H. Gillette (formerly Isotopes Division Superintendent, Oak Ridge National Laboratory).
11. Personal Communication, A. King, Laboratory Protection Division, Oak Ridge National Laboratory.
12. ORNL Building Directory, Civil and Architectural Engineering Department, Oak Ridge National Laboratory (September 1988).
13. U.S. Department of Energy, *Guidelines for Residual Radioactive Material at Formerly Utilized Sites, Remedial Action Program and Remote Surplus Facilities Management Program Sites* (Rev. 2, March 1987).
14. Personal Communication, Dvon Brogan (retired from Plant and Equipment Division, Oak Ridge National Laboratory).
15. Personal Communication, Clyde Thomas, Plant and Equipment Division, Oak Ridge National Laboratory.
16. T. Grizzard, *Inventory of ORNL Remedial Action Sites: 1. Solid Waste Storage Areas*, Oak Ridge National Laboratory, ORNL/RAP/LTR-86/35 (July 1986).
17. *RCRA Facilities Assessment (RFA) Oak Ridge National Laboratory, Addendum August 25, 1987*, Oak Ridge National Laboratory, ORNL/RAP-12/V3 (August 1987).

18. *Dosimetry Applications Research Facility*, Oak Ridge National Laboratory (descriptive pamphlet), 12 pp. (no date).

19. "Site Plan – Roads & Grading," Engineering Drawing No. S-20019-Y-005-E-1, Oak Ridge National Laboratory (February 1961).

20. Personal Communication, E. G. Bailiff, Research Reactors Division, Oak Ridge National Laboratory.

21. *Procedures Manual for the Health Physics Research Reactor (Including High-Level Gamma Facility)*, Oak Ridge National Laboratory, ORNL-3519 Special (December 1985).

22. "Site Details," Engineering Drawing No. S-20887-Y-038-E-1, Oak Ridge National Laboratory (February 1961).

APPENDIX: WAG 12 GROUNDWATER MONITORING DATA (1988)

Table A.1. Concentrations of gross alpha, gross beta, ^{60}Co, and ^{137}Cs in groundwater samples collected December 13, 1988, from piezometer wells at WAG 12.

Sample ID[a]	Concentrations in pCi/mL (Bq/L)			
	Gross alpha[b,c]	Gross beta[b,d]	^{60}Co[e,f]	^{137}Cs[e,f]
912G	0.014 ± 0.02 (0.50 ± 0.8)	0.049 ± 0.03 (1.8 ± 1)	-0.016 ± 0.005 (-0.60 ± 0.2)	0.0011 ± 0.003 (0.040 ± 0.1)
912H	0.0 ± 0.002 (0.0 ± 0.6)	0.0062 ± 0.01 (0.23 ± 0.5)	-0.0024 ± 0.007 (0.090 ± 0.2)	-0.00081 ± 0.005 (-0.030 ± 0.2)
913G	0.0 ± 0.001 (0.0 ± 0.05)	1.1 ± 0.2 (41 ± 6)	0.00027 ± 0.005 (0.010 ± 0.2)	0.0030 ± 0.003 (0.11 ± 0.1)
913H	0.0054 ± 0.01 (0.20 ± 0.5)	0.0 ± 0.01 (0.0 ± 0.5)	0.0019 ± 0.006 (0.070 ± 0.2)	0.00081 ± 0.006 (0.030 ± 0.2)
914G	0.016 ± 0.02 (0.60 ± 0.9)	0.0027 ± 0.01 (0.10 ± 0.5)	0.0035 ± 0.004 (0.13 ± 0.2)	0.0024 ± 0.005 (0.090 ± 0.2)
914H	0.014 ± 0.02 (0.50 ± 0.8)	0.027 ± 0.03 (1.0 ± 1)	0.0015 ± 0.003 (0.055 ± 0.1)	0.00027 ± 0.003 (0.010 ± 0.1)
915G	0.014 ± 0.02 (0.50 ± 0.9)	0.081 ± 0.05 (3.0 ± 2)	-0.0011 ± 0.006 (-0.040 ± 0.2)	-0.0024 ± 0.005 (-0.090 ± 0.2)
915H	0.014 ± 0.02 (0.50 ± 0.9)	0.054 ± 0.03 (2.0 ± 1)	-0.0024 ± 0.006 (-0.090 ± 0.2)	0.0038 ± 0.005 (0.14 ± 0.2)
916G	0.011 ± 0.02 (0.39 ± 0.7)	0.076 ± 0.04 (2.8 ± 2)	0.0062 ± 0.005 (0.23 ± 0.2)	0.0014 ± 0.006 (0.050 ± 0.2)
916H	0.0054 ± 0.01 (0.20 ± 0.5	0.027 ± 0.03 (0.99 ± 1)	0.0014 ± 0.006 (0.050 ± 0.2)	0.00081 ± 0.005 (0.030 ± 0.2)
917G	0.0073 ± 0.02 (0.27 ± 0.6)	0.081 ± 0.05 (3.0 ± 2)	-0.0022 ± 0.008 (-0.080 ± 0.3)	-0.0032 ± 0.007 (-0.12 ± 0.3)
917H	0.032 ± 0.04 (1.2 ± 1)	0.0068 ± 0.02 (0.25 ± 0.6)	0.0014 ± 0.005 (0.050 ± 0.2)	0.0049 ± 0.004 (0.18 ± 0.1)

[a]Piezometer well locations are shown on Fig. 11.

[b]Gross alpha and gross beta analyses were performed in accordance with U.S. Environmental Protection Agency (EPA) procedure 900.0.

[c]Uncontaminated groundwater in the Oak Ridge area usually contains <0.054 pCi/mL (<2 Bq/L) gross alpha (see ref. 8).

[d]Uncontaminated groundwater in the Oak Ridge area usually contains <0.14 pCi/mL (<5 Bq/L) gross beta (see ref. 8).

[e]Cobalt-60 and ^{137}Cs analyses were performed in accordance with U.S. EPA procedure 901.1.

[f]Uncontaminated groundwater in the Oak Ridge area usually contains <0.014 pCi/mL (<0.5 Bq/L) ^{60}Co and ^{137}Cs (see ref. 8).

Table A.2. Concentrations of mercury in groundwater samples collected December 13, 1988, from piezometer wells at WAG 12

Well no.[a]	Concentration (μg/mL)[b]
912	<0.0001
913	<0.0001
914	<0.0001
915	<0.0001
916	<0.0001
917	<0.0001

[a]Piezometer well locations are shown on Fig. 11.

[b]Mercury analyses performed in accordance with U.S. Environmental Protection Agency (EPA) procedure 245.1 (modified).

Table A.3. Results of analyses for volatile organics in groundwater samples collected December 13, 1988, from piezometer wells at WAG 12

Parameter[b]	Chemical Abstracts Service No.	Results from wells[a] 912 through 917 (μg/L)					
		912A	913A	914A	915A	916A	917A
1,1,1-trichloroethane	71-55-6	*c*	*c*	*c*	*c*	*c*	*c*
1,1,2,2-tetrachloroethane	79-34-5	*c*	*c*	*c*	*c*	*c*	*c*
1,1,2-trichloroethane	79-00-5	*c*	*c*	*c*	*c*	*c*	*c*
1,1-dichloroethane	75-35-3	*c*	*c*	*c*	*c*	*c*	*c*
1,1-dichloroethene	75-35-4	*c*	*c*	*c*	*c*	*c*	*c*
1,2-dichloroethane	107-06-2	*c*	*c*	*c*	*c*	*c*	*c*
1,2-dichloroethene (total)	540-59-0	*c*	*c*	*c*	*c*	*c*	*c*
1,2-dichloropropane	78-87-5	*c*	*c*	*c*	*c*	*c*	*c*
2-butanone	78-93-3	*c*	*c*	*c*	*c*	*c*	*c*
2-hexanone	591-78-6	*c*	*c*	*c*	*c*	*c*	*c*
4-methyl-2-pentanone	108-10-1	*c*	*c*	*c*	*c*	*c*	*c*
acetone	67-64-1	*d*	*d*	*d*	*d*	*c*	*c*
benzene	71-43-2	*d*	*c*	*c*	*c*	*c*	*c*
bromodichloromethane	75-27-4	3[e]	*c*	*c*	*c*	2[e]	*c*
bromoform	75-25-2	*c*	*c*	*c*	*c*	*c*	*c*
bromomethane	74-83-9	*c*	*c*	*c*	*c*	*c*	*c*
carbon disulfide	75-15-0	*c*	*c*	*c*	*c*	*c*	*c*
carbon tetrachloride	56-23-5	*c*	*c*	*c*	*c*	*c*	*c*
chlorobenzene	108-90-7	*c*	*c*	*c*	*c*	*c*	*c*
chloroethane	75-00-3	*c*	*c*	*c*	*c*	*c*	*c*
chloroform	67-66-3	*f*	*c*	*d*	*c*	8[g]	1[e]
chloromethane	74-87-3	*c*	*c*	*c*	*c*	*c*	*c*
cis-1,3-dichloropropene	10061-01-5	*c*	*c*	*c*	*c*	*c*	*c*
dibromochloromethane	124-48-1	*c*	*c*	*c*	*c*	*c*	*c*
ethylbenzene	100-41-4	*c*	*c*	*c*	*c*	*c*	*c*
methylene chloride	75-09-2	*d*	*d*	*d*	*d*	*d*	*d*
styrene	100-42-5	*c*	*c*	*c*	*c*	*c*	*c*
tetrachloroethene	127-18-4	*c*	*c*	*c*	*c*	*c*	*c*
toluene	108-88-3	*c*	*c*	*c*	*c*	*c*	*c*
trans-1,3-dichloropropene	10061-02-6	*c*	*c*	*c*	*c*	*c*	*c*
trichloroethene	79-01-6	*c*	*c*	*c*	*c*	*c*	*c*
vinyl acetate	108-05-4	*c*	*c*	*c*	*c*	*c*	*c*
vinyl chloride	75-01-4	*c*	*c*	*c*	*c*	*c*	*c*
xylene (total)	133-02-7	*c*	*c*	*c*	*c*	*c*	*c*

[a]Piezometer well locations are shown on Fig. 11.

[b]Analyses performed in accordance with U.S. Environmental Protection Agency (EPA) procedure 8240.

[c]Compound was analyzed for but was not detected.

[d]Estimated value below the quantitation limit. Compound detected in both the sample and its associated blank indicating a possible laboratory contaminant.

[e]Estimated value that is below the quantitation limit.

[f]Compound detected in both the sample and its associated blank indicating a possible laboratory contaminant.

[g]Value slightly above the quantitation limit for chloroform (5 μg/L).

Table A.4. Results of analyses for base/neutral/acid extractable organics in groundwater samples collected December 13, 1988, from piezometer wells at WAG 12

Parameter[b]	Chemical Abstracts Service No.	Results from wells[a] 912 through 917 (μg/L)					
		912C	913C	914C	915C	916C	917C
1,2,4-trichlorobenzene	120-82-1	*c*	*c*	*c*	*c*	*c*	*c*
1,2-dichlorobenzene	95-50-1	*c*	*c*	*c*	*c*	*c*	*c*
1,3-dichlorobenzene	541-73-1	*c*	*c*	*c*	*c*	*c*	*c*
1,4-dichlorobenzene	106-46-7	*c*	*c*	*c*	*c*	*c*	*c*
2,4,5-trichlorophenol	95-95-4	*c*	*c*	*c*	*c*	*c*	*c*
2,4,6-trichlorophenol	88-06-2	*c*	*c*	*c*	*c*	*c*	*c*
2,4-dichlorophenol	120-83-2	*c*	*c*	*c*	*c*	*c*	*c*
2,4-dimethylphenol	105-67-9	*c*	*c*	*c*	*c*	*c*	*c*
2,4-dinitrophenol	51-28-5	*c*	*c*	*c*	*c*	*c*	*c*
2,4-dinitrotoluene	121-14-2	*c*	*c*	*c*	*c*	*c*	*c*
2,6-dinitrotoluene	606-20-2	*c*	*c*	*c*	*c*	*c*	*c*
2-chloronaphthalene	91-58-7	*c*	*c*	*c*	*c*	*c*	*c*
2-chlorophenol	95-57-8	*c*	*c*	*c*	*c*	*c*	*c*
2-methylnaphthalene	91-57-6	*c*	*c*	*c*	*c*	*c*	*c*
2-methylphenol	95-48-7	*c*	*c*	*c*	*c*	*c*	*c*
2-nitroaniline	88-74-4	*c*	*c*	*c*	*c*	*c*	*c*
2-nitrophenol	88-75-5	*c*	*c*	*c*	*c*	*c*	*c*
3,3'-dichlorobenzidine	91-94-1	*c*	*c*	*c*	*c*	*c*	*c*
3-nitroaniline	99-09-2	*c*	*c*	*c*	*c*	*c*	*c*
4,6-dinitro-2-methylphenol	534-52-1	*c*	*c*	*c*	*c*	*c*	*c*
4-bromophenyl-phenylether	101-55-3	*c*	*c*	*c*	*c*	*c*	*c*
4-chloro-3-methylphenol	59-50-7	*c*	*c*	*c*	*c*	*c*	*c*
4-chloroaniline	106-47-8	*c*	*c*	*c*	*c*	*c*	*c*
4-chlorophenyl-phenylether	7005-72-3	*c*	*c*	*c*	*c*	*c*	*c*
4-methylphenol	106-44-5	*c*	*c*	*c*	*c*	*c*	*c*
4-nitroaniline	100-01-6	*c*	*c*	*c*	*c*	*c*	*c*
4-nitrophenol	100-02-7	*c*	*c*	*c*	*c*	*c*	*c*
acenaphthene	83-32-9	*c*	*c*	*c*	*c*	*c*	*c*
acenaphthylene	208-96-8	*c*	*c*	*c*	*c*	*c*	*c*
anthracene	120-12-7	*c*	*c*	*c*	*c*	*c*	*c*
benzo(a)anthracene	56-55-3	*c*	*c*	*c*	*c*	*c*	*c*
benzo(a)pyrene	50-32-8	*c*	*c*	*c*	*c*	*c*	*c*
benzo(b)fluoranthene	205-99-2	*c*	*c*	*c*	*c*	*c*	*c*
benzo(g,h,i)perylene	191-24-2	*c*	*c*	*c*	*c*	*c*	*c*
benzo(k)fluoranthene	207-08-9	*c*	*c*	*c*	*c*	*c*	*c*
benzoic acid	65-85-0	*c*	*c*	*c*	*c*	*c*	*c*
benzyl alcohol	100-51-6	*c*	*c*	*c*	*c*	*c*	*c*
bis(2-chloroethoxy)methane	111-91-1	*c*	*c*	*c*	*c*	*c*	*c*
bis(2-chloroethyl)ether	111-44-4	*c*	*c*	*c*	*c*	*c*	*c*
bis(2-chloroisopropyl)ether	39638-32-9	*c*	*c*	*c*	*c*	*c*	*c*
bis(2-ethylhexyl)phthalate	117-81-7	*c*	4[d]	8[d]	*c*	*c*	8[d]
butylbenzylphthalate	85-68-7	*c*	*c*	*c*	*c*	*c*	*c*
chrysene	218-01-9	*c*	*c*	*c*	*c*	*c*	*c*
di-n-butylphthalate	84-74-2	*c*	*c*	*c*	*c*	*c*	*c*

Table A.4 (continued)

Parameter[b]	Chemical Abstracts Service No.	Results from wells[a] 912 through 917 (μg/L)					
		912C	913C	914C	915C	916C	917C
di-n-octylphthalate	117-84-0	*c*	*c*	*c*	*c*	*c*	*c*
dibenz(a,h)anthracene	53-70-3	*c*	*c*	*c*	*c*	*c*	*c*
dibenzofuran	132-64-9	*c*	*c*	*c*	*c*	*c*	*c*
diethylphthalate	84-66-2	*c*	*c*	*c*	*c*	*c*	*c*
dimethylphthalate	131-11-3	*c*	*c*	*c*	*c*	*c*	*c*
fluoranthene	206-44-0	*c*	*c*	*c*	*c*	*c*	*c*
fluorene	86-73-7	*c*	*c*	*c*	*c*	*c*	*c*
hexachlorobenzene	118-74-1	*c*	*c*	*c*	*c*	*c*	*c*
hexachlorobutadiene	87-68-3	*c*	*c*	*c*	*c*	*c*	*c*
hexachlorocyclopentadiene	77-47-4	*c*	*c*	*c*	*c*	*c*	*c*
hexachloroethane	67-72-1	*c*	*c*	*c*	*c*	*c*	*c*
indeno(1,2,3-cd)pyrene	193-39-5	*c*	*c*	*c*	*c*	*c*	*c*
isophorone	78-59-1	*c*	*c*	*c*	*c*	*c*	*c*
n-nitroso-di-n-propylamine	621-64-7	*c*	*c*	*c*	*c*	*c*	*c*
n-nitrosodiphenylamine (1)	86-30-6	*c*	*c*	*c*	*c*	*c*	*c*
naphthalene	91-20-3	*c*	*c*	*c*	*c*	*c*	*c*
nitrobenzene	98-95-3	*c*	*c*	*c*	*c*	*c*	*c*
pentachlorophenol	87-86-5	*c*	*c*	*c*	*c*	*c*	*c*
phenanthrene	85-01-8	*c*	*c*	*c*	*c*	*c*	*c*
phenol	108-95-2	*c*	*c*	*c*	*c*	*c*	*c*
pyrene	129-00-0	*c*	*c*	*c*	*c*	*c*	*c*

[a]Piezometer well locations are shown on Fig. 11.

[b]Analyses performed in accordance with U.S. Environmental Protection Agency (EPA) procedure 8270.

[c]Compound was analyzed for but was not detected.

[d]Estimated value that is below the quantitation limit of 10 μg/L.

INTERNAL DISTRIBUTION

1. W. S. Aaron
2. T. L. Ashwood
3. E. G. Bailiff
4-5. L. D. Bates
6. J. T. Bell
7. B. A. Berven
8. W. J. Boegly, Jr.
9. H. M. Braunstein
10. T. W. Burwinkle
11. H. M. Butler, Jr.
12. R. F. Carrier
13. K. W. Cook
14. H. R. Gaddis
15. S. B. Garland
16. C. T. Garten, Jr.
17. R. K. Genung
18-22. D. F. Hall
23. J. R. Hightower
24. L. D. Hyde
25. S. V. Kaye
26. A. King
27. P. Y. Lu
28. C. E. Nix
29. J. E. Nyquist
30-33. P. T. Owen
34. D. J. Pruett
35-39. J. L. Quillen
40. C. S. Sims
41. B. P. Spalding
42-46. R. E. Swaja
47. P. F. Tiner
48-49. J. R. Trabalka
50-54. M. S. Uziel
55. L. D. Voorhees
56. J. W. Wade
57-61. J. K. Williams
62. Laboratory Records – RC
63. ORNL Patent Section