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**ENVIRONMENTAL  
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**Surface Radiological Investigations  
at the 0816 Site,  
Waste Area Grouping 13,  
Oak Ridge National Laboratory,  
Oak Ridge, Tennessee**

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**Surface Radiological Investigations at the 0816 Site, Waste Area  
Grouping 13, Oak Ridge National Laboratory, Oak Ridge, Tennessee**

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## EXECUTIVE SUMMARY

A surface radiological investigation was conducted intermittently from July through September 1994 at the 0816 site, located within Waste Area Grouping (WAG) 13. The purpose of the survey was to ascertain and document the surface radiological condition of the site subsequent to remedial action activities completed in May 1994. The survey was designed to determine whether any residual surface soil contamination in excess of 120 pCi/g <sup>137</sup>Cs remained at the site.

Typical background surface gamma exposure rates (10 to 16  $\mu$ R/h) were found along the south fence except near the south entrance gate where a cluster of hot spots ranged from 20 to 175  $\mu$ R/h. Spotty contamination (with surface gamma levels ranging from 16 to 40  $\mu$ R/h) was found up to the edge of the former contaminated enclosures where excavation and soil replacement had taken place. Numerous hot spots ranging from 20 to 860  $\mu$ R/h were scattered generally more toward the north side of the site. Several large areas (totaling ~14,000 ft<sup>2</sup>) of elevated surface gamma exposure rates (20 to 195  $\mu$ R/h) were found north of the former contaminated enclosures. A marshy, drainage area paralleling the north fence for ~850 ft also exhibited elevated surface gamma levels (16 to 40  $\mu$ R/h). Most surface gamma levels were  $\leq$ 175  $\mu$ R/h; highest hot-spot measurements were 690 and 860  $\mu$ R/h.

Gamma spectrometry analysis of 1 vegetation sample collected where surface gamma exposure rates measured 690  $\mu$ R/h showed elevated concentrations of <sup>137</sup>Cs (16  $\pm$  7 pCi/g, dry wt). Eleven surface soil samples collected at locations ranging from 32 to 860  $\mu$ R/h contained <sup>137</sup>Cs concentrations of 13  $\pm$  1 to 9000  $\pm$  400 pCi/g (dry wt). Cesium-137 concentrations at depths of 0 to 6 in. exceeded 120 pCi/g in 80% of the samples. Concentrations at depths of 6 to 12 in. exceeded 120 pCi/g in 50% of the samples. Concentrations at depths of 12 to 18 in. were all  $<$ 120 pCi/g.

Correlation of surface gamma exposure rates with <sup>137</sup>Cs levels in surface soil indicated that at locations where gamma radiation levels were  $>$ 40  $\mu$ R/h, concentrations of <sup>137</sup>Cs in surface soil were  $>$ 120 pCi/g. Therefore, it should be conservatively assumed that all locations with surface gamma exposure rates  $\geq$ 40  $\mu$ R/h may have <sup>137</sup>Cs concentrations  $>$ 120 pCi/g. Since surface gamma exposure rates at all six of the large areas and 75% of the discrete spots or small areas equaled or exceeded 40  $\mu$ R/h, soil <sup>137</sup>Cs concentrations  $>$ 120 pCi/g can be assumed to be prevalent at this site.

## 1. INTRODUCTION

A surface radiological investigation was conducted intermittently from July through September 1994 at the 0816 site, located within Waste Area Grouping (WAG) 13. The survey was performed by members of the Measurement Applications and Development Group, Health Sciences Research Division, Oak Ridge National Laboratory (ORNL) at the request of ORNL Site Environmental Restoration Program Facility Management. The purpose of the survey was to ascertain and document the surface radiological condition of the site subsequent to remedial action activities completed in May 1994. The survey was designed to determine whether any residual surface soil contamination in excess of 120 pCi/g  $^{137}\text{Cs}$  (specified by the Interim Record of Decision<sup>1</sup>) remained at the site.

## 2. SITE HISTORY

The following background information taken from *Radiation Exposures From a Cesium-Contaminated Field* (ORNL/RAP-46)<sup>2</sup> is useful in understanding the origin and extent of contamination at the site.

Because of civil defense interest in postattack survival, a weapons fallout field study was commissioned at the 0816 site during 1966. The fallout study used <sup>137</sup>Cs, an important long-lived component of weapons fallout, as the source of radiation. This radionuclide has a 30-year half-life and emits both beta (0.52- and 1.18-MeV) and gamma (0.66-MeV) radiation.

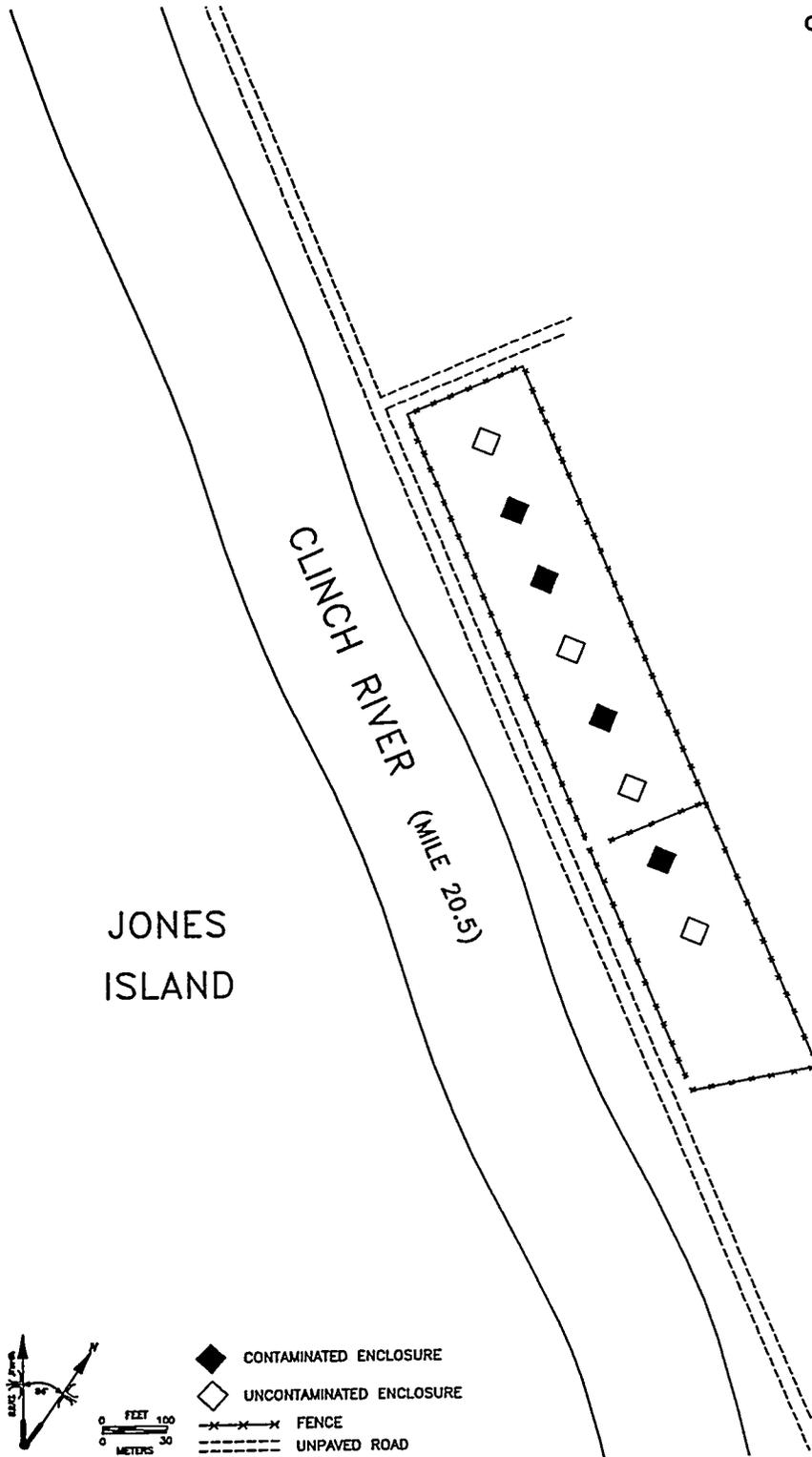
The 5-acre fenced 0816 site is part of the 0800 Environmental Research Area, a ~50-acre fescue-dominated field located 330 ft north of the Clinch River at Clinch River Mile 20.5. The study area is also located ~1.3 miles south of the intersection of Bethel Valley Road and State Highway 95 at ORNL grid coordinates (measured in feet) N 17,480, E 20,370.

Within the fenced area, eight 33- by 33-ft treatment plots were enclosed by metal sheeting extending 18 in. below the surface and 24 in. above ground. In August 1968, enclosures 2, 4, 6, and 7 were contaminated with <sup>137</sup>Cs, and the remaining four enclosures were used as controls. (See Fig. 2.1.)

The contaminant consisted of <sup>137</sup>Cs fused at high temperatures to silica sand particles (100  $\mu$ Ci/g). The particles ranged from 88 to 177  $\mu$ m in diameter and were spread at a load of 72 g/m<sup>2</sup> over the plots. Each enclosure received approximately 2.2 Ci of <sup>137</sup>Cs, which resulted in a total of 8.8 Ci to the site. The particle-size distribution was selected to simulate particle diameters characteristic of weapons fallout.

A surface radiological investigation was conducted in the area between June 1987 and March 1988. Gamma exposure rates on the river and on Jones Island rarely exceeded background, but exposure rates on the shoreline at the closest point to the <sup>137</sup>Cs-contaminated field approached three times background levels. Inside the fenced area, gamma rates at 1 m above the ground surface averaged 3 to 4 mR/h and measured 27 mR/h at the corner of one contaminated enclosure.

Between August and October 1993 the soil in the 4 contaminated enclosures was excavated to depths of 3 to 4.5 ft and removed to underground silos at WAG 6.<sup>3</sup> As specified by the Interim Record of Decision for WAG 13,<sup>1</sup> excavation at each enclosure was terminated when laboratory results demonstrated residual contamination  $\leq$ 120 pCi/g dry wt.<sup>3</sup> Hot spots located within 10 ft of the northern boundary of each contaminated enclosure and within 5 to 10 ft of the east and west boundaries were excavated to a depth of 6 to 12 in. Hot spot excavation was completed in May 1994.<sup>3</sup>



**Fig. 2.1. Diagram of the 5-acre, fenced 0816 site used in <sup>137</sup>Cs fallout studies in the 1960s.**

### 3. SURVEY METHODS

#### 3.1 GAMMA RADIATION

Gamma radiation was measured with a sodium iodide (NaI) scintillation probe connected to a Victoreen Model 490 Thyac III ratemeter. Because NaI gamma scintillators are energy-dependent, measurements of gamma radiation levels made with these instruments must be normalized to pressurized ionization chamber (PIC) measurements to estimate gamma exposure rates. The function developed for these conversions is

$$y = CF \times x + b$$

where

$y$  = the exposure rate ( $\mu\text{R/h}$ ),

$CF$  = the slope of the regression line calculated by plotting a selected number of PIC measurements ( $\mu\text{R/h}$ ) vs scintillometer measurements (kcpm) at the same locations,

$x$  = the scintillometer measurements in thousand counts per minute (kcpm),

$b$  = the  $y$  intercept.

For this site  $CF = 1.7$  and  $b = 6.2$ .

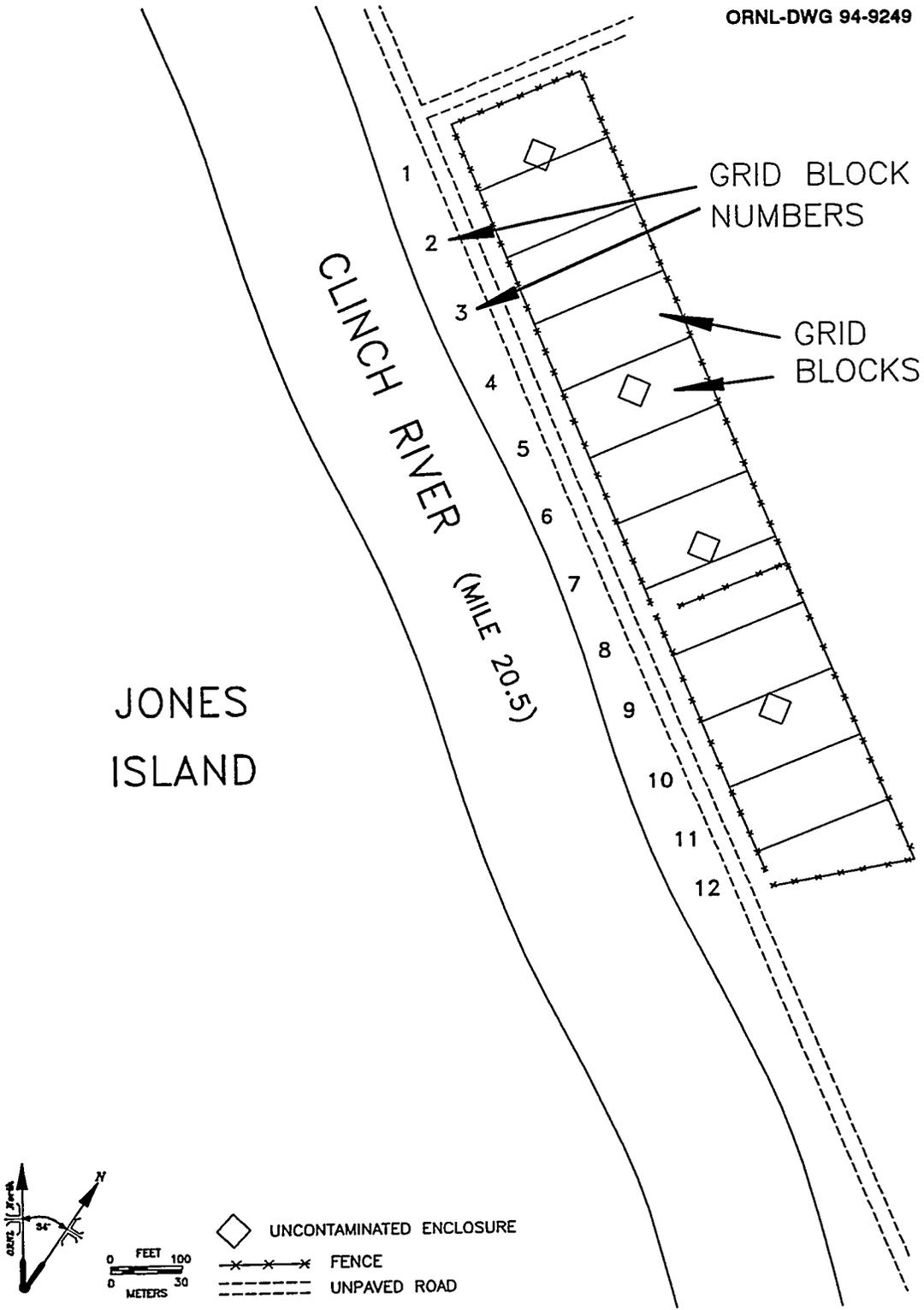
#### 3.2 SECTIONING OF SURVEY AREA

The 5-acre plot was divided into grid blocks to aid in identifying the location of contamination. The blocks were established by beginning at the southwest corner of the plot and measuring 100-ft sections eastward along the fence. Each grid block covered the entire width of the plot, which varied from 175 ft to 190 ft. Eleven rectangular blocks were established with dimensions of 100 ft by ~180 ft, and the twelfth block at the east end of the plot was a trapezoid. (See Fig. 3.1.)

#### 3.3 SCOPE OF THE SURVEY

The survey included the following:

- Measurement of background gamma exposure rates outside the fence in areas deemed to be free of radiological contamination.
- A visual inspection for debris or any other indication of possibly contaminated material.



**Fig. 3.1. Diagram showing Grid Blocks 1 through 12 established at the 0816 site.**

- A surface gamma radiation scan on all accessible portions of the 5-acre site. Approximately 95% of the site was accessible for surveying. (Inaccessible areas included locations where brush could not be cut or cleared due to the presence of debris, the control enclosures that remain in place, and the two buildings.) Areas with surface measurements  $>40 \mu\text{R/h}$  were flagged and recorded.
- PIC measurements at 9 locations to enable calculation of a conversion factor.
- Collection of 23 soil samples at depths ranging from 6 to 18 in. at 11 locations throughout the site.
- Collection of 1 sample of vegetation growing in an area of contaminated soil.
- Gamma spectrometry analysis of the environmental samples conducted by the Analytical Services Organization at ORNL.

## 4. SURVEY RESULTS

### 4.1 GAMMA EXPOSURE RATES

Background gamma exposure rates measured in uncontaminated areas on the Oak Ridge Reservation generally range from 8 to 13  $\mu\text{R/h}$  at 1 m above ground surface and from 10 to 17  $\mu\text{R/h}$  at the ground surface.<sup>4</sup> Similar levels were measured outside the 0816 fence where gamma exposure rates ranged from 10 to 13  $\mu\text{R/h}$  at 1 m above the ground surface and from 10 to 16  $\mu\text{R/h}$  at the ground surface.

Results of the surface gamma scan inside the fence are shown in Figs. 4.1 and 4.2, with Grid Blocks 1 through 6 displayed in Fig. 4.1 and Blocks 7 through 12 displayed in Fig. 4.2. Surface gamma levels near the south fence of most blocks ranged from 10 to 16  $\mu\text{R/h}$ , similar to the typical background range. One grid block (No. 10) exhibited no elevated gamma radiation levels. In most blocks, gamma levels increased as the survey moved northward away from the south fence.

Grid Blocks 1 through 6 contained 3 large areas of surface contamination. The first area (~4500  $\text{ft}^2$  in Grid Blocks 1 and 2) measured 20 to 44  $\mu\text{R/h}$  in Block 1, and 20 to 125  $\mu\text{R/h}$  in Block 2. The second area (~2600  $\text{ft}^2$  in Grid Blocks 3 and 4) measured 20 to 40  $\mu\text{R/h}$ . The third area (~800  $\text{ft}^2$  in Grid Block 6) measured 32 to 90  $\mu\text{R/h}$ . Approximately 23 discrete contaminated spots or small areas were identified with 21 of these ranging from 32 to 175  $\mu\text{R/h}$  and 2 measuring 690 and 860  $\mu\text{R/h}$ . One-meter gamma exposure rates measured at 5 soil sample locations varied from 23 to 92  $\mu\text{R/h}$ . Surface gamma levels at a marshy, drainage area running parallel to the north fence ranged from 16 to 40  $\mu\text{R/h}$ .\* The 2 experimental enclosures and a brushy area in Grid Block 5 were inaccessible.

Grid Blocks 7 through 12 contained 3 large areas of surface contamination. The first area (~3100  $\text{ft}^2$  in Grid Block 7) ranged from 32 to 195  $\mu\text{R/h}$ . The second area (~2800  $\text{ft}^2$  in Grid Blocks 8 and 9) ranged from 40 to 140  $\mu\text{R/h}$ . The third area (~600  $\text{ft}^2$  in Grid Block 12) ranged from 23 to 90  $\mu\text{R/h}$ . Approximately 27 discrete contaminated spots or small areas were identified with 24 of these ranging from 20 to 175 and 3 measuring 260, 520, and 690  $\mu\text{R/h}$ . One-meter gamma exposure rates measured 175  $\mu\text{R/h}$  at one soil sample location. Surface gamma levels at the marshy, drainage area running parallel to the north fence in Grid Blocks 6 and 7 measured 20 to 40  $\mu\text{R/h}$ .\* The drainage area began at the ~2800  $\text{ft}^2$  area in Block 8 and 9 with surface gamma exposure rates ranging from 40 to 140  $\mu\text{R/h}$  (described above). Two experimental enclosures and three brushy spots were inaccessible. The interior of the 2 buildings was not surveyed.

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\*As part of another survey, this marshy, drainage area was surveyed beyond the west fence and ~20 ft west of the road. The marshy area drained beneath the road where it narrowed and became a small creek west of the road. The road was not contaminated. The highest surface gamma level found on the creek bank was ~23  $\mu\text{R/h}$  with exposure levels quickly dropping to ~16  $\mu\text{R/h}$  as the survey moved downstream.

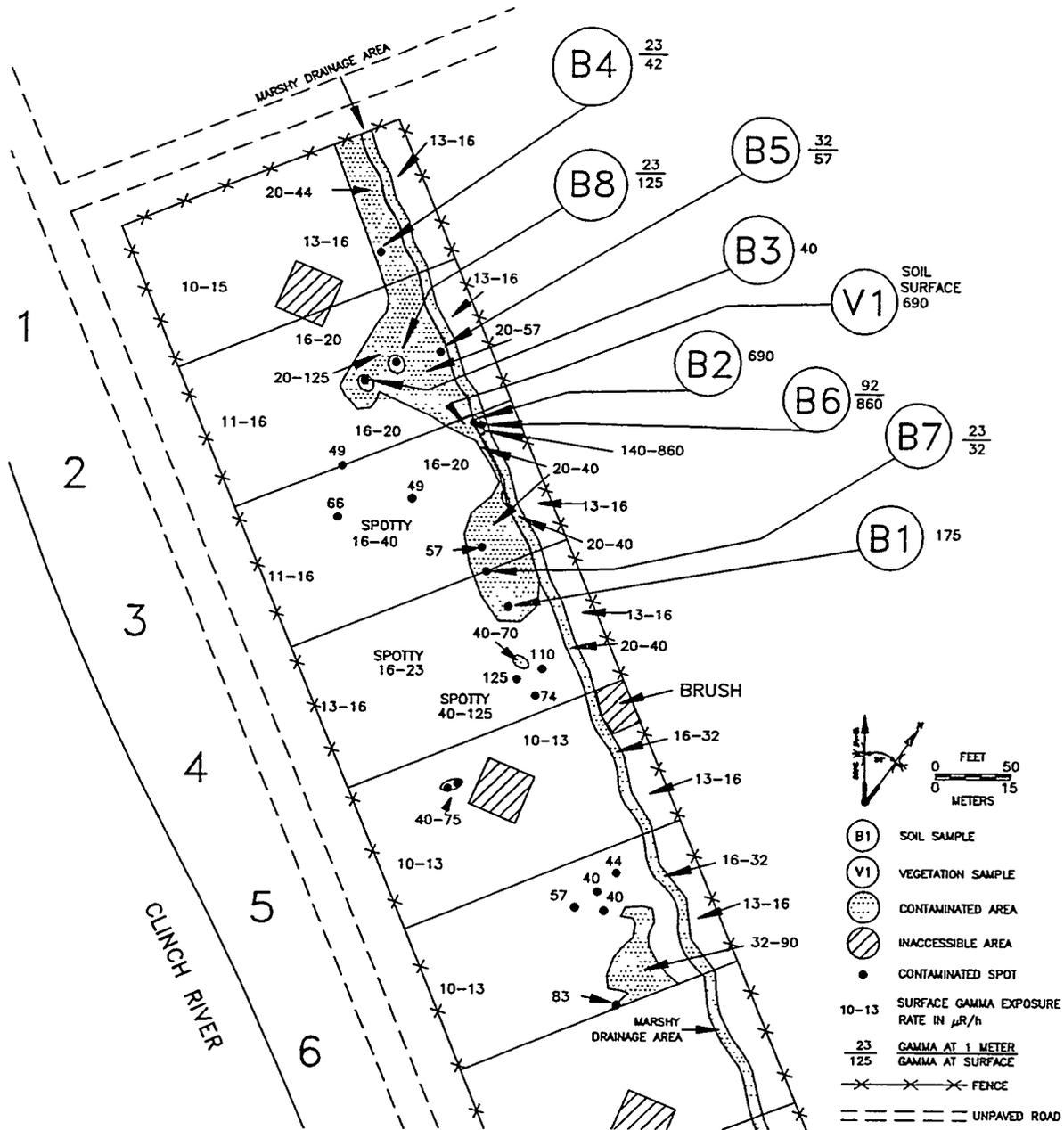


Fig. 4.1. Diagram showing surface and selected 1-m gamma exposure rates ( $\mu\text{R}/\text{h}$ ) in Grid Blocks 1 through 6 at the 0816 site. Locations of soil (B) and vegetation (V) samples are also indicated.

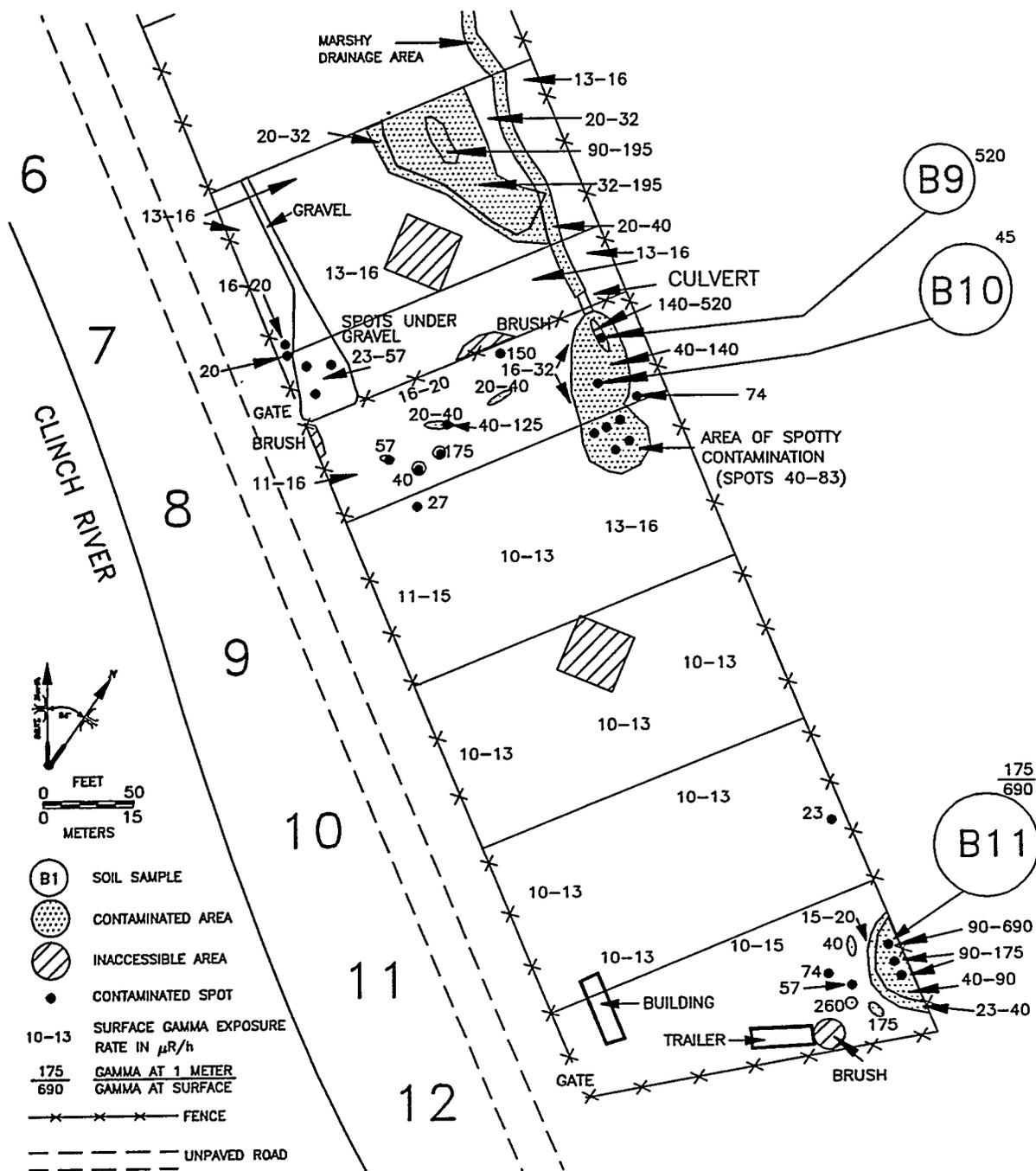


Fig. 4.2. Diagram showing surface gamma exposure rates ( $\mu\text{R}/\text{h}$ ) and soil sample locations (B) in Grid Blocks 7 through 12 at the 0816 site.

## 4.2 SOIL SAMPLE ANALYSES

Results of soil sample analysis are given in Table 4.1, and sample locations are identified in Figs. 4.1 and 4.2. Surface gamma exposure rates at soil sample locations ranged from 32 to 860  $\mu\text{R}/\text{h}$ . Soil  $^{137}\text{Cs}$  concentrations did not increase directly in relation to gamma exposure rates because only a small aliquot of the sample is randomly selected for analysis, and the radionuclides are seldom distributed uniformly throughout a sample.

Background  $^{137}\text{Cs}$  concentrations measured at 4 sites outside the Oak Ridge Reservation having only natural radioactivity ranged from 0.35 to 0.6 pCi/g.<sup>5</sup> When compared to these background levels, all soil samples collected during this survey contained elevated concentrations of  $^{137}\text{Cs}$ . Surface soil samples collected at depths of 0 to 6 in. ranged from  $13 \pm 1$  to  $9000 \pm 400$  (dry wt) with  $^{137}\text{Cs}$  concentrations exceeding 120 pCi/g in 9 of the 11 samples (80%). Samples collected at depths of 6 to 12 in. varied from  $4.3 \pm 0.6$  to  $2900 \pm 40$  pCi/g with  $^{137}\text{Cs}$  concentrations exceeding 120 pCi/g in 4 of the 8 samples (50%). Samples collected at depths of 12 to 18 in. ranged from  $3.5 \pm 0.3$  to  $85 \pm 3$  pCi/g with  $^{137}\text{Cs}$  concentrations <120 pCi/g in all 4 samples. Except for sample B2,  $^{137}\text{Cs}$  concentrations decreased with increasing depth.

## 4.3 VEGETATION SAMPLE ANALYSIS

One vegetation sample was collected in the vicinity of soil sample location B2 (Fig. 4.1) where surface gamma exposure rates measured 690  $\mu\text{R}/\text{h}$  and  $^{137}\text{Cs}$  soil concentrations measured  $1200 \pm 30$  pCi/g at 0 to 6 in. and  $2900 \pm 40$  pCi/g at 6 to 12 in. Radionuclide analysis (Table 4.1) showed that the vegetation contained elevated concentrations of  $^{137}\text{Cs}$  ( $16 \pm 7$  pCi/g, dry wt).

Table 4.1. Concentrations of  $^{137}\text{Cs}$  in soil (B) and vegetation (V) samples collected at the 0816 site

Sample ID	Sample depth (in.)	Gamma exposure rate ( $\mu\text{R/h}$ )	$^{137}\text{Cs}^a$ (pCi/g dry wt)	Comments
B1	0-6	<u>175 at surface</u> 23 at depth of 6 in.	$1200 \pm 30$	Block 4; small spot
B2A	0-6	<u>690 at surface</u> 860 at depth of 6 in.	$1200 \pm 30$	Block 3; area $\sim 5 \times 8$ ft
B2B	6-12	350 at depth of 12 in.	$2900 \pm 40$	Same as B2A
B3	0-6	<u>40 at surface</u>	$13 \pm 1$	Block 2; area $\sim 10 \times 10$ ft
B4A	0-6	23 at 1 m <u>42 at surface</u> 44 at depth of 6 in.	$150 \pm 4$	Block 1
B4B	6-12	23 at depth of 12 in.	$25 \pm 1$	Same as B4A
B5A	0-6	32 at 1 m <u>57 at surface</u> 57 at depth of 6 in.	$140 \pm 4$	Block 2
B5B	6-12	32 at depth of 12 in.	$6 \pm 1$	Same as B5A
B6A	0-6	92 at 1 m <u>860 at surface</u> 690 at depth of 6 in.	$9000 \pm 400$	Block 3
B6B	6-12	278 at depth of 12 in.	$680 \pm 30$	Same as B6A
B6C	12-18	117 at depth of 18 in.	$85 \pm 3$	Same as B6A
B7	0-6	23 at 1 m <u>32 at surface</u>	$45 \pm 3$	Boundary Block 3 and 4

Table 4.1. Concentrations of  $^{137}\text{Cs}$  in soil (B) and vegetation (V) samples collected at the 0816 site

Sample ID	Sample depth (in.)	Gamma exposure rate ( $\mu\text{R/h}$ )	$^{137}\text{Cs}^a$ (pCi/g dry wt)	Comments
B8A	0-6	23 at 1 m <u>125 at surface</u> 74 at depth of 6 in.	1750 $\pm$ 34	Block 2
B8B	6-12	35 at depth of 12 in.	4.3 $\pm$ 0.6	Same as B8A
B9A	0-6	<u>520 at surface</u> 600 at depth of 6 in.	2300 $\pm$ 40	Block 8
B9B	6-12	220 at depth of 12 in.	280 $\pm$ 3	Same as B9A
B9C	12-18	57 at depth of 18 in.	45 $\pm$ 3	Same as B9A
B10A	0-6	<u>45 at surface</u> 60 at depth of 6 in.	220 $\pm$ 3	Block 8
B10B	6-12	35 at depth of 12 in.	10.5 $\pm$ 0.3	Same as B10A
B10C	12-18	23 at depth of 18 in.	3.5 $\pm$ 0.3	Same as B10A
B11A	0-6	175 at 1 m <u>690 at surface</u> 810 at depth of 6 in.	4100 $\pm$ 340	Block 12
B11B	6-12	390 at 12 in.	540 $\pm$ 30	Same as B11A
B11C	12-18	120 at 18 in.	44 $\pm$ 3	Same as B11A
V1	NA <sup>b</sup>	c	16 $\pm$ 7	Block 3

<sup>a</sup>Analytical Procedure No. EPA-901.1.

<sup>b</sup>Not applicable.

<sup>c</sup>Soil gamma exposure rate 690  $\mu\text{R/h}$  at surface, 860  $\mu\text{R/h}$  at depth of 6 in., and 350  $\mu\text{R/h}$  at depth of 12 in.

## 5. SIGNIFICANCE OF FINDINGS

At the 0816 site, numerous hot spots ranging from 20 to 860  $\mu\text{R/h}$  were scattered generally more toward the north side of the site. Several large areas (totaling  $\sim 14,000 \text{ ft}^2$ ) of elevated surface gamma exposure rates (20 to 195  $\mu\text{R/h}$ ) were found north of the former contaminated enclosures. Typical background surface gamma exposure rates (10 to 16  $\mu\text{R/h}$ ) were found along the south fence except near the south entrance gate where a cluster of hot spots ranged from 20 to 175  $\mu\text{R/h}$ . Spotty contamination (with surface gamma levels ranging from 16 to 40  $\mu\text{R/h}$ ) was found up to the edge of the former contaminated enclosures where excavation and soil replacement had taken place. A marshy, drainage area paralleling the north fence for  $\sim 850 \text{ ft}$  also exhibited elevated surface gamma levels (16 to 40  $\mu\text{R/h}$ ). Most surface gamma levels were  $\leq 175 \mu\text{R/h}$ ; highest hot-spot measurements were 690 and 860  $\mu\text{R/h}$ .

One vegetation sample collected from a contaminated area contained elevated concentrations of  $^{137}\text{Cs}$  indicating that  $^{137}\text{Cs}$  may be present in other vegetation found in similar areas of the 0816 site. Soil samples collected at a range of surface gamma exposure rates contained  $^{137}\text{Cs}$  at concentrations of  $13 \pm 1$  to  $9000 \pm 400 \text{ pCi/g}$  (dry wt). Correlation of surface gamma exposure rates with  $^{137}\text{Cs}$  levels in surface soil indicated that at locations where gamma radiation levels were  $>40 \mu\text{R/h}$ , concentrations of  $^{137}\text{Cs}$  in surface soil were  $>120 \text{ pCi/g}$ . Therefore, it should be conservatively assumed that all locations with surface gamma exposure rates  $\geq 40 \mu\text{R/h}$  may have  $^{137}\text{Cs}$  concentrations  $>120 \text{ pCi/g}$ . Since surface gamma exposure rates at all six of the large areas and 75% of the discrete spots or small areas equaled or exceeded  $40 \mu\text{R/h}$ , soil  $^{137}\text{Cs}$  concentrations  $>120 \text{ pCi/g}$  can be assumed to be prevalent at this site.

These data can be used in any subsequent verification of cleanup actions at the 0816 site; however, subsurface sampling and analysis are necessary to fully evaluate the radiological status of the site.

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