ORISE
OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION
Managed by ORAU for the U.S. Department of Energy

October 19, 2011

Ms. Joy Sager
U.S. Department of Energy
Oak Ridge Office
P.O. Box 2001
Oak Ridge, TN 37831

SUBJECT: DOE CONTRACT NO. DE-AC0506OR23100
CHARACTERIZATION REPORT FOR STRONTIUM TITANATE IN SWSA 7 AND ADJACENT PARCELS IN SUPPORT OF THE NATIONAL PRIORITIES LIST SITE BOUNDARY DEFINITION PROGRAM, OAK RIDGE, TENNESSEE
DOE/OR/01-2548
DCN: 5102-SR-01-D1

Dear Ms. Sager:

Enclosed are thirteen hard copies and two PDF copies of the final report describing activities and results from characterizing the nature and extent of strontium titanate particle contamination in and around Solid Waste Storage Area 7. This final report includes results from similar studies conducted in 1995, 1997, and 1999. Please contact me at 865.574.0685 or Tim Vitkus at 865.576.5073 should you have any questions or require additional information.

Sincerely,

David A. King, CHP
Project Manager/Sr. Health Physicist
Independent Environmental
Assessment and Verification

DAK:fr

Enclosure

c: File/5102

electronic: R. Butler, CJE
T. Vitkus, ORISE
S. Roberts, ORISE

Telephone: 865.574.0685 **Fax: 865.241.3497** **E-mail: david.king@orau.org**
P.O. Box 117 | Oak Ridge, TN 37831 | www.orise.orau.gov

DOE/OR/01-2548

CHARACTERIZATION REPORT FOR STRONTIUM TITANATE IN SWSA 7 AND ADJACENT PARCELS IN SUPPORT OF THE NATIONAL PRIORITIES LIST SITE BOUNDARY DEFINITION PROGRAM OAK RIDGE, TENNESSEE

This document is approved for public release per review by:

David Hamrin 9/9/11
Public Information Officer Date
DOE/ORR Office of Public Affairs

THIS PAGE LEFT BLANK INTENTIONALLY

DOE/OR/01-2548

CHARACTERIZATION REPORT FOR STRONTIUM TITANATE IN SWSA 7 AND ADJACENT PARCELS IN SUPPORT OF THE NATIONAL PRIORITIES LIST SITE BOUNDARY DEFINITION PROGRAM OAK RIDGE, TENNESSEE

Prepared by

David A. King, CHP

Independent Environmental Assessment and Verification Program
Oak Ridge Institute for Science and Education
Oak Ridge, Tennessee 37831-0017

Prepared for the
U.S. Department of Energy

ISSUED OCTOBER 2011

This report is based on work performed by the Oak Ridge Institute for Science and Education under contract number DE-AC05-06OR23100 with the U.S. Department of Energy.

THIS PAGE LEFT BLANK INTENTIONALLY

APPROVALS

Sampling and Analysis Plan/Quality Assurance Project Plan for Characterization of Strontium Titanate in SWSA 7 and Adjacent Parcels, Oak Ridge, Tennessee

DOE/OR/01-2548

October 2011

Prepared by:

David A. King, Project Manager — 10-19-11 Date
Oak Ridge Institute for Science and Education

Paige Benton, Quality Assurance Specialist — 10-19-11 Date
Oak Ridge Institute for Science and Education

Erika Bailey, Deputy Survey Project Manager — 10-19-11 Date
Oak Ridge Institute for Science and Education

THIS PAGE LEFT BLANK INTENTIONALLY

CONTENTS

THIS PAGE LEFT BLANK INTENTIONALLY

FIGURES

TABLES

THIS PAGE LEFT BLANK INTENTIONALLY

ACRONYMS

cpm	counts per minute
DOE	U.S. Department of Energy
GPS	global positioning system
NIST	National Institute of Standards and Technology
ORISE	Oak Ridge Institute for Science and Education
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
QAPP	Quality Assurance Project Plan
SAP	Sampling and Analysis Plan
$SrTiO_3$	strontium titanate
SU	survey unit
SWSA	Solid Waste Storage Areas

THIS PAGE LEFT BLANK INTENTIONALLY

CHARACTERIZATION REPORT FOR STRONTIUM TITANATE IN SWSA 7 AND ADJACENT PARCELS IN SUPPORT OF THE NATIONAL PRIORITIES LIST SITE BOUNDARY DEFINITION PROGRAM OAK RIDGE, TENNESSEE

1. INTRODUCTION

The U.S. Department of Energy (DOE) Oak Ridge Office requested support from the Oak Ridge Institute for Science and Education (ORISE) contract to delineate the extent of strontium titanate ($SrTiO_3$) contamination in and around Solid Waste Storage Area (SWSA) 7 as part of the Oak Ridge National Priorities List Site boundary definition program. The study area is presented in Fig. 1.1 relative to the Oak Ridge Reservation (ORR). The investigation was executed according to Sampling and Analysis Plan/Quality Assurance Project Plan (SAP/QAPP) (DOE 2011) to supplement previous investigations noted below and to determine what areas, if any, have been adversely impacted by site operations.

In the 1960s, Oak Ridge National Laboratory (ORNL) developed an insoluble compound of Sr-90 to be used as a power source in weather stations, as well as navigational sonar and light beacons. Strontium titanate was produced in Bldg. 3517 in the ORNL main plant area. Waste from the process was stored in a lead-lined dumpster until it was transported to SWSA 5 in Melton Valley and dumped into trenches. The dumping process allowed particles to become airborne. These particles were presumably carried downwind and deposited on lands east of the High Flux Isotope Reactor (ORNL 1995, DOE 2000).

Between June 1994 and June 1995, a radiological investigation was performed at the SWSA 7 site by the Measurement Applications and Development Group of ORNL. Results of the investigation were included in a report to the ORNL Waste Management and Remedial Action Division (ORNL 1995). The approach included surveys of 42 10-ft × 10-ft plots in SWSA 7. The soils within each plot were surveyed from the 0- to 6-inch depth interval using a Geiger-Mueller detector. Ten additional plots outside of SWSA 7 were investigated using the same method in 1997 (ORNL 1997). A large number of strontium titanate particulates were identified during both the 1995 and 1997 efforts.

An off-ORR investigation was conducted in June 1999 at two 328-ft × 328-ft (100-m × 100-m) plots in the Gallaher Bend area near the intersection of West Gallaher Ferry Road and Manning Lane. This study area is across the Bearden Branch Embayment and Clinch River as shown in Fig. 1.1. Three composite samples were collected from each plot, with each composite containing soils from 31 6-inch cores. No significant Sr-90 concentrations were encountered (DOE 2000).

Results from the 1995, 1997, and 1999 investigations are considered in this report.

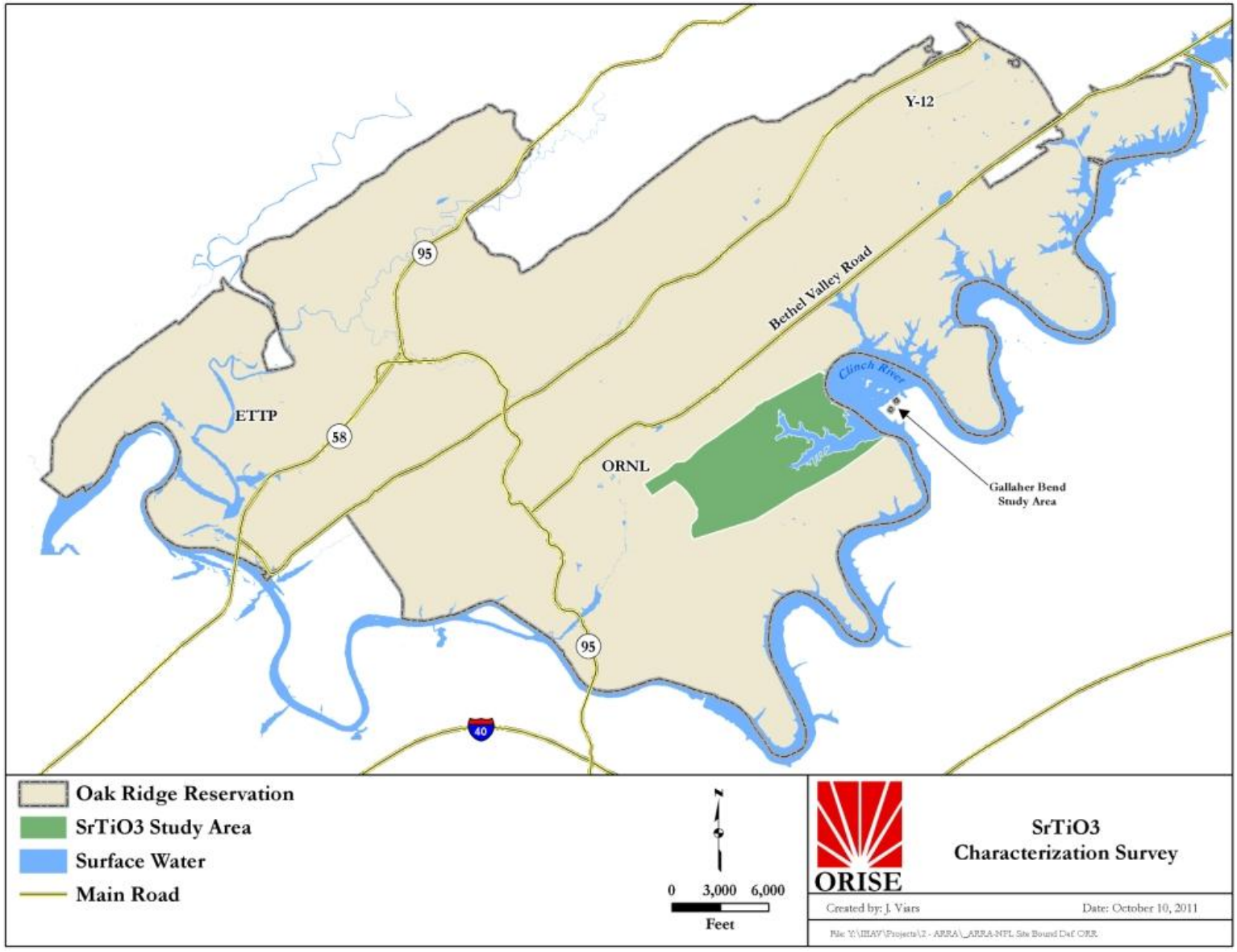

Fig. 1.1. Strontium titanate characterization study area location map.

2. METHOD

2.1 GENERAL SURVEY DESIGN

The overall study area of approximately 1400 acres is bound on the north by the crest of Haw Ridge, the south by Copper Ridge, the west by the Melton Valley Record of Decision boundary, and the east by the Bearden Creek Embayment and the Clinch River. A 328-ft (100-m) interval square grid was overlaid across the study area using a random start point and producing a total of 547 grid intersections of nodes spread across 10 survey units (SUs). Of these 547 nodes, 144 fall within the 314 acre primary study area shown in Fig. 2.1. The primary study area is split into two survey units (SU-1 and SU-2) that contain the strontium titanate particle contamination documented in ORNL 1995 plus a buffer expected to define the extent of contamination. The balance (or secondary area) of 1083 acres contains 403 nodes split across SU-3 through SU-10, representing an area less likely but still plausibly contaminated by the release event. Fifty-five of the secondary nodes were randomly selected for scanning using Visual Sampling Plan software, Version 6, and the criteria described in DOE 2011. The first particle identified per SU was collected, for a possible maximum of ten samples (one per SU). Figures 2.2, 2.3, and 2.4 illustrate the location of final grid nodes as executed.

2.2 NODE SURVEY METHOD

Per the ORNL 1995 recommendations, each node-specific investigation covered a 10.8-ft^2 (1-m^2) area to a maximum depth of 6 inches. Scans were performed at the ground surface (after raking away leaf litter), and at 2-in., 4-in., and 6-in. depth intervals. Removed soil was placed bottom-side-up on plastic sheeting and scanned along with the newly exposed soil surface. Soils were placed back into the hole upon survey completion.

Beta radiation scans were completed using Ludlum Model 43-68 gas proportional detectors connected to Ludlum Model 2221 ratemeter/scalers. Scans were performed using audible output after soil surfaces were hand-leveled to maximize the geometry and detection capabilities. The detector response, depth, and relative location of each particle identified were recorded on a survey form found in Appendix B of the SAP/QAPP.

2.3 SAMPLE AND ANALYTICAL METHODS

When sampled, a small volume of soil containing the strontium particles was placed in a plastic bag, maintained under chain of custody, and submitted to the ORISE radioanalytical laboratory for total radioactive strontium analysis. Particles were isolated in the laboratory to the extent possible, though some unknown volume of soil was dissolved with the matrixed strontium particle. The analytical method was modified from CHEM-TP-SR.1 (1998) from the DOE Radiological and Environmental Laboratory to include total dissolution of strontium titanate particles contained in soil. The method has been tested against several samples traceable to the National Institute of Standards and Technology (NIST), including source number MAPEP-10-Ma-S22 administered from DOE oversight. The method has been used for over 15 years by the ORISE analytical laboratory with over 98% acceptance from performance evaluation samples, has been applied to samples distributed by NIST, and is American National Standards Institute N42.22 traceable.

The Oak Ridge Sample Management Office will verify and validate the single submitted data package using approved procedures, as described in Sects. 8.2 and 8.3, respectively, of the SAP/QAPP (DOE 2011). No results were rejected as of the delivery of this D1 report.

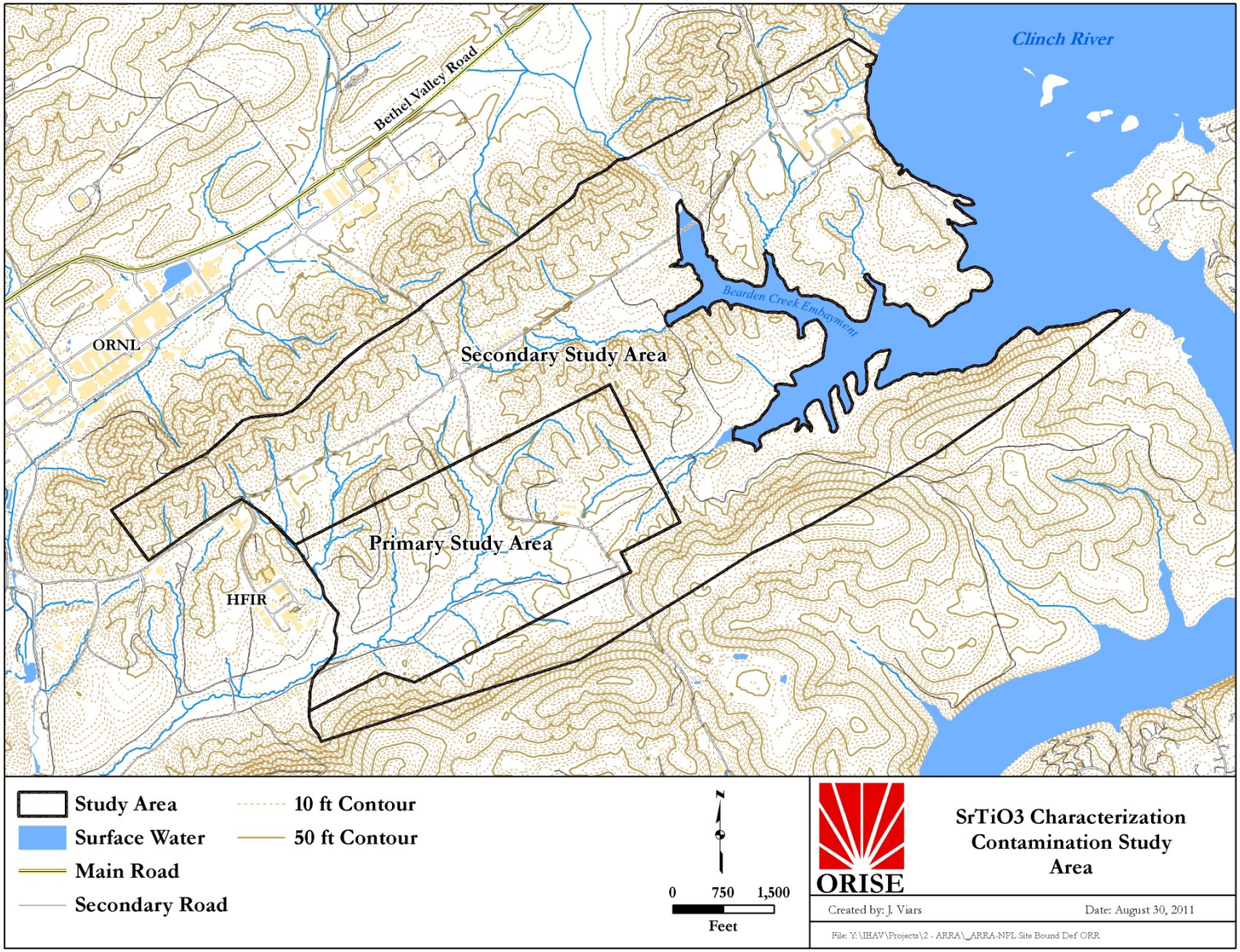

Fig. 2.1. Location of the strontium titanate characterization study area.

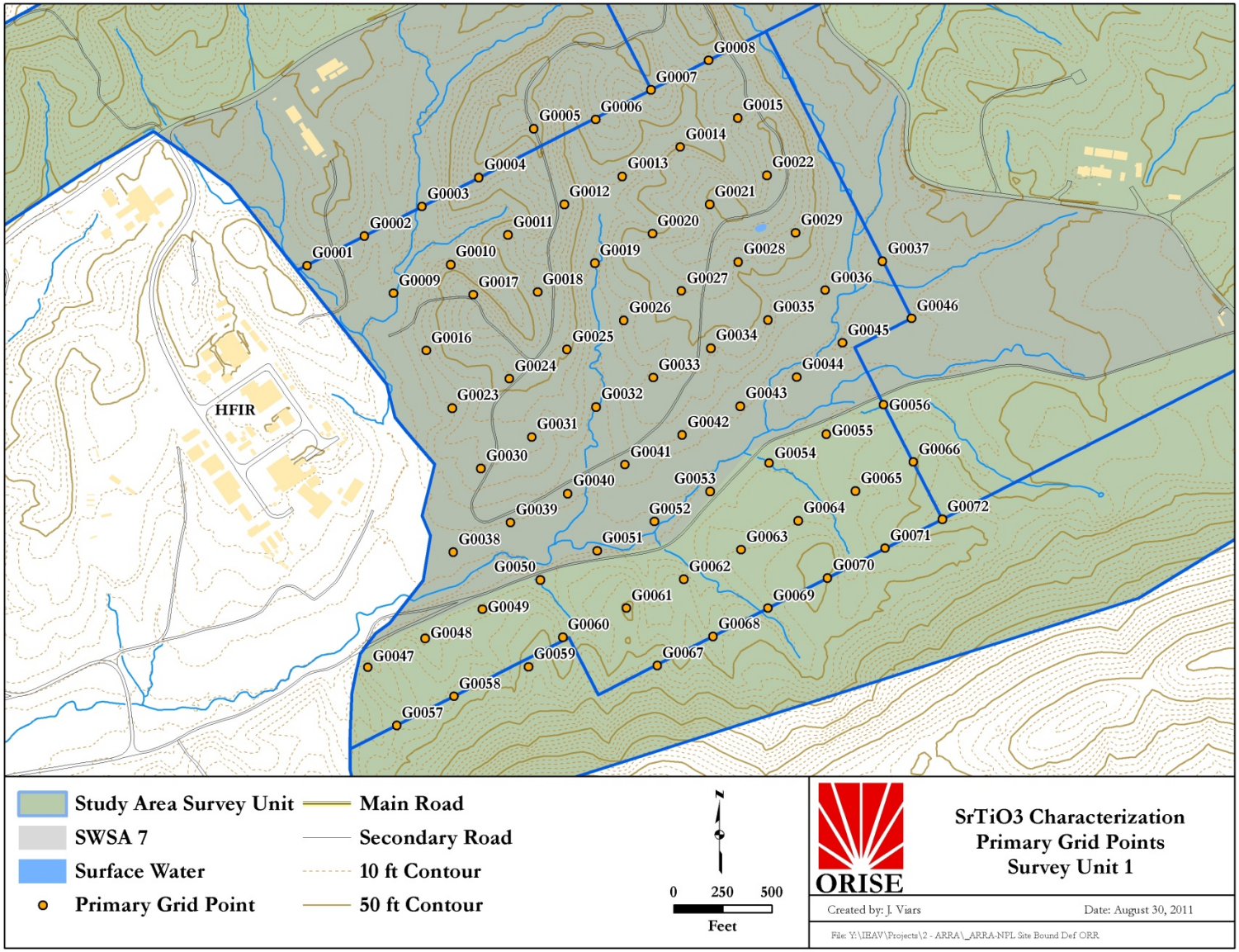

Fig. 2.2. Survey Unit 1 grid nodes.

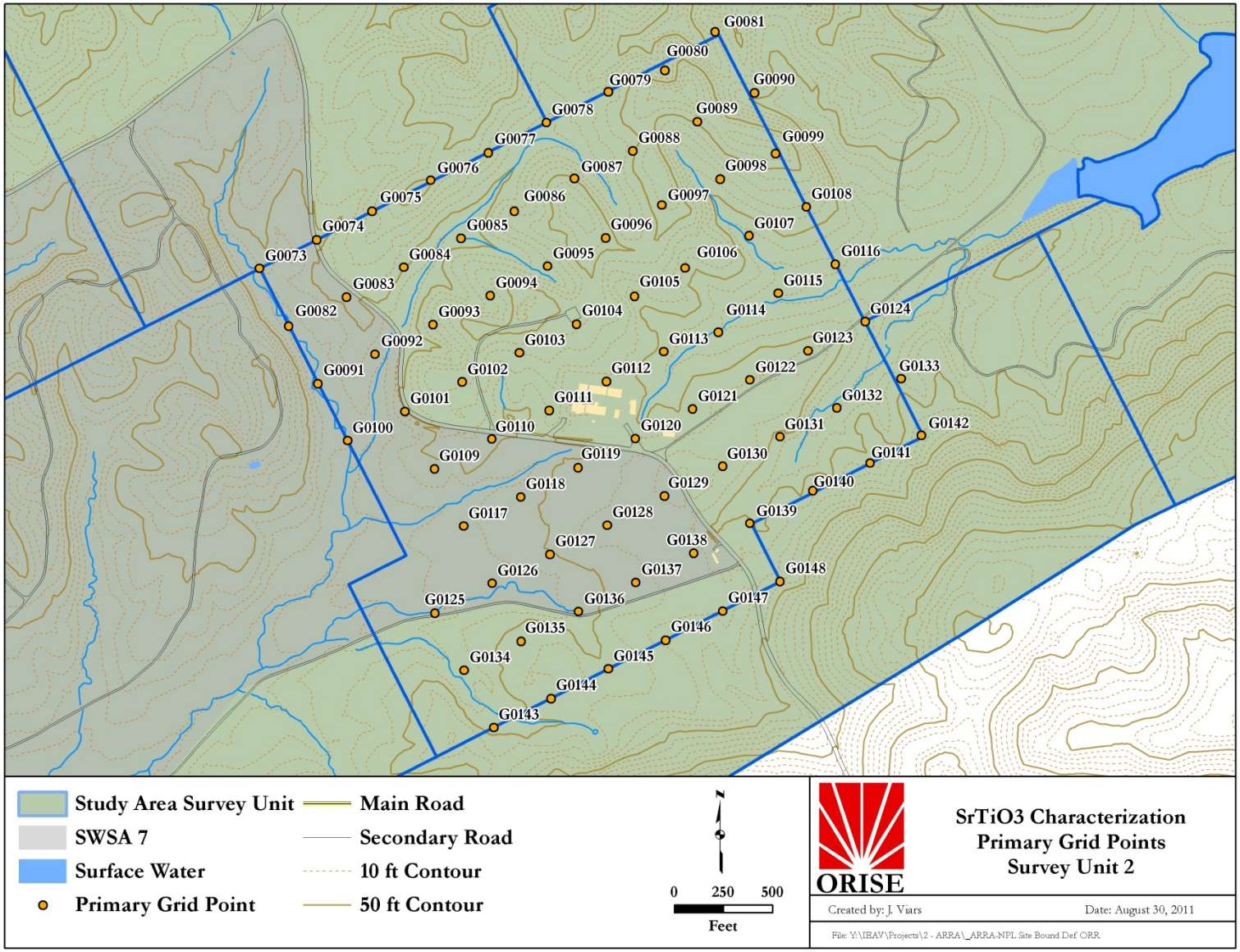

Fig. 2.3. Survey Unit 2 grid nodes.

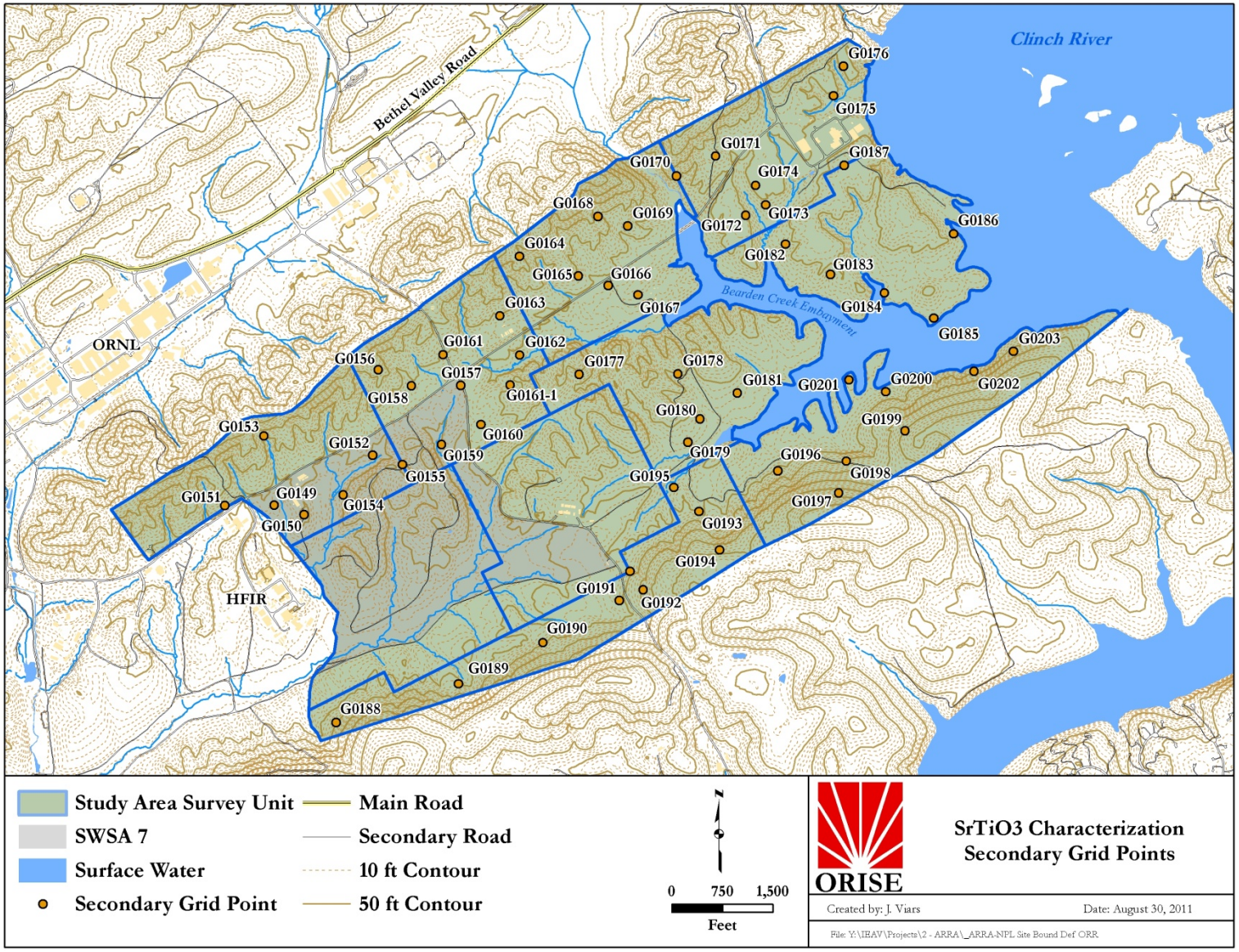

Fig. 2.4. Survey Unit 3-10 grid nodes.

THIS PAGE LEFT BLANK INTENTIONALLY

3. CHARACTERIZATION RESULTS

3.1 SURVEY RESULTS

Table 3.1 lists grid nodes where particles were identified, the depth interval in which the particle was found, the corresponding detector response, and the associated sample identification number (if applicable). A total of 24 particles were identified in three SUs and at 18 grid nodes. Survey Unit 1 contained the most particles with 12, SU-2 produced 11, and SU-7 produced only 1. Grid node G0123 in SU-2 produced the most particles with 5 and the particle on G0115, also in SU-2, produced the maximum detector response at 6939 counts per minute (cpm).

The most particles were found in the 2-in. interval with nine followed closely by the surface interval with eight. Five particles were found at the 4-in interval and two were found at the 6-in. interval. These findings parallel the 1995 study.

Most particles were found along a northeastern trajectory running in a relative depression between ridges. This is expected given the transport mechanisms. Airborne particles would likely travel with the wind along low-lying areas where air resistance is minimal. There is spatial correlation (based on visual inspection) between the 2011, 1997, and 1995 investigations, though the 1995 investigation identified a significant number of particles in the eastern-most finger of SWSA 7 while the 2011 investigation did not. This could be because the 1995 nodes covered 100 ft^2 (9.3 m^2) at biased locations while the 2011 nodes covered only 10.8 ft^2 (1 m^2) on a systematic grid with random start. In either case the investigations identified highly radioactive strontium titanate particles in SWSA 7 and, in the case of the 2011 and 1997 efforts, in adjacent parcels. Figure 3.1 presents combined results from the 1995, 1997, and 2011 efforts with the number of particles shown per 100 ft^2. Note only nodes with identified particles are shown and the 2011 results are converted from particles per 10.8 ft^2 (1 m^2) to 100 ft^2 (9.3 m^2) for consistency.

Table 3.1. Strontium titanate survey results by survey unit and grid node

Survey	Grid	Number	Detector Response by Depth Interval (cpm)				Sample
Unit	Node	Particles	Surface	2-in.	4-in.	6-in.	Number
1	G0006	1				1737	
	G0009	1				1400	
	G0033	1			1020		
	G0037	1	1662				
	G0038	1		3538			M0001
	G0039	1		1565			
	G0040	1		1326			
	G0044	2	1259	1390			
	G0053	1			966		
	G0054	1	1111				
	G0061	1	1961				
2	G0095	1		2132			
	G0113	1	2202				
	G0115	1	6939				
	G0122	2		1370	1237		M0002[a]
	G0123	5	1408	1538 & 1007	994 & 1696		
	G0124	1		1493			
7	G0178	1	2800				
Totals	**18**	**24**	**8**	**9**	**5**	**2**	**2**

[a]Sample collected from the 2-in. interval

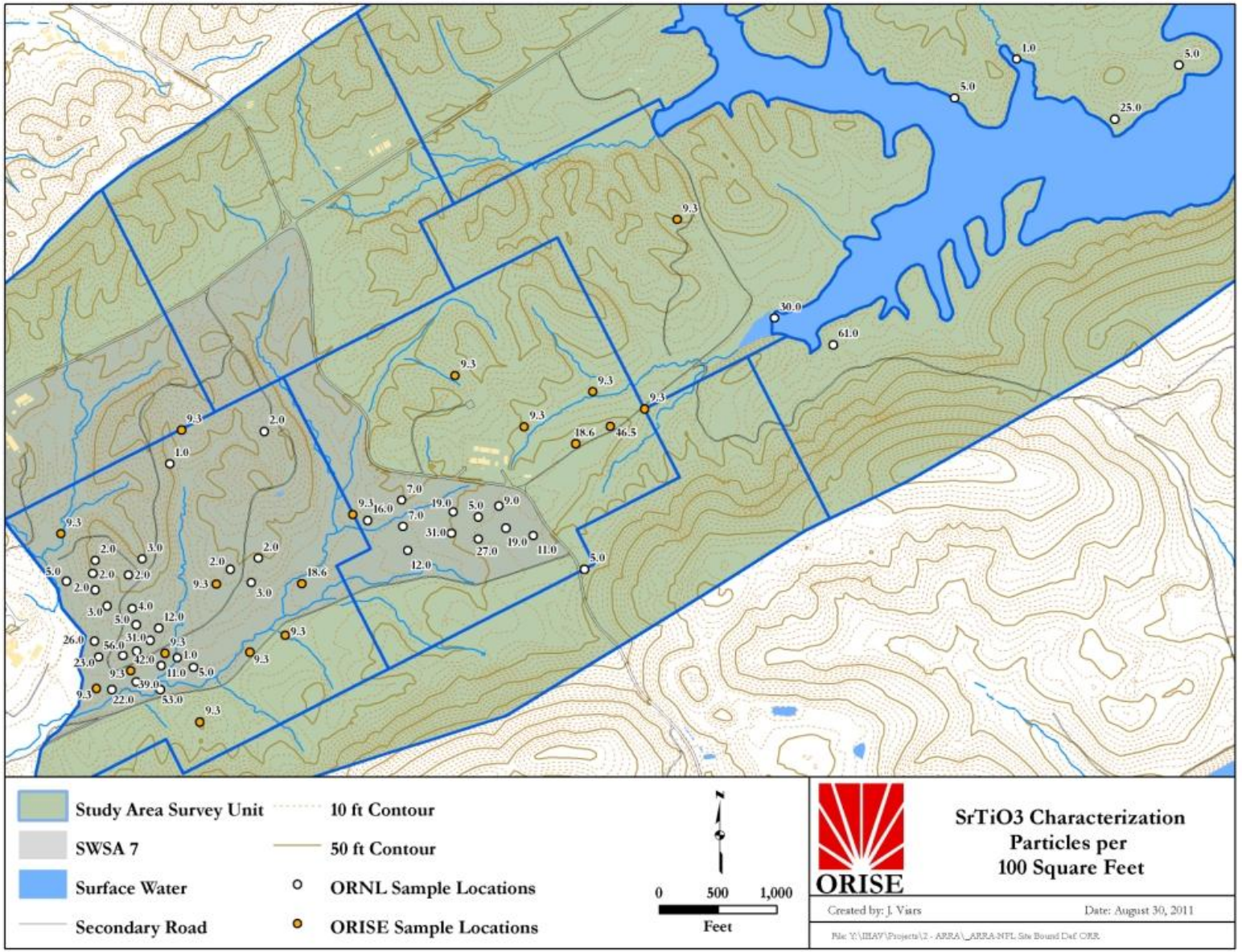

Fig. 3.1. Survey unit strontium titanate particle distribution.

No particles were encountered east of 2011 investigation nodes G0124 and G0178, suggesting particles depositions were limited to the ORR. This is consistent with findings from the 1999 effort which concluded no particles reached beyond the Bearden Creek Embayment to public lands (DOE 2000).

3.2 ANALYTICAL RESULTS

Two samples were submitted for analysis: M0001 from Station G0038 in SU-1, and M0002 from station G0122 in SU-2. The 43-68 response for M0001 was 3538 cpm and the analytical result is 7320 ± 210 pCi/sample. The 43-68 response for M0002 was 1370 cpm and the analytical result is 841 ± 25 pCi/sample. The mass of each particle could not be determined as the strontium titanate particles are matrixed into the soil. However, the total particle masses are a small fraction of a gram (about the size of a grain of salt) and concentrations are likely in the tens of thousands of pCi/g or higher. This is consistent with findings documented in ORNL 1995 with a reported concentration of 73,000 pCi/g. ORNL 1997 reports a Sr-90 concentration of 220 pCi/g in a composite soil sample.

3.3 FIELD CHANGES AND UNCERTAINTIES

3.3.1 Issues Related to the Execution of a Draft Plan

Due to a protracted review cycle, fieldwork was conducted with regulatory and DOE approval using the draft (D0) SAP/QAPP. Between the original draft submission in April and the final approval in July the location of several grid nodes were moved. This resulted in the field crew surveying one additional node in SU-4 (G0161), bringing the total number of nodes to 204. Additionally, four nodes were added between D0 to D1 SAP/QAPP versions. These complicating factors resulted in some duplicate effort by the field crew to assure final nodes identification numbers match the final (D1) SAP/QAPP.

3.3.2 Overhead Interferences

The thick leaf canopy, combined in some areas with interferences along steep elevation gradients, often limited the function of global positioning system (GPS) equipment. Field crews, therefore, had frequent difficulty locating preselected grid node locations. Additional crews were deployed to stake nodes ahead of surveys until new GPS units, less sensitive to overhead interferences, were procured.

3.3.3 Particle Collection

The first and only particle found at node G0178 of SU-7 (see Fig. 2.4) produced a detector response of 2800 cpm. Surveyors attempted to collect the particle as M0007, but in disturbing the soils during sampling, lost contact with the particle. The elevated response could not be repeated and, ultimately, the sample was not collected.

3.3.4 Relocation of Some Grid Nodes

Several node locations were moved slightly off grid. These adjustments were terrain driven or necessary because the location fell in an inaccessible location (fallen tree, creek, etc.). The field team was also instructed to move nodes, if necessary, onto undisturbed soils. The objective was to conduct surveys over soils that might have been exposed in the 1960s when the release occurred. Therefore, field crews would move, for example, from a built-up road embankment to just inside the nearest tree line. As mentioned and as shown on Fig. 2.4, node G0161 was surveyed using coordinates presented in D0 SAP/QAPP. Node G0161-1 was surveyed to match the final (D1) SAP/QAPP.

3.3.4 Particle Depth Intervals

Soils could not be lifted in perfect 2-in sheets and laid out intact for surveys because shovels were used and soils often crumbed in the hole or on the plastic sheeting. This added uncertainty to the depth interval estimate to which the particle was assigned. It is possible, for example, that a microscopic particle encountered at the 6-in. interval was originally in a clump of dirt in the 2-in. to 4-in. lift.

4. CONCLUSIONS

Strontium titanate particles were identified at 18 grid node locations, most notably in a line running along the southern half of SWSA 7 toward the Bearden Creek Embayment. A small number of particles were discovered off this trajectory but at a limited frequency. Individual particles are highly dispersed and microscopic, but exhibit activity levels on the order of thousands of pCi. These results, combined with those from efforts in 1995 and 1997, lead to the conclusion that a large swath of land at least from the western SWSA 7 boundary and extending to the edge of the ORR is adversely impacted by the circa 1960s strontium titanate release.

5. REFERENCES

DOE (U.S. Department of Energy) 2000. *Radiological Assessment for Potential Exposure to Strontium Titanate (SrTiO) in ORNL Off-Site Soils,* January.

DOE 2011. *Sampling and Analysis Plan/Quality Assurance Project Plan for Characterization of Strontium Titanate in SWSA 7 and Adjacent Parcels, Oak Ridge, Tennessee,* DOE/OR/01-2518&D1, prepared by Oak Ridge Associated Universities for the Office of Environmental Management, July.

ORNL (Oak Ridge National Laboratory) 1995. *Surface Radiological Investigations at the Proposed SWSA 7 Site, Oak Ridge National Laboratory, Oak Ridge, Tennessee*, ORNL/TM-13039, August.

ORNL 1997. "Results of the Strontium Particle Plot Surveys in the Melton Valley Area," memorandum from Michael E. Murphy to Elizabeth A. Krispin, October 2.