







ESOP

Environmental Surveillance and Oversight Program

2013 DATA REPORT

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South Carolina Department of Health and Environmental Control

CR-004111 3/15

Introduction

The South Carolina Department of Health and Environmental Control's (SCDHEC) Environmental Surveillance and Oversight Program (ESOP) supports and complements SCDHEC's comprehensive regulatory program at the Savannah River Site (SRS) by focusing on those activities not supported or covered through our normal regulatory framework. The primary function of the ESOP is to evaluate the effectiveness of SRS monitoring activities. To accomplish this function, the ESOP conducts non regulatory monitoring activities on and around the SRS, conducts evaluations of the SRS monitoring program and provides an independent source of information to the public pertaining to levels of contaminants in the environment from historical and current SRS operations.

This report includes a description of the ESOP's multi-media monitoring network and activities along with a summary of the findings of the ESOP from the 2013 calendar year monitoring period.

Table of Contents

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Section 1 2013 Air Monitoring

Chapter 1 Radiological Atmospheric Monitoring

2013 Radiological Atmospheric Monitoring On and Adjacent to the Savannah River Site

Environmental Surveillance and Oversight Program

97AA007

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Table of Contents

1.0 PROJECT SUMMARY

Atmospheric transport has a significant potential to impact the citizens of South Carolina from releases associated with activities at the Savannah River Site (SRS). This project provides independent quantitative monitoring of atmospheric radionuclide releases associated with the SRS. This provides monitoring of atmospheric media on a routine basis to measure radionuclide concentrations in the surrounding environment and to identify trends that may require further investigation. Radiological atmospheric monitoring sites were established to provide spatial coverage of the project area.

The South Carolina Department of Health and Environmental Control (SCDHEC) Environmental Surveillance and Oversight Program (ESOP) air monitoring capabilities in 2013 included eight air-monitoring stations with the capacity for sample collection using glass fiber filters, rain collection pans, silica gel columns, and 19 thermoluminescent dosimeters (TLDs). Five of the air-monitoring stations are on or within two miles of the SRS perimeter; New Ellenton (NEL), Jackson (JAK), Allendale Barricade (ABR), South Carolina Advanced Technology Park in Snelling (SCT), and Dark Horse at the Williston Barricade (DKH); one at the center of the site, Burial Grounds North (BGN); and two are within 25 miles of the site - Aiken (AIK) and Allendale (ALN). Thirteen of the TLDs are on or near the site perimeter, one is in the center of the site, and five are within 25 miles of the site in surrounding population centers. Only perimeter air monitoring stations and TLDs are used for comparison to SRS data. Refer to Map 1 in Section 4.0 for specific monitoring locations.

The glass fiber filters were used to collect total suspended particulates (TSP). Particulates were screened weekly for gross alpha and gross beta-emitting activity. Precipitation, when present, was sampled and analyzed monthly for tritium. Silica gel distillates of atmospheric moisture were analyzed monthly for tritium. TLDs were collected and analyzed every quarter for ambient beta/gamma levels. SCDHEC emphasizes monitoring for radionuclides in atmospheric media around the SRS at potential public exposure locations.

SCDHEC data substantiated historically reported Department of Energy-Savannah River (DOE-SR) values for radionuclides in the ambient environment at or near the SRS boundary. Average DOE-SR atmospheric radiological monitoring results for gross alpha/beta in air, ambient beta/gamma, and tritium in precipitation at the SRS boundary were within two standard deviations of the SCDHEC reported average values. Variations in atmospheric radiological monitoring results between SCDHEC and DOE-SR are likely a result of differences in monitoring locations, local meteorological conditions, frequency of sampling, and number of locations. Reported differences are for regional background levels and present no difference with regard to the impact on public health.

In summary, no United States Environmental Protection Agency (USEPA) air standards were exceeded at the monitored locations. Sampling results by SCDHEC indicate that SRS activities had a measurable but negligible impact on local air quality.

2.0 RESULTS AND DISCUSSION

Total Suspended Particulates

Gross Alpha

During the 2013 sampling period, gross alpha activity ranged from less than the lower limit of detection (<LLD) to 0.0054 picocuries per cubic meter (pCi/m^3) at the site perimeter (NEL, JAK, ABR, SCT, and DKH). The maximum gross alpha detection was collected on October 1 at the SCT air station. Values in this range are typically associated with naturally occurring alpha-emitting radionuclides, primarily as decay products of radon, and are considered normal (Kathren 1984). The SCDHEC average gross alpha radionuclide concentration in 2013 was 0.0018 (± 0.0009) pCi/m^3. The DOE-SR gross alpha average of 0.0010 (± 0.0004) pCi/m^3 is within one standard deviation of the SCDHEC gross alpha activity average (SRNS 2014). Section 5.0, Figure 1 shows average gross alpha activity for SRS perimeter locations and illustrates trending of gross alpha values for SCDHEC and DOE-SR. Figures 6-8 show SCDHEC 2013 trending.

Gross Beta

During the 2013 sampling period, the site perimeter (NEL, JAK, ABR, SCT, and DKH) gross beta concentrations ranged from 0.0085 to 0.0421 pCi/m^3. The maximum gross beta detection was collected on February 20 at the JAK air station. The average gross beta concentration reported by SCDHEC in 2013 was 0.0223 (± 0.0077) pCi/m^3. Section 5.0, Figures 6 - 11 show SCDHEC trending for 2013 for both gross alpha and gross beta. Values in this range are typically associated with naturally occurring beta-emitting radionuclides, primarily as decay products of radon (Kathren 1984). Small seasonal variations at each monitoring location have been consistent with historically reported SCDHEC values (SCDHEC 2012). The USEPA Office of Radiation and Indoor Air uses gross beta counts as an indicator to determine if additional analyses will be performed. A gamma scan is conducted if the gross beta activity exceeds 1 pCi/m^3 (USEPA 2013). This tiering of definitive analyses is used for all total suspended particulate sampling associated with RadNet. RadNet is comprised of a nationwide network of sampling stations that identify trends in the accumulation of long-lived radionuclides in the environment (USEPA 2005). The DOE-SR gross beta average of 0.0126 (± 0.0047) pCi/m^3 is within two standard deviations of the SCDHEC gross beta activity average (SRNS 2014). Section 5.0, Figure 2 shows average gross beta activity for the SRS perimeter locations and illustrates trending of gross beta values for SCDHEC and DOE-SR. Figures 9-11 show SCDHEC 2013 trending.

Gamma

First quarter glass fiber filters were also scanned weekly for gamma emitting radionuclides. No non-naturally occurring radionuclides were detected.

Radiochemical Particulate Data

First quarter glass fiber filters were composited and analyzed for plutonium 238 (Pu-238) and 239/240 (Pu-239/240). The DKH air station had detections of both Pu-238 at 0.000017 (±

0.000013) pCi/m^3, and Pu-239/240 at 0.000046 (± 0.000021) pCi/m^3. Both detections are below regulatory limits (ANL 2007).

Ambient Beta/Gamma

SCDHEC conducts ambient beta/gamma monitoring through the deployment of TLDs around the perimeter of the SRS. Ambient beta/gamma levels measured with TLDs are provided for all quarters of 2013. It should be noted that 4 millirem (mrem) are subtracted from the reported result for each TLD to account for the transcontinental flight from South Carolina to California and back (Walter 1995). During the 2013 sampling period, total combined quarterly ambient beta/gamma ranged from 61 to 107 mrem at the site perimeter. The maximum ambient beta/gamma detection was collected at the US 278 at Upper Three Runs Creek location (TLD-17). The SCDHEC average ambient beta/gamma activity for perimeter TLDs in 2013 was 84.15 (±13.09) mrem. The DOE-SR average ambient beta/gamma activity was 86.73 (± 9.10) mrem for 2013 (SRNS 2014). The DOE-SR ambient/beta gamma average was within one standard deviation of the SCDHEC average. During the sampling period, SCDHEC external radiation levels at monitored locations were slightly lower than levels reported by DOE-SR. Over the past six years, there have been no major increases or decreases in the average ambient beta/gamma activity reported by DOE-SR or SCDHEC. Section 5.0, Figure 3 shows trends at the SRS perimeter for averaged ambient beta/gamma values for DOE-SR and SCDHEC.

Tritium

Tritium continues to be the predominant radionuclide detected in the perimeter samples. During 2013, DOE-SR released approximately 24,300 Ci of tritium from SRS (SRNS 2014). Most of the tritium detected in SCDHEC perimeter samples may be attributed to the release of tritium from tritium facilities, separation areas, and from diffuse and fugitive sources (SRNS 2014).

Tritium In Air

Tritium in air values reported by SCDHEC are the result of using the historical method of calculating an air concentration of tritium based on the upper limit value of absolute humidity (11.5 grams of atmospheric moisture per cubic meter) in the geographic region (NCRP 1984). SCDHEC tritium results greater than the LLD are then converted from picocuries per liter (pCi/L) to pCi/m^3 using the formula:

$$\text{pCi/L} = \frac{\text{pCi/ml}(11.5)}{1000} = \text{pCi/m}^3$$

During the 2013 sampling period, tritium in air ranged from <LLD to 15.20 pCi/m^3. The maximum perimeter tritium in air activity was collected at the SCT air station in February. The SCDHEC average measured activity for tritium in air was 4.62 (± 2.52) pCi/m^3. The SCDHEC average for tritium activity was well below the USEPA equivalent yearly average standard of 20,000 pCi/m^3 for airborne tritium activity (ANL 2007). The DOE-SR average measured value for tritium activity in air at the SRS perimeter was 16.59(± 14.47) pCi/m^3 (SRNS 2014). DOE-SR average measured values for tritium in atmospheric moisture were higher than SCDHEC average measured values for the SRS perimeter (SRNS 2014). The DOE-SR average measured activity for tritium was within one standard deviation of the SCDHEC measured average. This difference may be attributed to a dilution that occurs when desiccants are used for collecting

atmospheric moisture for tritium analysis. Prior to deployment in the field, silica-gel desiccant is dried to remove any moisture. However, a small percentage of water remains in the desiccant. This results in a slight dilution of the collected sample, which is reflected in the distillate. Another factor that may contribute to the lower SCDHEC air tritium values is that only two of the monitoring stations are exactly on the SRS perimeter (property line); while the other three points used for this comparison are located in population centers, approximately two miles from the SRS property line.

Average DOE-SR tritium in air activity was higher than the SCDHEC measured activity but well within the same order-of-magnitude. These variations could be caused by different sampling locations, number of locations, or sample frequency.

Average tritium in air activity at the SRS perimeter reported by SCDHEC for 2013 was higher than reported in 2012 and has fluctuated over the last six years. DOE-SR also reported a slight increase from 2012 to 2013 with fluctuations over the past six years. Section 5.0, Figure 4 illustrates trending of atmospheric tritium activity for SCDHEC and DOE-SR as measured and calculated at the SRS perimeter. Section 5.0, Figures 12-14 show SCDHEC 2013 trending.

Tritium In Precipitation

During the 2013 sampling period, tritium in precipitation ranged from <LLD to 346.02 pCi/L. The maximum reported value for SCDHEC perimeter locations was collected at the JAK air station in July. The SCDHEC average measured activity for tritium in precipitation was 279.64 (± 56.39) pCi/L. The DOE-SR average measured value for tritium activity in precipitation at the SRS perimeter was 747.29 (± 803.12) pCi/L (SRNS 2014). The SCDHEC and DOE-SR averages for tritium activity were well below the USEPA standard of 20,000 pCi/L in drinking water (USEPA 2002). The DOE-SR averages for tritium activity were within one standard deviation of the SCDHEC average. Section 5.0, Figure 5 shows average tritium in precipitation activity for SRS perimeter locations and illustrates trending tritium in precipitation values for SCDHEC and DOE-SR. Section 5.0, Figures 15 - 17 show trending for 2013 for SCDHEC.

3.0 CONCLUSIONS/RECOMMENDATIONS

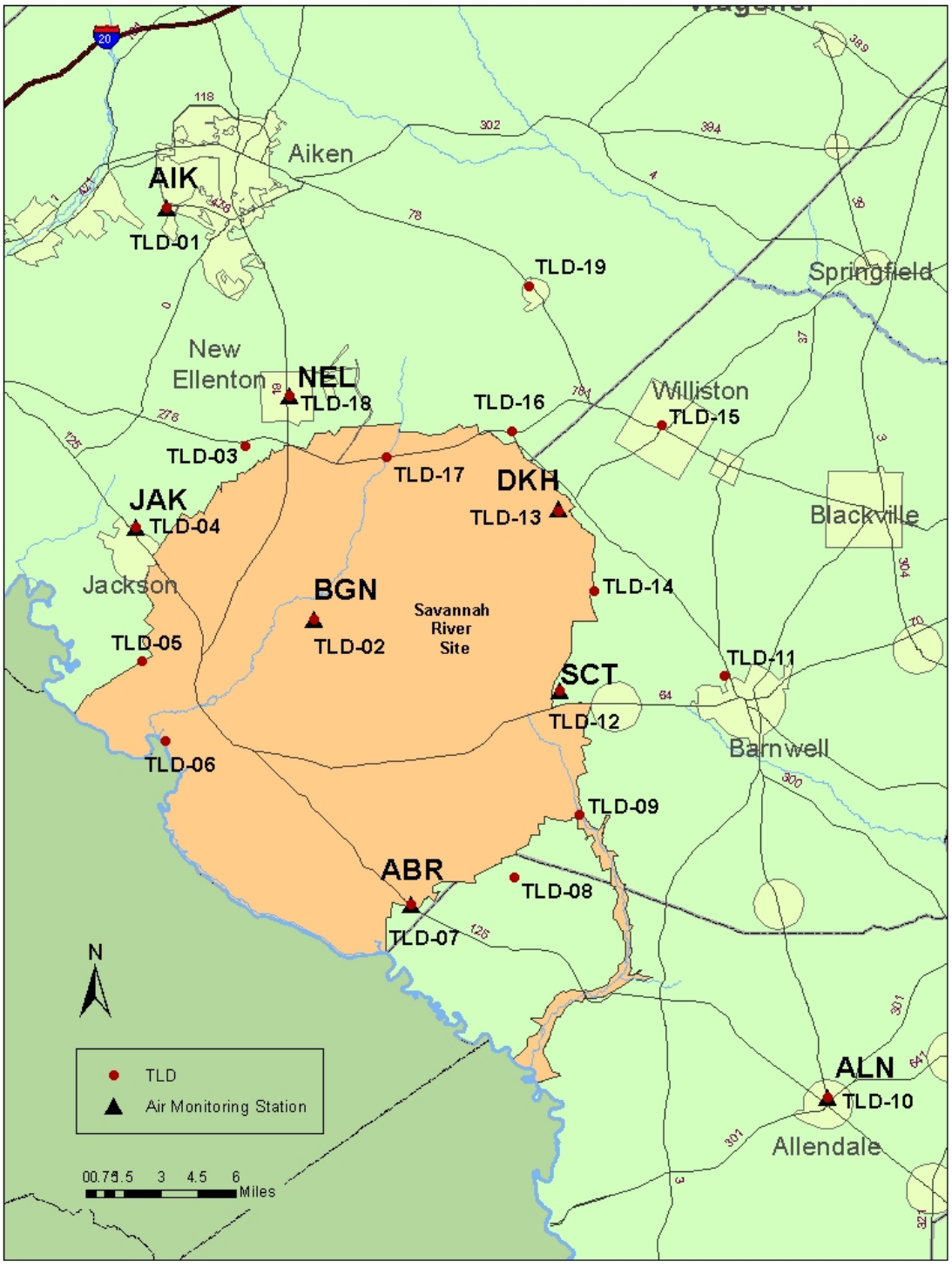
All SCDHEC data collected in 2013 confirmed historically reported DOE-SR values for gross alpha/beta, ambient beta/gamma and tritium in the environment at the SRS boundary, with no anomalous data noted for any monitored parameters.

Even with the variability of environmental data and sampling frequencies, DOE-SR gross alpha/beta in air, tritium in precipitation, tritium in air, and ambient beta/gamma averages were within two standard deviations of SCDHEC measured averages.

No USEPA air standards were exceeded at the monitored locations. Sampling results by SCDHEC indicate that SRS activities did have a measurable but negligible impact on local air quality.

Due to continued releases from site facilities (tritium facilities, separations areas, etc.), SCDHEC will continue to collect weekly TSP for gross alpha/beta, monthly for atmospheric and precipitation tritium, and quarterly ambient beta/gamma samples.

4.0 MAP
2013 ESOP RADIOLOGICAL ATMOSPHERIC MONITORING LOCATIONS



5.0 TABLES AND FIGURES

2013 Radiological Atmospheric Monitoring On and Adjacent to SRS

Table 1. SCDHEC and DOE-SR Sample Frequency Comparison

Sample Frequency		
	SCDHEC	DOE-SR
Total Suspended Particulates	Weekly	Bi-weekly
Precipitation	Monthly	Bi-weekly
Atmospheric Moisture	Monthly	Monthly
Thermoluminscent Dosimeters	Quarterly	Quarterly

Figure 1. DOE-SR and SCDHEC Comparison of Average Gross Alpha For Total Suspended Particulates at the SRS Perimeter

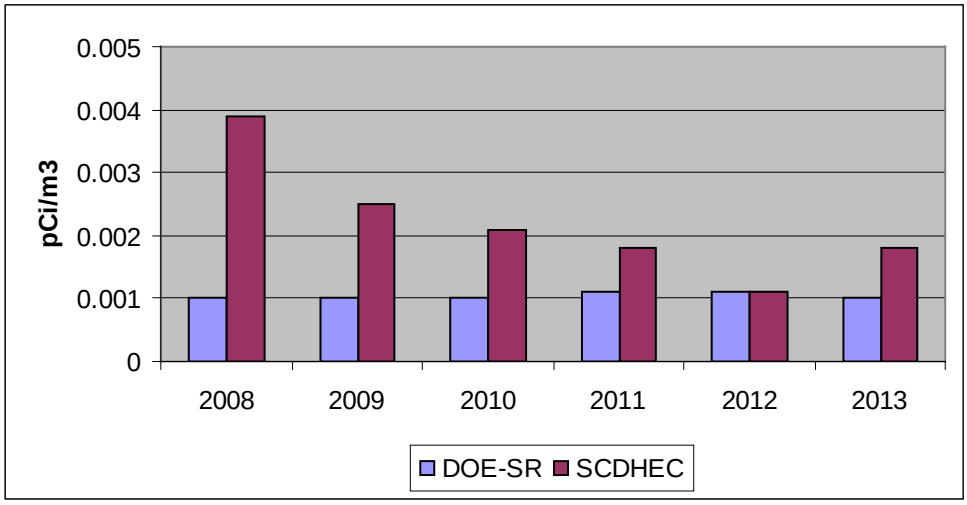


Figure 2. DOE-SR and SCDHEC Comparison of Average Gross Beta For Total Suspended Particulates at the SRS Perimeter

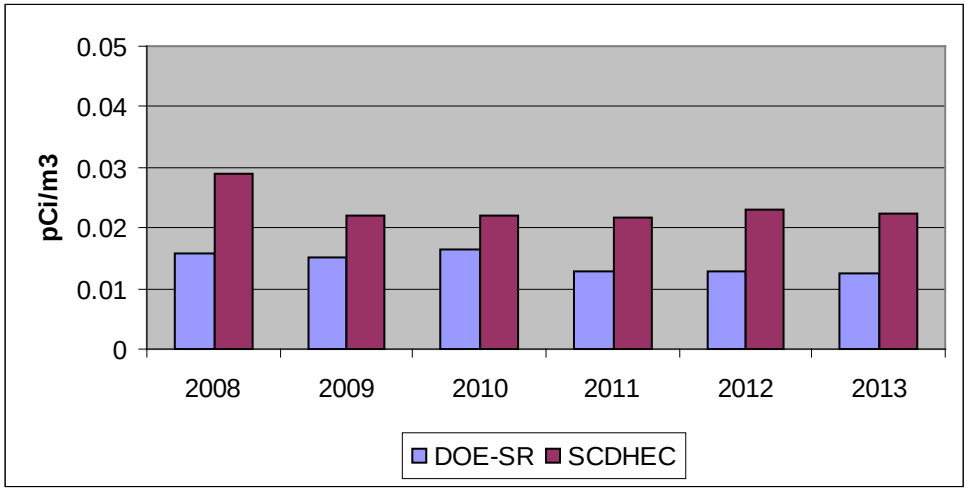


Figure 3. DOE-SR and SCDHEC Comparison of Average Ambient Beta/Gamma at the SRS Perimeter

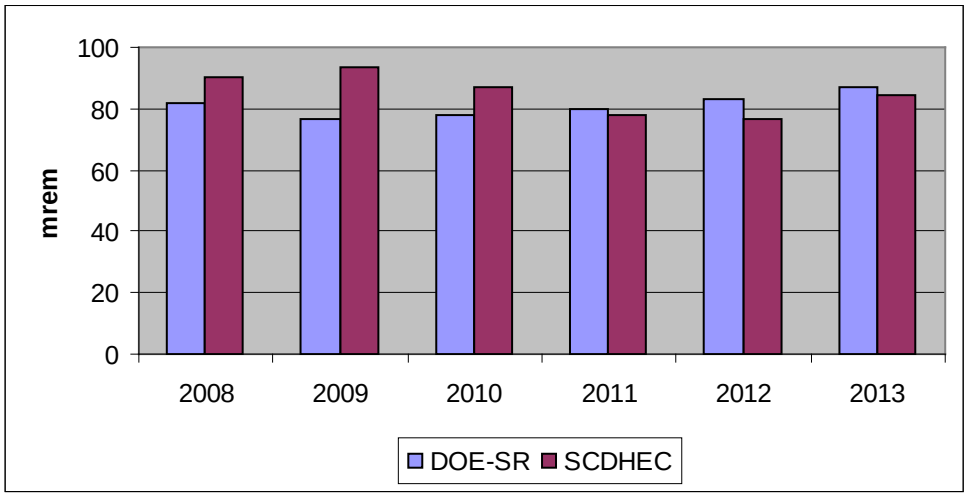


Figure 4. DOE-SR and SCDHEC Comparison of Average Tritium in Air at the SRS Perimeter

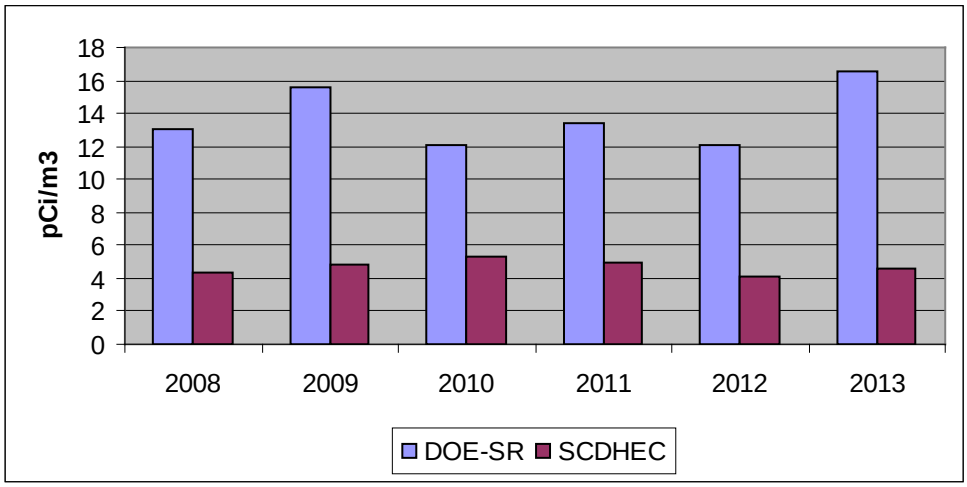


Figure 5. DOE-SR and SCDHEC Comparison of Average Tritium in Precipitation at the SRS Perimeter

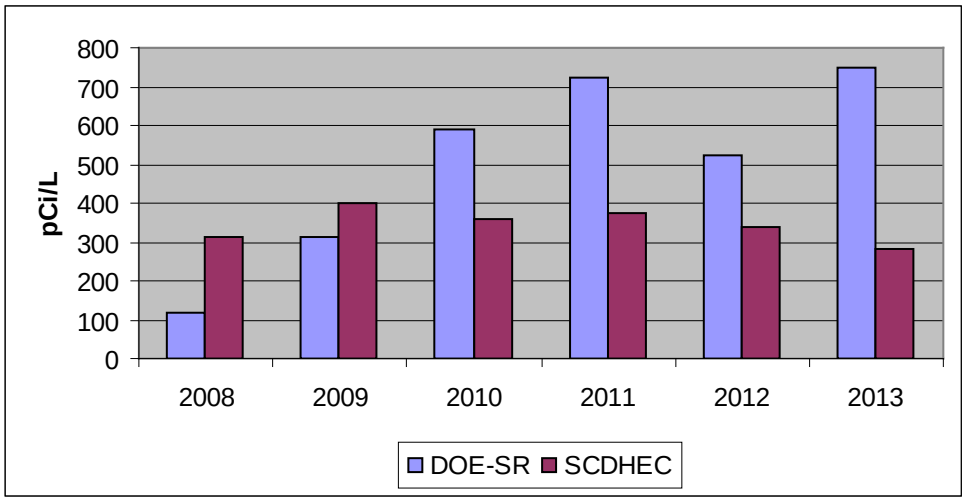


Figure 6. Weekly Gross Alpha in Air (Perimeter Stations)

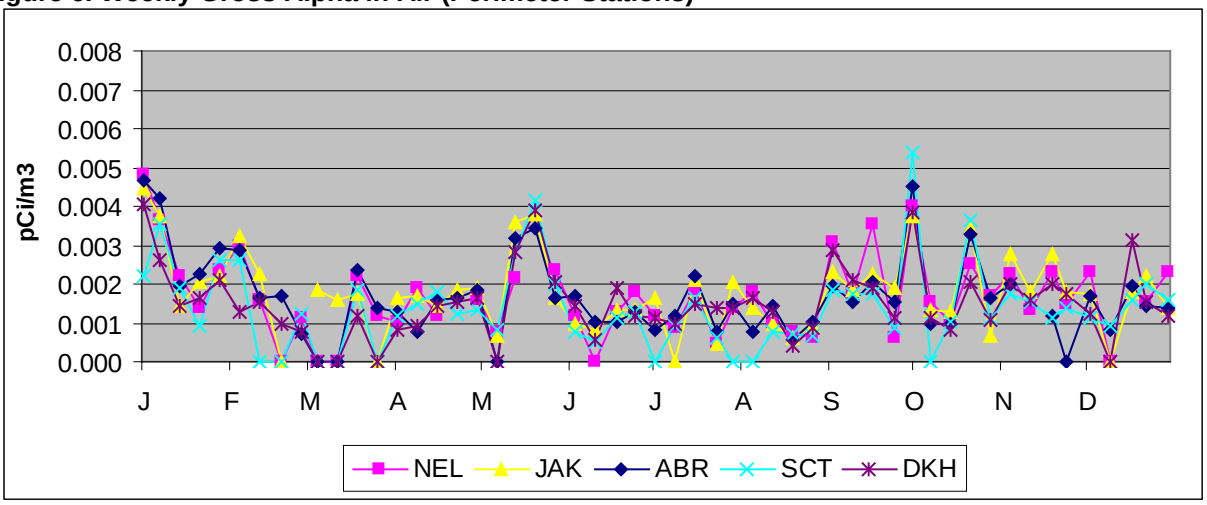


Figure 7. Weekly Gross Alpha in Air (Non-Perimeter Stations)

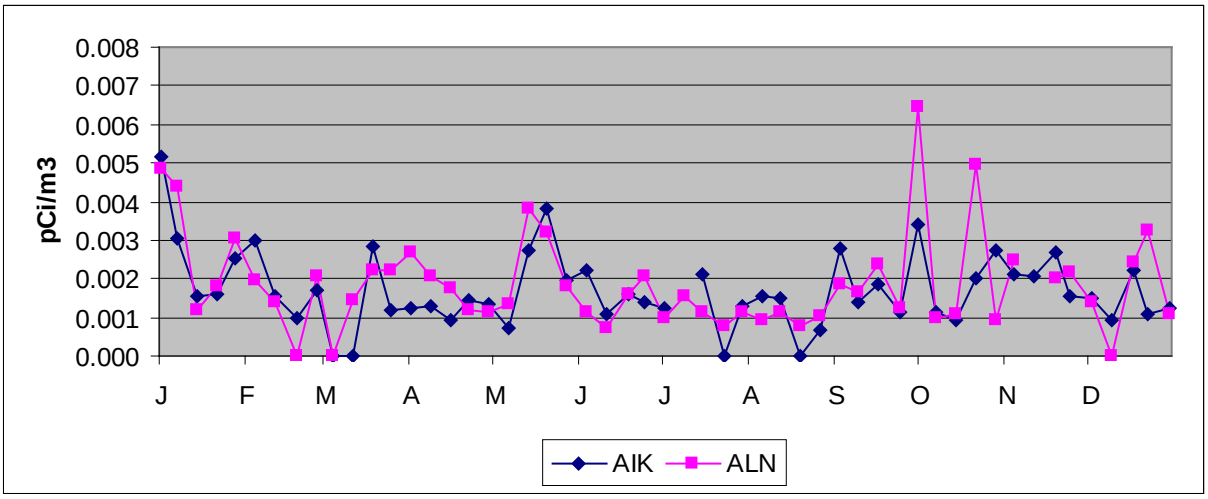
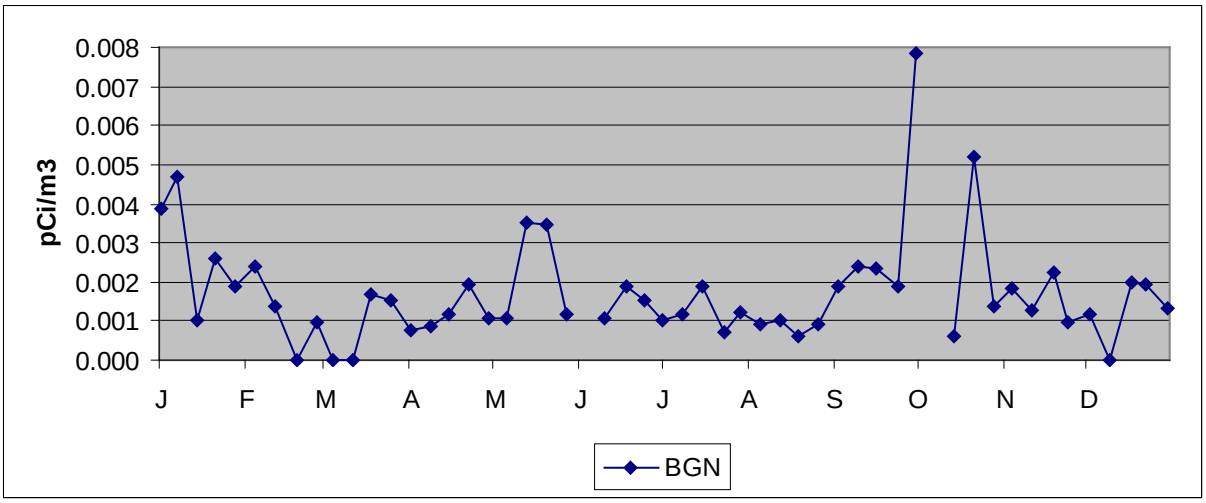


Figure 8. Weekly Gross Alpha in Air (SRS Center Station)



Note: Breaks in data indicate where no sample was available.

Figure 9. Weekly Gross Beta in Air (Perimeter Stations)

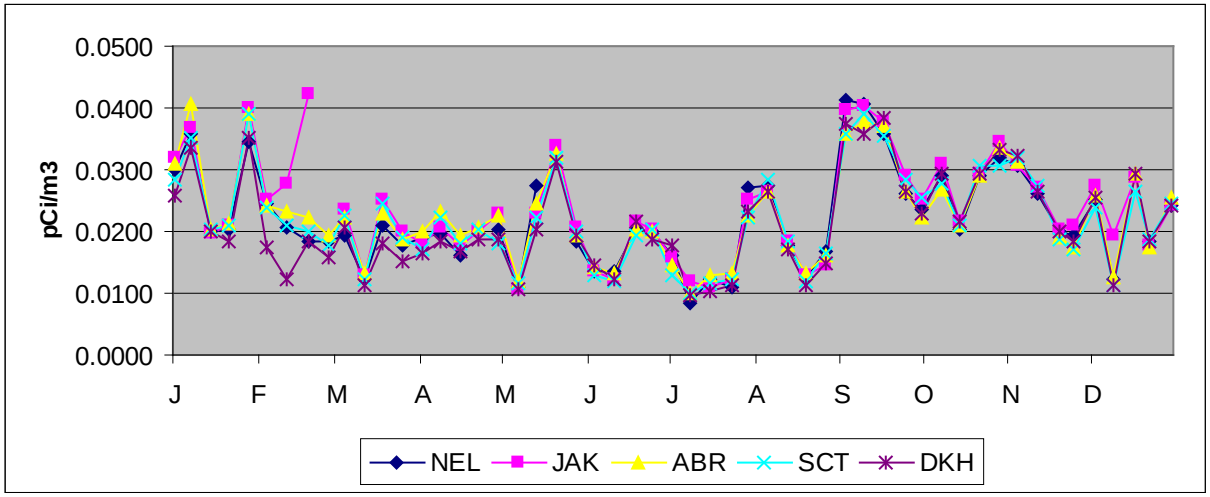


Figure 10. Weekly Gross Beta in Air (Non-Perimeter Stations)

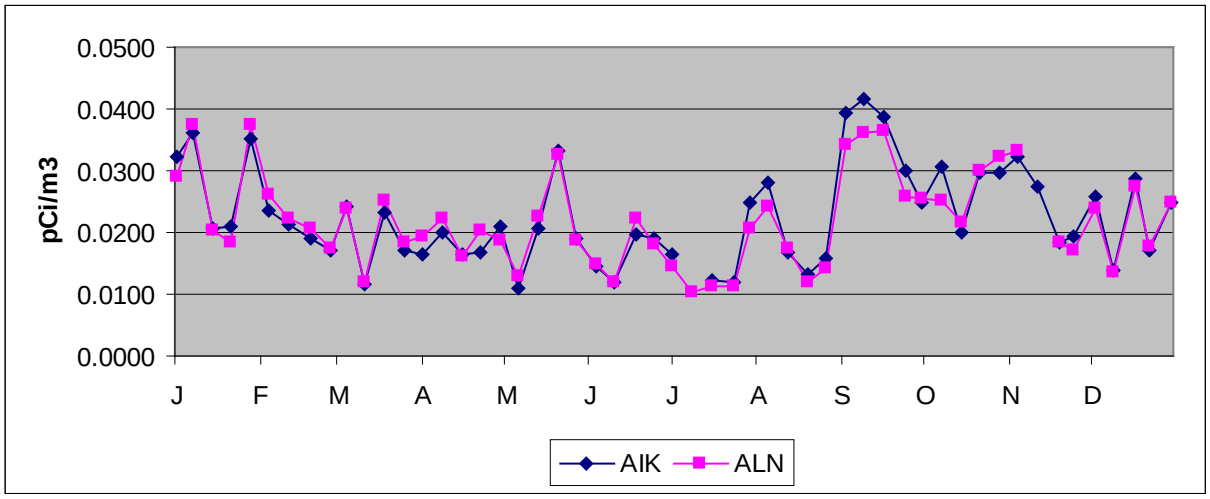
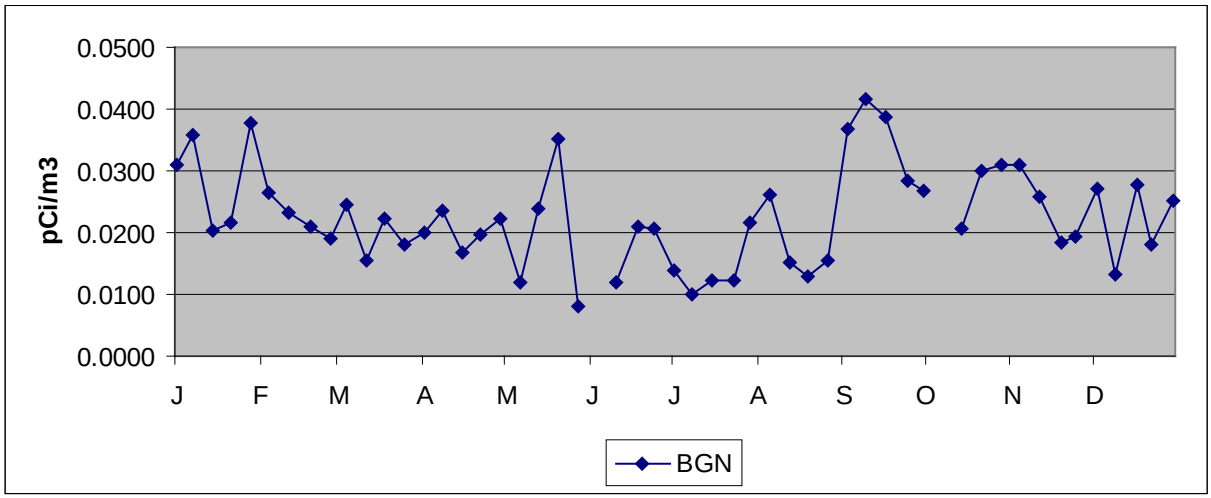


Figure 11. Weekly Gross Beta in Air (SRS Center Station)



Note: Breaks in data indicate where no sample was available.

Figure 12. Tritium in Air (Perimeter Stations)

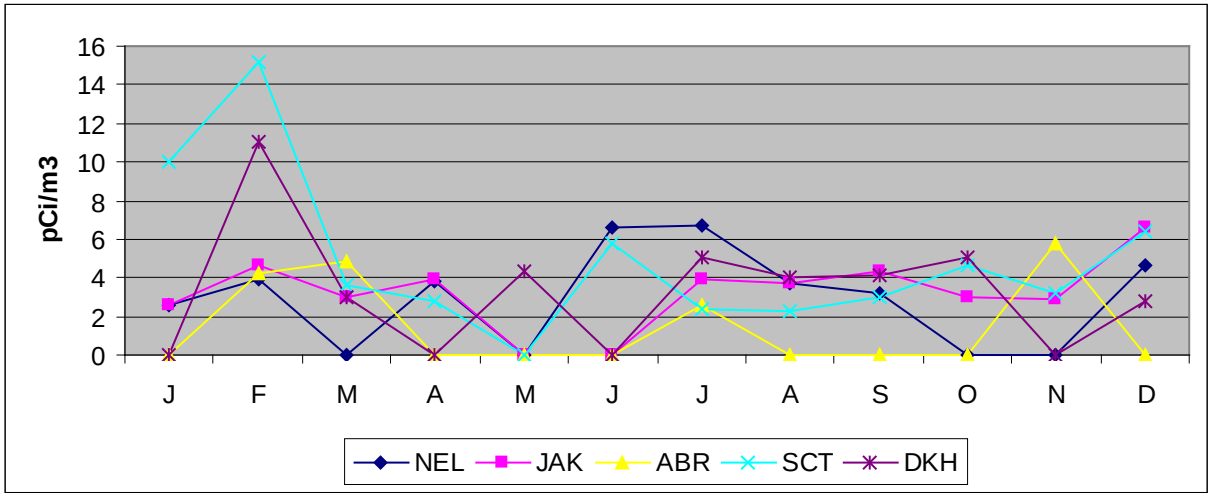


Figure 13. Tritium in Air (Non-Perimeter Stations)

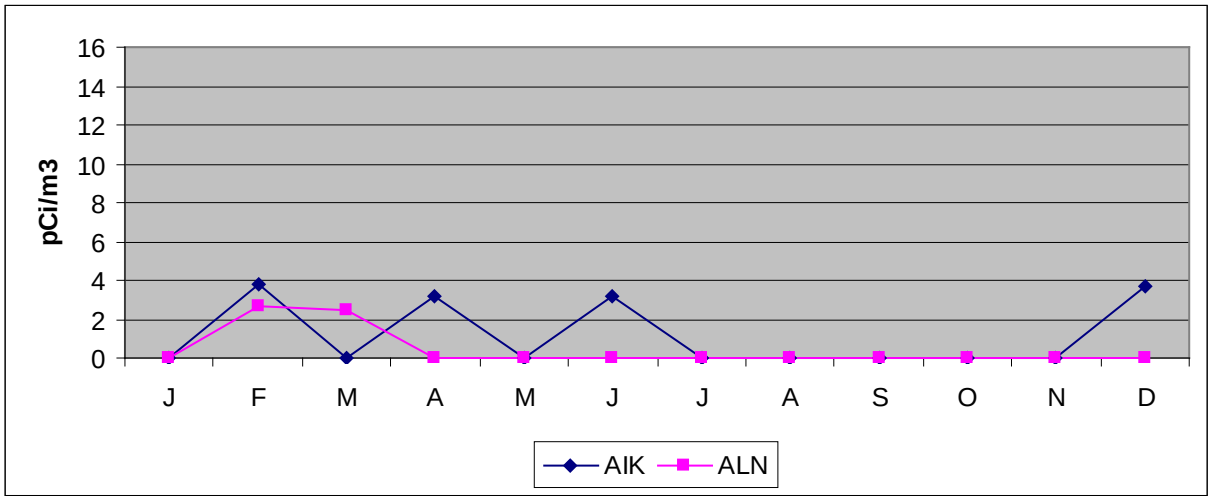
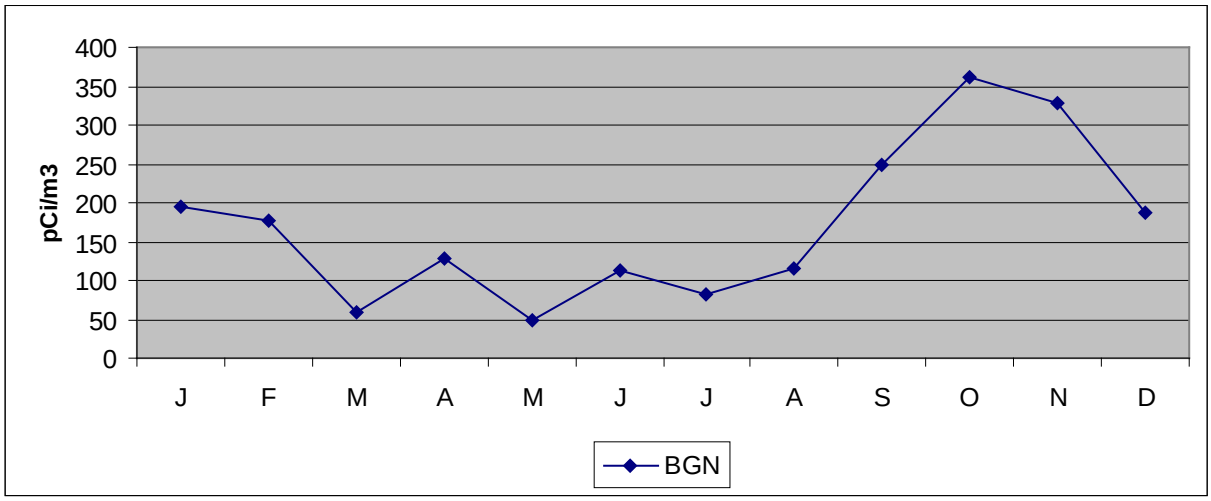


Figure 14. Tritium in Air (SRS Center Station)



Note: Breaks in data indicate where no sample was available.

Figure 15. Tritium in Precipitation (Perimeter Stations)

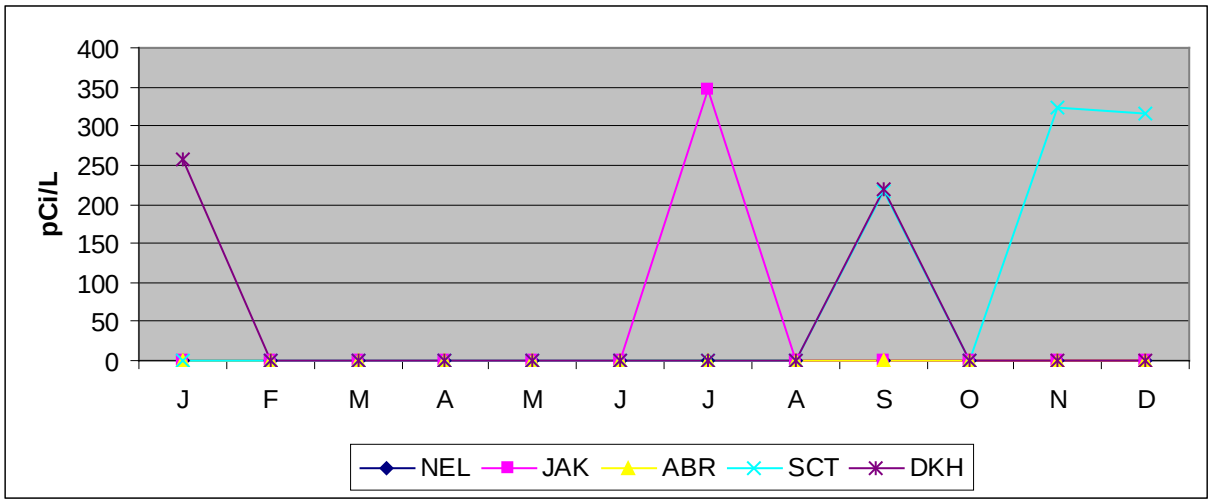


Figure 16. Tritium in Precipitation (Non-Perimeter Stations)

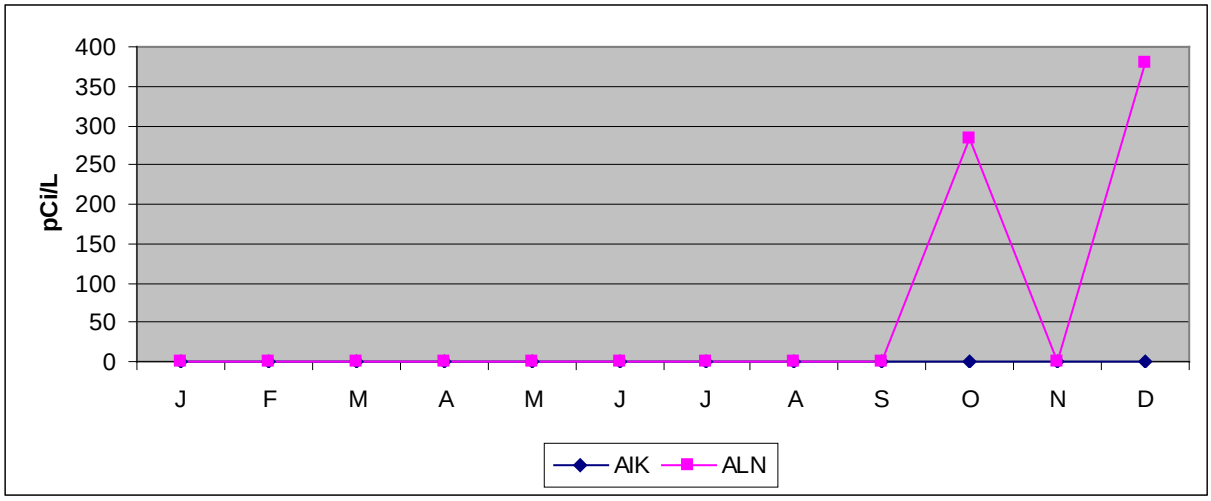
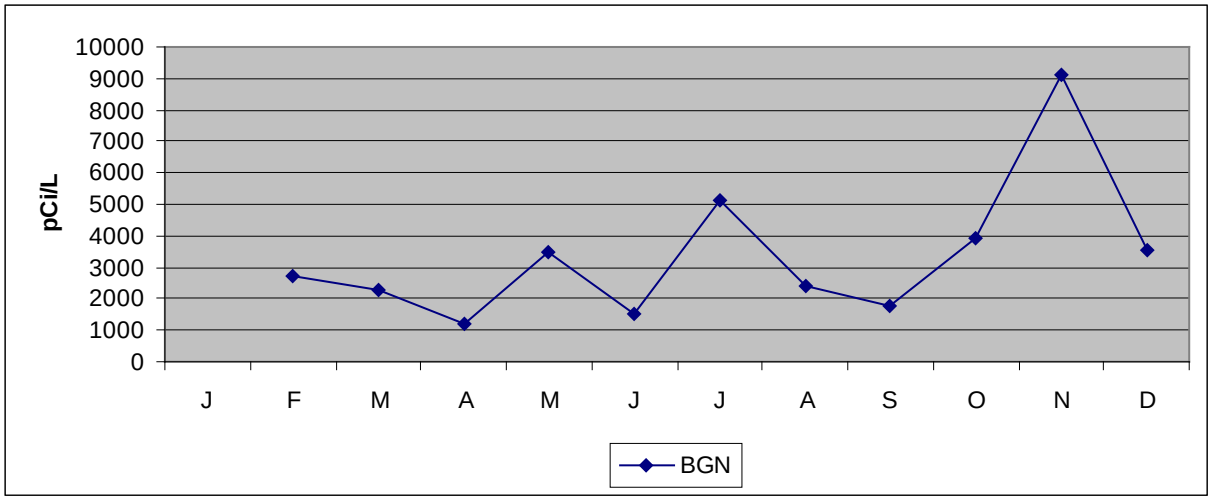


Figure 17. Tritium in Precipitation (SRS Center Station)



Note: Breaks in data indicate where no sample was available.

6.0 SUMMARY STATISTICS

Note:
Avg—Average
Std Dev—Standard Deviation
Min—Minimum
Max—Maximum
N—Number of Samples
( )—Number of Detections
P—Perimeter

Ambient Beta/Gamma Summary Statistics 2013

Sample Location	Quarterly Avg	Std Dev	Min	Max	Median
	mrem	mrem	mrem	mrem	mrem
Colocated with AIK Air Station	16.00	2.00	15.00	19.00	15.00
Colocated with BGN Air Station	28.25	3.10	24.00	31.00	29.00
Green Pond (P)	20.00	1.83	18.00	22.00	20.00
Colocated with JAK Air Station (P)	16.75	2.22	15.00	20.00	16.00
Crackerneck Gate (P)	22.50	2.65	19.00	25.00	23.00
TNX Boat Ramp (P)	24.00	2.83	20.00	26.00	25.00
Colocated with ABR Air Station (P)	15.25	2.22	12.00	17.00	16.00
Junction of Millet Road and Round Tree Road (P)	21.50	2.38	18.00	23.00	22.50
Patterson Mill Road at Lower Three Runs Creek (P)	24.00	0.82	23.00	25.00	24.00
Colocated with ALN Air Station	18.50	2.08	16.00	21.00	18.50
Barnwell Airport	19.00	0.82	18.00	20.00	19.00
Colocated with SCT Air Station (P)	18.25	0.50	18.00	19.00	18.00
Colocated with DKH Air Station (P)	20.00	2.58	17.00	23.00	20.00
Seven Pines Road Colocated with SRS Air Station (P)	24.50	3.11	20.00	27.00	25.50
Williston Police Department	22.50	1.91	21.00	25.00	22.00
Junction of US 278 and SC 781 (P)	20.25	2.06	18.00	23.00	20.00
US 278 near Upper Three Runs Creek (P)	26.75	1.71	25.00	29.00	26.50
Colocated with NEL Air Station (P)	19.75	2.50	17.00	23.00	19.50
Windsor Post Office	20.25	2.50	17.00	23.00	20.50
Control TLD (Kept in Office)	23.25	3.30	21.00	28.00	22.00
Lead (Kept in Lead Brick Enclosure)	10.25	1.26	9.00	12.00	10.00

2013 Summary Statistics

Statistical Review Of Radiological Monitoring at Aiken Elementary Water Tower (AIK)				
Analyte	Gross Alpha in Air	Gross Beta in Air	Tritium in Air	Tritium in Rain
Units	pCi/m^3	pCi/m^3	pCi/m^3	pCi/L
N	52 (48)	52 (52)	12 (4)	12 (0)
Mean	0.0018	0.0226	3.47	No Detections
Std Dev	0.0009	0.0078	0.32	
Median	0.0016	0.0206	3.47	
Min	0.0007	0.0109	3.16	
Max	0.0052	0.0415	3.78	

Statistical Review Of Radiological Monitoring at New Ellenton, SC (NEL)				
Analyte	Gross Alpha in Air	Gross Beta in Air	Tritium in Air	Tritium in Rain
Units	pCi/m^3	pCi/m^3	pCi/m^3	pCi/L
N	50 (45)	50 (50)	12 (8)	12 (0)
Mean	0.0018	0.0219	4.39	No Detections
Std Dev	0.0009	0.0077	1.51	
Median	0.0016	0.0201	3.85	
Min	0.0004	0.0085	2.61	
Max	0.0048	0.0413	6.73	

Statistical Review Of Radiological Monitoring at Jackson, SC (JAK)				
Analyte	Gross Alpha in Air	Gross Beta in Air	Tritium in Air	Tritium in Rain
Units	pCi/m^3	pCi/m^3	pCi/m^3	pCi/L
N	52 (48)	52 (52)	12 (10)	12 (1)
Mean	0.0019	0.0237	3.83	One Detect of 346.02
Std Dev	0.0009	0.0083	1.17	
Median	0.0018	0.0223	3.82	
Min	0.0005	0.0107	2.57	
Max	0.0045	0.0421	6.57	

Statistical Review Of Radiological Monitoring at Burial Grounds North, SRS (BGN)				
Analyte	Gross Alpha in Air	Gross Beta in Air	Tritium in Air	Tritium in Rain
Units	pCi/m^3	pCi/m^3	pCi/m^3	pCi/L
N	51 (47)	51 (51)	12 (12)	11 (11)
Mean	0.0019	0.0226	170.32	3362.29
Std Dev	0.0013	0.0080	100.55	2220.20
Median	0.0014	0.0215	152.97	2707.04
Min	0.0006	0.0081	48.25	1203.13
Max	0.0078	0.0417	361.59	9087.64

Statistical Review Of Radiological Monitoring at Allendale Barricade (ABR)				
Analyte	Gross Alpha in Air	Gross Beta in Air	Tritium in Air	Tritium in Rain
Units	pCi/m^3	pCi/m^3	pCi/m^3	pCi/L
N	52 (48)	52 (52)	12 (4)	12 (0)
Mean	0.0018	0.0226	4.36	No Detections
Std Dev	0.0010	0.0075	1.36	
Median	0.0016	0.0219	4.52	
Min	0.0006	0.0099	2.59	
Max	0.0047	0.0408	5.82	

2013 Summary Statistics

Statistical Review Of Radiological Monitoring at Allendale, SC (ALN)				
Analyte	Gross Alpha in Air	Gross Beta in Air	Tritium in Air	Tritium in Rain
Units	pCi/m^3	pCi/m^3	pCi/m^3	pCi/L
N	52 (49)	52 (52)	12 (2)	12 (2)
Mean	0.0020	0.0219	2.56	331.09
Std Dev	0.0012	0.0074	0.19	68.40
Median	0.0016	0.0206	2.56	331.09
Min	0.0007	0.0103	2.42	282.72
Max	0.0064	0.0375	2.69	379.46

Statistical Review Of Radiological Monitoring at Snelling, SC (SCT)				
Analyte	Gross Alpha in Air	Gross Beta in Air	Tritium in Air	Tritium in Rain
Units	pCi/m^3	pCi/m^3	pCi/m^3	pCi/L
N	53 (44)	53 (53)	12 (11)	12 (3)
Mean	0.0017	0.0220	5.38	285.14
Std Dev	0.0010	0.0075	3.98	59.80
Median	0.0014	0.0209	3.60	315.22
Min	0.0005	0.0100	2.29	216.27
Max	0.0054	0.0390	15.20	323.92

Statistical Review Of Radiological Monitoring at Dark Horse (DKH)				
Analyte	Gross Alpha in Air	Gross Beta in Air	Tritium in Air	Tritium in Rain
Units	pCi/m^3	pCi/m^3	pCi/m^3	pCi/L
N	53 (48)	53 (53)	12 (8)	12 (2)
Mean	0.0017	0.0212	4.92	238.20
Std Dev	0.0008	0.0076	2.61	28.61
Median	0.0015	0.0188	4.22	238.20
Min	0.0004	0.0096	2.77	217.97
Max	0.0041	0.0385	11.04	258.43

LIST OF ACRONYMS

ABR	Allendale Barricade
AIK	Aiken
ALN	Allendale
BGN	Burial Grounds North
DKH	Dark Horse at the Williston Barricade
DOE-SR	Department of Energy-Savannah River
ESOP	Environmental Surveillance and Oversight Program
JAK	Jackson
LLD	Lower Limit of Detection
NEL	New Ellenton
SCDHEC	South Carolina Department of Health and Environmental Control
SCT	South Carolina Advanced Technology Park
SRS	Savannah River Site
TLD	Thermoluminescent Dosimeter
TSP	Total Suspended Particulates
USEPA	United States Environmental Protection Agency

Units of Measure

Ci	Curie
mrem	millirem
pCi/L	picoCuries per liter
pCi/m^3	picoCuries per cubic meter
±	Plus or minus. Refers to one standard deviation unless otherwise stated

References

Argonne National Laboratory (ANL). 2007. Health-Based Radionuclide Concentrations in Drinking Water and Air. Human Health Fact Sheet.

Kathren, R.L. 1984. Radioactivity in the Environment: Sources, Distribution, and Surveillance. Harwood Academic Publishers, New York, New York.

National Council on Radiation Protection and Measures (NCRP). 1984. Radiological Assessment: Predicting the Transport, Bioaccumulation, and Uptake by Man of Radionuclides Released to the Environment. NCRP Report No. 76, Bethesda, MD.

Savannah River Nuclear Solutions, LLC (SRNS). 2014. Savannah River Site Environmental Report for 2013. Savannah River Site Aiken, SC. SRNS–STI–2014–00006.

South Carolina Department of Health and Environmental Control. 2012. 2011 Radiological Atmospheric Monitoring Data Report, Bureau of Environmental Services, Environmental Surveillance and Oversight Program, Aiken, South Carolina.

United States Environmental Protection Agency (USEPA). 2002. National Primary Drinking Water Regulations. Title 40, Chapter 1, Part 141.

USEPA. 2005. Office of Radiation and Indoor Air, Environmental Radiation Data, Report 123 July - September, Montgomery, AL.

USEPA. 2007. Maximum Contaminant Levels and Regulatory Dates for Drinking Water U.S.EPA vs. California.

USEPA. 2013. Email between author and Charles Petko of USEPA's National Air and Radiation Environmental Laboratory. September 3, 2013.

Walter, A. E., 1995. America the Powerless, Facing our Nuclear Energy Dilemma, Library of Congress Card Number: 95-080187.

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Section 2 2013 Water Monitoring

2013 Ambient Groundwater Monitoring Adjacent to the Savannah River Site

Environmental Surveillance and Oversight Program

96GW003

Shane S. Shull, Project Manager

January 01, 2013 - December 31, 2013

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D H E C
PROMOTE PROTECT PROSPER
South Carolina Department of Health and Environmental Control

Table of Contents

1.0 PROJECT SUMMARY

The Environmental Surveillance and Oversight Program (ESOP) of the South Carolina Department of Health and Environmental Control (SCDHEC) samples an ambient groundwater monitoring network adjacent to the Savannah River Site (SRS) to characterize groundwater quality in the area. This annual evaluation is conducted to determine possible offsite groundwater impacts due to operations conducted at the SRS. ESOP provides this project report annually as an independent source of information concerning Department of Energy-Savannah River (DOE-SR) activities and the potential impacts of those activities to public health and the environment.

SCDHEC currently utilizes a regional groundwater monitoring well network consisting of cluster wells (C-wells) and network wells (consisting of private wells and public water systems). This groundwater well network consists of approximately 75 wells that are routinely sampled by SCDHEC. The C-wells are owned and maintained by the South Carolina Department of Natural Resources (SCDNR). These cluster wells are screened from shallow surficial aquifers to depths exceeding 1,400 feet below ground surface. The C-well clusters are situated throughout the perimeter of the SRS.

The following items outline the objectives of the project, as well as the importance of sampling for radionuclides throughout the groundwater well network:

- Evaluate groundwater quality adjacent to SRS;
- Compare results with historical data;
- Determine any SRS contaminant migration offsite;
- Expand current ambient water quality databases;
- Provide the public with independently generated, region specific, groundwater quality information.

The study area is composed of a 10-mile perimeter extending from the SRS boundary, as well as random background locations found throughout the state of South Carolina. The 10-mile sampling perimeter was selected based on groundwater well availability and overall proximity to the SRS. As part of the ongoing ambient groundwater study, sampling of random background (B locations) will continue throughout the state of South Carolina. These sample locations are selected at random using a designated quadrant system that extends throughout the state of South Carolina. These samples are collected from either private or municipal groundwater wells. Map 1 in Section 4.0 depicts the network groundwater well locations, the extent of the study area, and the wells sampled during the 2013 sampling event. ESOP evaluates five aquifer zones (Upper Three Runs, Gordon, Crouch Branch, McQueen Branch, and the Piedmont Hydrogeologic Province) from the water table to confined aquifers more than 1,400 feet deep (Section 5.0, Table 2).

The SCDHEC analytical laboratory data from the 2013 groundwater sampling event revealed limited contaminants present in the groundwater wells sampled. These groundwater wells, along with the extent of contaminants, will be detailed in Section 2.0 of this report. Due to the low concentrations and limited extent of the contaminants identified in these groundwater wells, it is

likely the sources of these contaminants are a result of naturally occurring processes in the subsurface.

2.0 RESULTS AND DISCUSSION

The 2013 groundwater sampling event was scheduled for sample collection from 21 C-wells. Of these 21 groundwater wells, six wells were not sampled due to inoperable pumps at the time of sampling. Additionally, three background samples were collected at random locations in South Carolina. The 15 C-wells and the three background sample locations are featured in Section 4.0, Map 1. Based on a review of the wet chemistry, metals, tritium, gross alpha, non-volatile beta, and gamma-emitting radioisotope analytical data provided by the SCDHEC analytical and radiological laboratories, various contaminants were detected in the 18 groundwater wells sampled. Please see Section 5.0, Table 1 for a list of all wells, their locations, and sampling schedule. To view the electronic groundwater data set, please see Appendix A – ESOP Data.

Alpha activity was detected at eight of the groundwater well locations sampled during the 2013 sampling event (GWM06501, GWM06503, GWM06506, GWM06507, GWM02306, GWM02305, GWM02303, GWB01), none of which exceeded the United States Environmental Protection Agency (USEPA) maximum contaminant level (MCL) of 15 picocuries per liter (pCi/L) (USEPA 2002). Of these eight wells, seven of them are C-wells and one is a background location. No tritium activity was detected at any of the well locations sampled during the 2013 event. Non-volatile beta was detected at two of the C-wells sampled (GWM06503 and GWM02305). The activity of these samples was 4.62 pCi/L and 12.4 pCi/L respectively. The USEPA MCL for non-volatile beta (8 pCi/L) (USEPA 2002) was exceeded in well GWM02305. This exceedance is likely due to the presence of elevated levels of Radium 226 and Radium 228, which occur naturally in the area (ATSDR 2007).

The 2013 groundwater sampling event revealed additional contamination in several groundwater well locations. One or more of the following contaminants: nitrate/nitrite, barium, cadmium, and lead were detected in 11 well locations (GWM06503, GWM02202, GWM02204, GWM02303, GWM02104, GWM02102, GWM02101, GWM06501, GWM02306, GWM02305, GWM02205). The sample collected at GWM02205 yielded a lead concentration of 0.016 mg/L. This concentration exceeds the USEPA action level for lead which is set at 0.015 mg/L (USEPA 2002); however, elevated lead concentrations sometimes occur naturally in this region (ATSDR 2007). No other contaminants detected exceeded the USEPA established MCLs or action levels for drinking water.

The 2013 groundwater analytical data suggests the extent of the contaminants are isolated and likely the result of dissolved metals and radionuclides from naturally occurring geologic formations.

Contaminants commonly found in the SRS groundwater include: volatile organic compounds, metals, and tritium. In the event known contaminants (commonly found in SRS groundwater) are found in wells located within the SCDHEC sampling network, the affected wells would be investigated further to help determine the source. Due to the extensive groundwater contamination on the SRS, SCDHEC will continue to monitor groundwater quality to identify any future SRS offsite contaminant migration.

Radiological Parameter Results

The presence of naturally occurring radionuclides has been well documented in the groundwater regime across the state of South Carolina. Groundwater investigations performed by state and federal agencies such as SCDHEC, SCDNR, and the United States Geological Survey (USGS) have confirmed the presence of these radionuclides.

Gross alpha was detected at eight of the 18 groundwater wells sampled during the 2013 event (Figure 1). These eight locations (7 C-wells and 1 background) are identified as GWM06501, GWM06503, GWM06506, GWM06507, GWM02306, GWM02305, GWM02303, and GWB01 and yielded activities of 7.56 pCi/L, 2.08 pCi/L, 3.31 pCi/L, 6.24 pCi/L, 8.67 pCi/L, 2.26 pCi/L, 2.94 pCi/L, and 4.10 pCi/L respectively. None of these locations exceeded the USEPA drinking water limit of 15 pCi/L.

Non-volatile beta was detected in two of the groundwater wells sampled (Figure 2). These two locations (C-wells) are identified as GWM06503 and GWM02305 and yielded activities of 4.62 pCi/L and 12.4 pCi/L respectively. The sample collected at GWM02305 exceeded the established MCL of 8 pCi/L for non-volatile beta (USEPA 2002). This exceedance ; however, this groundwater well is for monitoring purposes only and is not intended or used for human consumption. As previously stated, the presence of naturally occurring radionuclides has been well documented in the groundwater regime across the state of South Carolina. As a result, continued sampling for non-volatile beta activity in the future will continue.

Tritium was not detected in any of the 18 groundwater wells sampled in 2013. However, due to the known tritium groundwater contamination on the SRS and the overall concern from local stakeholders such as the Aiken Citizens Advisory Board, tritium sampling will continue and be addressed in all future project reports.

Gamma analysis was conducted on all groundwater samples for the 2013 sampling event. Gamma activity was below the detection level for all samples collected with the exception of four sample locations (GWM02204, GWM02205, GWM06502, and GWM06501) which yielded Pb-214 activities of 8.78 pCi/L, 48.36 pCi/L, 77.51 pCi/L, and 286.80 pCi/L respectively. The Pb-214 found in these samples are likely daughter products of Uranium-238, which is naturally occurring in the Earth's crust and fairly common in this area. These detections were found in samples collected from groundwater monitoring wells and are not intended or used for human consumption.

Nonradiological Parameter Results

The presence of metals and other nonradiological contaminants in the environment can be attributed to man-made processes such as industrial manufacturing and/or the natural decay of deposits. However, a review of the following metal and nonradiological contaminants detected indicates their limited presence and concentration is most likely due to the erosion of natural deposits. Additionally, the position of these wells, as related to the SRS's centrally located process areas suggests the theory of natural occurrence. All analytical results can be found in Section 6.0.

During the 2013 groundwater sampling event, samples were collected for volatile organic compounds (VOCs); however, no VOCs were detected at any of the sampling locations in 2013.

Barium was detected at two groundwater well locations (GWM06503, GWM06501) with concentrations of 0.068 miligrams per liter (mg/L) and 0.060 mg/L respectively. Calculation revealed a barium average of 0.064 mg/L in these two groundwater well locations. Although the concentration of barium in these wells is detectable, they do not exceed the 2.00 mg/L MCL established by the USEPA (USEPA 2002). As a result, these concentrations are not considered known risks to human health.

Cadmium was detected in three groundwater wells (GWM02303, GWM02104, GWM02306) with concentrations of 0.00034 mg/L, 0.00032 mg/L, and 0.00021 mg/L respectively. Calculation revealed a cadmium average of 0.00029 mg/L in these three groundwater well locations. Although the concentrations of cadmium in these wells are detectable, they are well below the 0.005 mg/L MCL established by the USEPA (USEPA 2002).

Lead was detected in seven groundwater wells (GWM02202, GWM02204, GWM02303, GWM02104, GWM06501, GWM02305, GWM02205) yielding concentrations of 0.0089 mg/L, 0.0038 mg/L, 0.0033 mg/L, 0.0040 mg/L, 0.0095 mg/L, 0.0023 mg/L, and 0.016 mg/L respectively. The USEPA has established an action level for lead of 0.015 mg/L. Calculation revealed a lead average of 0.0068 mg/L in these seven groundwater well locations. Although the concentration of lead found in sample GWM02205 exceeded the USEPA action level by 0.001 mg/L, elevated lead levels in groundwater wells are often the result of naturally occurring deposits (ATSDR 2007). The remaining six samples have concentrations below the USEPA action level.

Nitrate/Nitrite was detected at concentrations well below the 10 mg/L MCL (USEPA 2002) in five groundwater wells (GWM02202, GWM02104, GWM02102, GWM02101, and GWM06501) yielding concentrations of 1.1 mg/L, 0.041 mg/L, 0.10 mg/L, 0.11 mg/L, and 0.52 mg/L respectively. Calculation revealed a nitrate/nitrite average of 0.37 mg/L in these five groundwater well locations. The presence of nitrate/nitrite is most likely due to the erosion of natural deposits and/or runoff from fertilizer use. Once in the soil, nitrate is mobile due to its water solubility characteristic, and therefore moves easily through the soil matrix at a speed comparable to groundwater flow velocity (USGS 1998).

ESOP and DOE-SR Data Comparison

Due to the fact DOE-SR collects groundwater samples from a separate onsite monitoring well network, direct SCDHEC offsite groundwater comparisons could not be made to their findings in the latest SRS Environmental Report for 2013. However, the 2013 SRS report identifies numerous areas of groundwater contamination throughout the SRS property. These areas of impacted groundwater include A-Area, C-Area, D-Area, E-Area, F-Area, H-Area, K-Area, L-Area, M-Area, P-Area, R-Area, Z-Area, Sanitary Landfill, TNX, and Chemicals Metals Pesticides (CMP) pits. The extent of the contamination varies and some of the contaminants include: chlorinated volatile organics, tritium, gross alpha, beta radionuclides, and strontium-90 (SRNS 2014). SCDHEC groundwater contaminates detected in the 2013 sample event include

gross alpha, non-volatile beta, gamma and various metals. Due to the presence of the aforementioned contaminants in the groundwater on the SRS, the ESOP groundwater project will continue sampling for these contaminants in future sampling events.

Summary Statistics

During the 2013 groundwater sampling event, 18 wells were sampled. Of these 18 wells, 15 are classified as C-wells and three are classified as random background wells. Laboratory analytical data revealed no detections for tritium.

Summary statistics from the groundwater wells sampled revealed a gross alpha average of 4.65 (± 2.52) pCi/L (based on eight detections). The calculated average is slightly higher than the single background detection of 4.10 pCi/L. None of the gross alpha detections exceeded the 15 pCi/L safe drinking water limits established by the USEPA.

Summary statistics from groundwater wells sampled revealed a non-volatile beta average of 8.51 (± 5.50) pCi/L (based on two detections). There were no detections for non-volatile beta in the three background samples collected.

3.0 CONCLUSIONS AND RECOMMENDATIONS

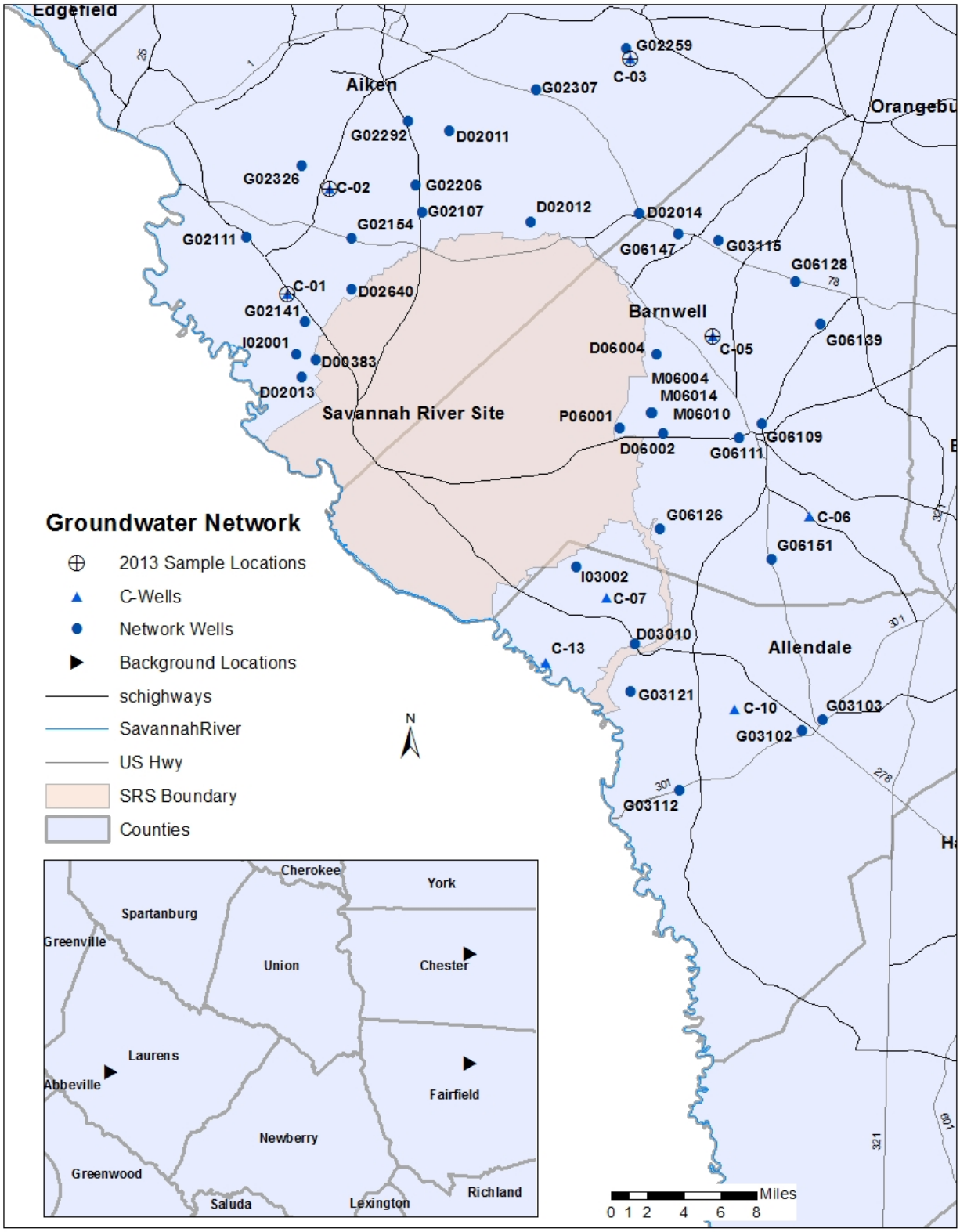
A review of the 2013 analytical data revealed various but limited nonradiological and/or radiological constituents in the majority of the 18 groundwater wells sampled. Although several of the wells sampled during this event revealed detectable concentrations, the data suggests the extent of the contaminants are isolated and likely the result of dissolved metals and radionuclides from naturally occurring geologic formations.

The Ambient Groundwater Quality Monitoring Project (AGQMP) attempted to determine if constituents, other than naturally occurring, have impacted groundwater within the monitoring network. The results of the 2013 groundwater sampling event indicate several nonradiological constituents and naturally occurring radionuclides are impacting groundwater quality in isolated regions throughout the groundwater monitoring well network as well as background locations. Independent monitoring of basic water quality parameters, metals, VOCs, tritium, gross alpha, non-volatile beta, and gamma-emitting radionuclides will continue throughout future annual groundwater investigations. In addition, statistical analysis of background data along with evaluating DOE-SR groundwater monitoring data, will be performed. Continued groundwater monitoring will provide a better understanding of actual groundwater quality parameters, their extent, and trends. As a result, comparisons with historical data can be made. In addition, ESOP will provide SCDHEC's Bureau of Water with groundwater data to assist in their evaluation of the extent of naturally occurring radionuclides in the region.

During future DOE-SR ambient groundwater sampling events (using the SRS P-wells), SCDHEC will request the opportunity to conduct split QA/QC (Quality Assurance/Quality Control) sampling. The term P-Wells is used to describe the groundwater monitoring well network used to sample groundwater within the SRS site boundary. Split sampling at random well locations throughout the SRS groundwater well network will help provide SCDHEC further annual confirmation.

4.0 Ambient Groundwater Monitoring

Map 1. Ambient Groundwater Quality Monitoring Well Network



5.0 Tables and Figures

Ambient Groundwater Monitoring

Table 1. ESOP Groundwater Monitoring Well Data

Well No.	Well Name	Sample Year	Top of Casing Elevation (ft amsl)	Total Depth (ft bgs)	Aquifer
G02292	Hunter's Glen	2010	unknown	210	SP
G02206	Oak Hill Subdivision	2010	445	240	SP
G02107	New Ellenton	2010	421	425	CB
G02259	Aiken State Park	2010	262	*	SP
G02154	Talatha Water District	2010	250	185	CB
G02141	Jackson	2010	225	105	SP
G02111	Beech Island Water District	2010	380	360	CB
G02326	ORA Site	2010	300	397	MB
D02014	Messer Well	2010	unknown	144	SP
G02307	Oakwood School	2010	428	404	CB
D02013	Cowden Plantation, Well 2	2010	124	*	SP
I02001	Cowden Plantation, Well 1	2010	132	*	CB
D02011	Mettlen Well	2010	400	180	SP
D02012	Windsome Plantation, House Well	2010	260	*	SP
G06109	Barnwell, Hwy. 3	2011	230	146	UTR
G06111	Barnwell, Rose St.	2011	220	166	UTR
G06128	Edisto Station	2011	322	360	GOR
G06147	Williston, Halford St.	2011	352	530	CB
G06139	Barnwell State Park	2011	248	163	UTR
D06002	Moore Well	2011	240	*	UTR
P06001	Allied General Nuclear, Well 1	2011	250	*	MB
D06004	J. Williams Well	2011	245	76.15	UTR
M06004	Chem Nuclear WO0061	2011	254.52	401	CB
M06014	Chem Nuclear WO0071	2011	255.33	250	GOR
M06010	Chem Nuclear WO0069	2011	254.28	145	UTR
D03010	Martin Post Office	2012	108	105	UTR
I03002	Ingrim Residence	2012	*	*	UTR
G03102	Allendale, Water St.	2012	201	343	UTR
G03103	Allendale, Googe St.	2012	180	347	UTR
G03112	Allendale Welcome Center	2012	143	100	UTR
G06151	Chappels Labor Camp	2012	250	260	UTR
G03121	Clariant	2012	180	812	CB
G03115	Martin District Fire Department	2012	*	*	*
G06126	Starmet (Carolina Metals)	2012	200	323	GOR

Table 1. (continued) ESOP Groundwater Monitoring Well Data

Well No.	Well Name	Sample Year	Top of Casing Elevation (ft amsl)	Total Depth (ft bgs)	Aquifer
M02101	SCDNR Cluster C-01, AIK-2378	**2013**	220.3	185	CB
M02102	SCDNR Cluster C-01, AIK-2379	**2013**	224.2	266	CB
M02103	SCDNR Cluster C-01, AIK-2380	**2013**	228.9	385	MB
M02104	SCDNR Cluster C-01, AIK-902	**2013**	231.9	511	MB
M02202	SCDNR Cluster C-02, AIK-825	**2013**	418.8	231	CB
M02203	SCDNR Cluster C-02, AIK-824	**2013**	418.6	365	CB
M02204	SCDNR Cluster C-02, AIK-818	**2013**	418.3	425	MB
M02205	SCDNR Cluster C-02, AIK-817	**2013**	418.9	535	MB
M02301	SCDNR Cluster C-03, AIK-849	**2013**	301.6	97	SP
M02302	SCDNR Cluster C-03, AIK-848	**2013**	299.7	131	CB
M02303	SCDNR Cluster C-03, AIK-847	**2013**	299	193	CB
M02304	SCDNR Cluster C-03, AIK-846	**2013**	297.8	255	CB
M02305	SCDNR Cluster C-03, AIK-845	**2013**	296.9	356	MB
M02306	SCDNR Cluster C-03, AIK-826	**2013**	294.9	500	MB
M06501	SCDNR Cluster C-05, BRN-360	**2013**	264.3	140	UTR
M06502	SCDNR Cluster C-05, BRN-359	**2013**	265.5	214	GOR
M06503	SCDNR Cluster C-05, BRN-367	**2013**	263.8	285	GOR
M06504	SCDNR Cluster C-05, BRN-368	**2013**	265.1	443	CB
M06505	SCDNR Cluster C-05, BRN-365	**2013**	263.5	539	CB
M06506	SCDNR Cluster C-05, BRN-366	**2013**	266.7	715	MB
M06507	SCDNR Cluster C-05, BRN-358	**2013**	265.6	847	MB
M03706	SCDNR Cluster C-07, ALL-368	2014	246.6	691	CB
M03707	SCDNR Cluster C-07, ALL-369	2014	242.1	800	CB
M03708	SCDNR Cluster C-07, ALL-370	2014	245.1	975	MB
M03709	SCDNR Cluster C-07, ALL-358	2014	243.1	1123	MB
M03131	SCDNR Cluster C-13, Artesian	2014	80	*	GOR
M03132	SCDNR Cluster C-13, ALL-378	2014	90	1060	MB
M03702	SCDNR Cluster C-07, ALL-364	2014	245.2	225	UTR
M03703	SCDNR Cluster C-07, ALL-365	2014	244.3	333	GOR
M03704	SCDNR Cluster C-07, ALL-366	2014	243.5	400	GOR
M03705	SCDNR Cluster C-07, ALL-367	2014	245.7	566	CB
M06601	SCDNR Cluster C-06, BRN-351	2014	207.3	95	UTR
M06602	SCDNR Cluster C-06, BRN-350	2014	207.4	170	UTR
M06603	SCDNR Cluster C-06, BRN-352	2014	207.1	293	GOR

Table 1. (continued) ESOP Groundwater Monitoring Well Data

Well No.	Well Name	Sample Year	Top of Casing Elevation (ft amsl)	Total Depth (ft bgs)	Aquifer
M06604	SCDNR Cluster C-06, BRN-354	2014	207.6	411	GOR
M06605	SCDNR Cluster C-06, BRN-353	2014	207.7	588	CB
M06608	SCDNR Cluster C-06, BRN-349	2014	208.6	1045	MB
M03101	SCDNR Cluster C-10, ALL-347	2014	281.6	1423	MB
M03104	SCDNR Cluster C-10, ALL-374	2014	280.9	580	GOR
D02640	Green Pond Road	2014	*	222	*
D00383	Brown Road	2014	*	*	*

Notes:
1. * - Total depth/top of casing information unknown, Aquifer assigned based on owner information.
2. ft amsl – feet above mean sea level
3. ft bgs – feet below ground surface
4. UTR – Upper Three Runs, CB – Crouch Branch, SP – Steeds Pond, GOR – Gordon, MB- McQueen Branch

Tables and Figures

Ambient Groundwater Monitoring

Table 2. Summary of the Stratigraphy and Hydrostratigraphy of the Study Area

PERIOD/EPOCH	GROUP	FORMATION	HYDROLOGIC UNIT	
Middle Miocene	Cooper	Upland Unit	Unsaturated Zone	
Tertiary / Eocene	Barnwell	Tobacco Road	Steed Pond Aquifer	Upper Three Runs Aquifer (UTR)
		Dry Branch/Clinchfield		
	Orangeburg	Tinker/Santee		Gordon Confining Unit
		Warley Hill		
		Congaree		Gordon Aquifer (GOR)
	Black Mingo	Fourmile		
Tertiary / Paleocene		Snapp		
		Lang Syne/Sawdust Landing	Crouch Branch Confining Unit	
Late Cretacious	Lumbee	Steel Creek	Crouch Branch Aquifer (CB)	
		Black Creek	McQueen Branch Confining Unit	
			McQueen Branch Aquifer (MB)	
		Middendorf		
Paleozoic or Precambrian		Cape Fear	Appleton Confining System	
		Crystalline Basement	Piedmont Hydrogeologic Province	

Tables and Figures

Ambient Groundwater Monitoring

Figure 1. 2013 Gross Alpha Activity

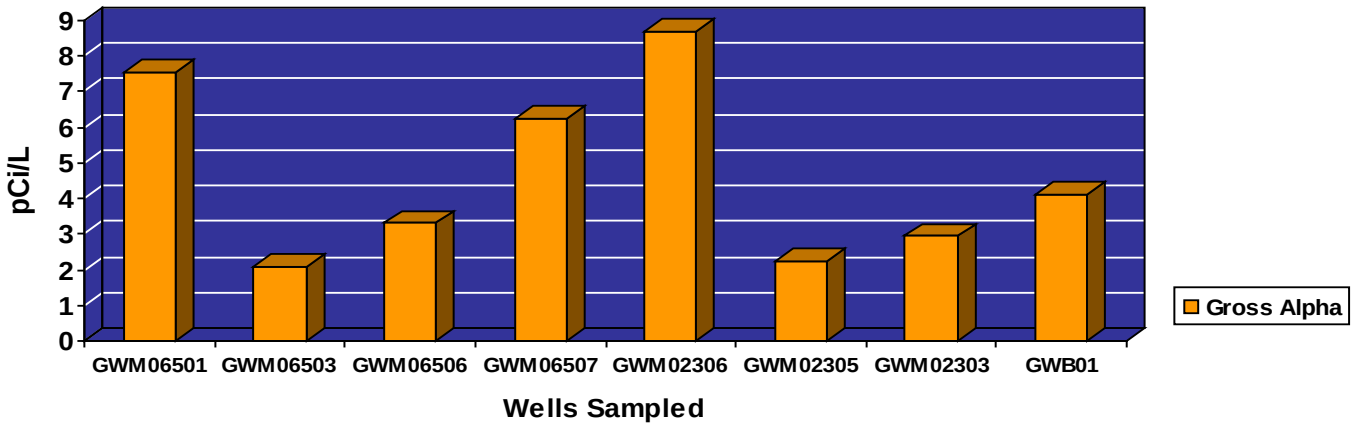
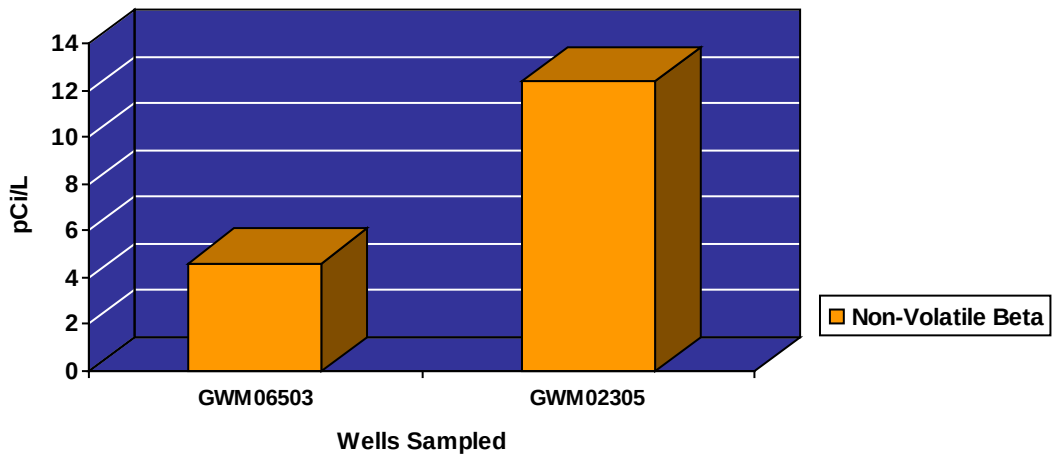


Figure 2. 2013 Non-Volatile Beta Activity



6.0 Summary Statistics

Ambient Groundwater Monitoring

Notes:

1. N/A = Not Applicable

2013 Radiological Summary Statistics

Location Description	Well Designation	Alpha (pCi/L)
GWM06501	C Well	7.56
GWM06503	C Well	2.08
GWM06506	C Well	3.31
GWM06507	C Well	6.24
GWM02306	C Well	8.67
GWM02305	C Well	2.26
GWM02303	C Well	2.94
GWB01	Background	4.10

Location Description	Well Designation	Beta (pCi/L)
GWM06503	C Well	4.62
GWM02305	C Well	12.40

C Wells						
	Mean	Std Dev	Median	Max	Min	Number
Alpha (pCi/L)	4.72	2.71	3.31	8.67	2.08	7

Background Wells						
	Mean	Std Dev	Median	Max	Min	Number
Alpha (pCi/L)	4.10	N/A	N/A	4.10	4.10	1

C Wells						
	Mean	Std Dev	Median	Max	Min	Number
Beta (pCi/L)	8.51	5.50	8.51	12.40	4.62	2

LIST OF ACRONYMS

AGQMP	Ambient Groundwater Quality Monitoring Project
CMP	Chemicals Metals Pesticides
DOE-SR	Department of Energy - Savannah River
ESOP	Environmental Surveillance and Oversight Program
GWM	Ground Water Monitoring (Sample Location)
LLD	Lower Limit of Detection
MCL	Maximum Contaminant Level
MDA	Minimum Detectable Activity
QA/QC	Quality Assurance/Quality Control
SCDHEC	South Carolina Department of Health and Environmental Control
SCDNR	South Carolina Department of Natural Resources
STD DEV	Standard Deviation
SRS	Savannah River Site
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VOC	Volatile Organic Compound

UNITS OF MEASURE

mg/L	Milligrams Per Liter
pCi/L	Picocuries per liter
±	Plus or minus. Refers to one standard deviation unless otherwise stated

References

Aadland, R. K., J. A. Gellici, P. A. Thayer 1995, "Hydrogeologic Framework of West Central South Carolina", South Carolina Department of Natural Resources, WRD Report 5.

Agency for Toxic Substances and Disease Registry (ATSDR) 2007. Evaluation of Off-Site Groundwater and Surface Water Contamination at the Savannah River Site (USDOE).

Savannah River Nuclear Solutions, LLC (SRNS) 2014. Savannah River Site Environmental Report for 2013. Savannah River Site Aiken, SC. SRNS-STI-2014-00007.

South Carolina Department of Health and Environmental Control (SCDHEC) 1999. Determination of Ambient Groundwater Quality Adjacent to the Savannah River Site, Annual Report, 1997, SCDHEC Environmental Surveillance and Oversight Program.

Westinghouse Savannah River Company (WSRC) 1992. SRP Baseline Hydrogeologic Investigation: Aquifer Characterization. Savannah River Laboratory, WSRC. WSRC-RP-92-450.

United States Environmental Protection Agency (USEPA). 2002. National Primary Drinking Water Regulations. Title 40, Chapter 1, Part 141.

United States Environmental Protection Agency 2013. http://www.epa.gov/safewater/contaminants/index.html.

United States Geological Survey (USGS). 1998. Nutrients National Synthesis Project. A National Look at Nitrate Contamination of Ground Water. http://water.usgs.gov/nawqa/nutrients/pubs/wcp_v39_no12/index.html.

APPENDIX B

Regional Geology

The study area, including SRS, is located in west-central South Carolina. The regional geology is characterized as the Aiken Plateau of the Coastal Plain physiographic province. SRS is located approximately 20 miles southeast of the fall line of the Piedmont physiographic province. A thickening wedge of Cenozoic and Cretaceous sediment, which overlies Paleozoic crystalline basement rock and Triassic sedimentary rocks, underlies the area south of the fall line (Aadland et al 1995). The sediment, consisting of alternating sands and clays with Tertiary carbonates, thickens toward the southeast from zero at the fall line to more than 1,800 feet at the Allendale-Hampton County line. The sediment is about 1,100 feet thick beneath the central portion of SRS and dips toward the southeast at about 35 feet per mile. Table 2 in Section 5.0 summarizes the stratigraphy and hydrostratigraphy of the study area. For a more detailed review of regional geology and hydrogeology, refer to the 1997 Annual Report (SCDHEC 1999).

Radiological Analytes Table

Radioisotope	Abbreviation
Actinium-228	Ac-228
Americium-241	Am-241
Berylium-7	Be-7
Cerium-144	Ce-144
Cobalt-58	Co-58
Cobalt-60	Co-60
Cesium-134	Cs-134
Cesium-137	Cs-137
Europium-152	Eu-152
Europium-154	Eu-154
Europium-155	Eu-155
Iodine-131	I-131
Potassium-40	K-40
Manganese-54	Mn-54
Sodium-22	Na-22
Lead-212	Pb-212
Lead-214	Pb-214
Radium-226	Ra-226
Ruthenium-103	Ru-103
Antimony-125	Sb-125
Uranium-238	U-238
Yttrium-88	Y-88
Zinc-65	Zn-65
Zirconium-95	Zr-95

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2013 Radiological Monitoring of Drinking Water Adjacent to the Savannah River Site

Environmental Surveillance and Oversight Program

97DW006

Shane S. Shull, Project Manager

January 01, 2013 - December 31, 2013

Midlands EQC Region - Aiken
206 Beaufort Street N.E.
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South Carolina Department of Health and Environmental Control

Table of Contents

1.0 PROJECT SUMMARY

The Environmental Surveillance and Oversight Program (ESOP) Drinking Water Monitoring Project, as part of South Carolina Department of Health and Environmental Control (SCDHEC), evaluates drinking water quality in communities that could potentially be impacted by Savannah River Site (SRS) operations. ESOP monitoring provides information to the public regarding the extent that radiological constituents may or may not have impacted community drinking water systems adjacent and downstream to the SRS. Additionally, ESOP provides analytical data from this project for comparison to published Department of Energy-Savannah River (DOE-SR) data. The project objectives are to collect monthly composite surface water samples from one location upstream from the SRS (North Augusta) as well as three locations downstream from the SRS (Purrysburg Beaufort/Jasper (B/J), Chelsea B/J, and Savannah, GA). Additionally, semi-annual grab samples are collected from selected public drinking water systems within 30 miles from the center point of the SRS. SCDHEC analyzes all samples for gross alpha, non-volatile beta, gamma-emitting radionuclides, and tritium. Non-detect values are not included when calculating averages for each analyte.

The study area was established as a 30-mile radius circle centered in the SRS. The 30-mile sampling perimeter was selected based on drinking water system availability and overall proximity to the SRS. Using the SCDHEC geographical information system, 19 primarily groundwater fed and four surface water fed public drinking water systems were selected (Section 4.0, Map 1). These sample locations were selected specifically to help ensure complete sample coverage around the perimeter of the SRS. These water systems serve approximately 281,000 customers with approximately 105,000 receiving their water from groundwater sources (Section 5.0, Table 1). None of the drinking water samples collected originated from the SRS drinking water system.

As part of the drinking water project, sampling of random background locations, also known as (DWB: Drinking Water Background) samples, will continue throughout the state of South Carolina. Sample locations are selected at random using a designated quadrant system that extends throughout the state. Once a random set of quadrants have been selected, samples are collected from identifyable public drinking water systems within the quadrants.

During 2013, DOE-SR collected surface water samples from four locations (North Augusta, Purrysburg B/J, Chelsea B/J, and Savannah) that are colocated with the ESOP surface water fed drinking water systems. Currently, DOE-SR does not conduct drinking water sampling from groundwater fed wells off-site.

Historically, tritium has been the primary environmental release due to operations at the SRS. Tritium was produced as a nuclear weapon enhancement component. The majority of tritium releases came from the production reactors and the separation areas (Till et al 2001). In addition to SRS activities, tritium can potentially be attributed to releases from other nuclear facilities within close proximity of the study area.

Man-made gamma-emitting radionuclides, such as iodine-131, cesium-137, and cobalt-60, were products of SRS activities. These radionuclides were produced by fission in reactor fuels and

were primarily released in surface streams in the 1960s or into the atmosphere in the separation areas (WSRC 1998).

2.0 RESULTS AND DISCUSSION

Surface Water System Network Results

Tritium

Historically, the primary tritium releases originated from processes associated with the reactors (R, P, K, L, and C), separation facilities (F-area and H-area), the heavy water facility (D-area), and tritium recovery in the tritium facilities. The main types of tritium releases originate from site facilities, migration from seepage basins in F-area and H-area, the burial ground, and the K-area containment basin. In the early operational years, nearly 100% of the releases to streams were related to direct releases. After the cessation of operational activities, most releases were a result of migration from the seepage basins. Since the mid 1970s, migration and outcropping to streams have accounted for most of the SRS tritium released to surface water (Till et al. 2001).

Tritium is naturally present in surface waters at 10 to 30 picocuries per liter (pCi/L) (ANL 2007). The maximum contaminant level (MCL) developed by the United States Environmental Protection Agency (USEPA) for tritium in drinking water is an average of 20,000 pCi of tritium per liter of water, over the course of a year. Tritium continues to be the most abundant radionuclide detected in public drinking water in the study area (Data Appendix). Detected in both groundwater and surface water systems, the ESOP tritium detectable average was 319 pCi/L (based on a single detection) for groundwater systems and 402.38 (± 113.68) pCi/L for surface water systems. The DOE-SR detectable average for surface water systems was 370 (± 16.98) pCi/L (SRNS 2014). These tritium activities, however, were quite low when compared to the USEPA drinking water MCL of 20,000 pCi/L (USEPA 2002). To view ESOP drinking water data, please access the electronic file *Appendix A – ESOP Data*.

Based on a review of the surface water data from the Savannah River, tritium was detected above the lower limit of detection (LLD) in approximately 69% of surface water composite samples. The LLD range for tritium in 2013 was 196 pCi/L to 251 pCi/L. Detectable tritium activity in these samples yielded an average of 402.38 (± 113.68) pCi/L and ranged from 221 to 923 pCi/L. These tritium activities are measurable but not significant when compared to the 20,000 pCi/L USEPA MCL (USEPA 2002). Of the 12 upstream North Augusta surface water composites, there were three detections above the LLD. Tritium activity in the North Augusta samples ranged from 244 to 331 pCi/L and averaged 277.33 (± 46.93) pCi/L. Of the 36 composite samples collected downstream from the SRS, 31 samples had a tritium activity slightly above the LLD. The tritium activity in these three downstream intakes (Chelsea B/J, Purrysburg B/J, and Savannah) had a range of 221 to 923 and averaged 460 (± 82.61) pCi/L. Figure 1 of Section 5.0 illustrates the trending data for surface water fed systems over the past five years.

Three background samples were also collected during the 2013 sampling event. Laboratory results revealed a single tritium detection of 228 pCi/L at DWB01. This activity is well below the 20,000 pCi/L USEPA drinking water standard and also below the calculated average for groundwater fed systems (319 pCi/L).

Gamma-emitting Radionuclides

Gamma-emitting radionuclides of concern (Section 5.0, Table 2) were not detected above the LLD and have not been detected for any of the surface water samples collected by ESOP or DOE-SR since 2002.

Gross Alpha and Non-volatile Beta

Gross alpha-emitting radionuclides were released to liquid effluent from the reactor materials area (M-area), separations areas (F-area and H-area), and the reactor areas. The primary stream affected by the M-area releases was Tims Branch, that ultimately flows into Upper Three Runs. Fourmile Creek is the stream most affected by releases coming from the separation areas. Releases from the reactor areas affected all streams with the exception of Upper Three Runs (Till et al 2001). Gross non-volatile beta-emitting radionuclides were released to liquid effluent from the separations areas (F-area and H-area). The aforementioned streams ultimately flow directly or indirectly into the Savannah River.

Gross alpha was detected at North Augusta, Chelsea B/J, Purrysburg B/J, and Savannah with an average activity of 6.39 (± 4.64) pCi/L and ranged from 1.23 to 12.30 pCi/L. Non-volatile beta was detected at three locations (Chelsea B/J, Purrysburg B/J, and Savannah). These three locations revealed non-volatile beta detections that averaged 4.77 (± 0.11) pCi/L and ranged from 4.58 to 5.06 pCi/L. Speciation is not conducted for gross alpha or non-volatile beta unless there is detection above the USEPA MCL of 15 pCi/L or 8 pCi/L, respectively (USEPA 2002). Alpha and beta activity is likely attributable to naturally occurring radionuclides.

Section 5.0 (Figures 2 and 3) illustrates the trends in gross alpha and non-volatile beta activities since the year 2009. Although there are several detections identified during the 2013 sampling event, none of these analytes have exceeded the USEPA established MCL for each of these contaminants. As a result, these concentrations are not considered to be known human health risks.

Groundwater System Network Results

Tritium

Based on a review of the analytical data, only one of the 19 groundwater fed systems sampled had tritium activities above the LLD. This tritium detection, located at the Talatha public water system, yielded an activity of 319 pCi/L. This tritium activity is measurable but not significant when compared to the 20,000 pCi/L USEPA MCL (USEPA 2002) and the background activity of 228 pCi/L. Figure 1 in Section 5.0 shows trending data from the past five years for the samples from groundwater fed systems that showed detections.

Gamma-emitting Radionuclides

Gamma-emitting radionuclides of concern were not detected above the LLD in any groundwater samples tested in 11 years of testing by ESOP. As a result of the history of non-detections for gamma-emitting radionuclides, no summary statistics were calculated (Section 6.0).

Gross Alpha and Non-volatile Beta

Gross alpha was detected in eight of the 19 primarily groundwater fed systems (New Ellenton, Williston, Montmorenci, Hilda, Jackson, Healing Springs, SCAT Park, and College Acres) tested in 2013. The range for gross alpha activity was 1.63 to 8.09 pCi/L with an average activity of 4.62 (± 2.04) pCi/L. All gross alpha samples were below the USEPA MCL of 15 pCi/L (USEPA 2002). Speciation is not conducted for gross alpha unless there is a detection above the USEPA MCL of 15 pCi/L. Summary statistics for groundwater fed systems are located in Section 6.

Non-volatile beta was detected in three of the 19 groundwater systems (Aiken, Jackson, and Barnwell) tested in 2013. The samples collected at these locations yielded an average activity of 3.89 (± 1.57) pCi/L. All 19 non-volatile beta samples collected were below the USEPA MCL of 8 pCi/L (USEPA 2002). Speciation is not conducted for non-volatile beta unless there is a detection above the USEPA MCL of 8 pCi/L.

Background Sample Results

During the 2013 drinking water sampling event, three background samples were collected at random throughout the state of South Carolina (DWB01, DWB02, DWB03). Each of these samples were tested for gross alpha, non-volatile beta, gamma, and tritium. Laboratory results revealed a single detection for tritium of 228 pCi/L at DWB01. Although this activity is detectable, it is well below the USEPA established 20,000 pCi/L drinking water limit.

ESOP and DOE-SR Data Comparison

DOE-SR conducts monthly composite sampling at the four water treatment plants (North Augusta, Purrysburg B/J, Chelsea B/J and Savannah) that use Savannah River surface water to supply drinking water for the local population.

Based on the DOE-SR 2013 annual report (SRNS 2014), tritium in the three downstream water intakes averaged 435 (± 17.53) pCi/L ranging from 76 to 1030 pCi/L while ESOP downstream detections averaged 460 (± 201.20) pCi/L ranging from 221 to 923 pCi/L. Figure 4 and Figure 5 illustrate DOE-SR finished water tritium detection averages over a five year time period. DOE-SR had an overall detected tritium average of 370 (± 16.98) pCi/L for all surface water samples collected in 2013. This was lower than the ESOP detected tritium average of 402 (± 113.68) pCi/L for the same period. The ESOP calculated average tritium activity for North Augusta is 277 (± 46.93) pCi/L. This average is lower than the averages for the other downstream locations due to the fact North Augusta is located upstream from the SRS (Section 5.0, Table 3). All samples were within two standard deviations as well as being lower than the USEPA MCL of 20,000 pCi/L (USEPA 2002). Tritium activity in 2013 is within two standard deviations of the running 5-year average. These activity levels are well below the USEPA MCL. Naturally

occurring radionuclides may account for variability in tritium activities. Tritium continues to be the most abundant radionuclide in the Savannah River.

Gamma-emitting radionuclides were not detected in DOE-SR or ESOP samples in 2013. DOE-SR and ESOP detected non-volatile beta in surface water samples. The DOE-SR non-volatile beta average (for all four locations) of 2.10 (± 0.12) pCi/L was slightly less than the ESOP non-volatile beta average (for Purrysburg B/J, City of Savannah, Chelsea B/J and North Augusta) of 4.77 (± 0.11) pCi/L. DOE-SR reported an average gross alpha activity (for all four locations) of 0.10 (± 0.05) pCi/L. ESOP had surface water gross alpha detections at all four locations with an average of 6.39 (± 4.64) pCi/L. All detections were less than the established USEPA MCL for gross alpha and non-volatile beta in drinking water (USEPA 2002).

Alphas (or betas) are not directly comparable due to the unknown nature (species) of the contributing alphas (or betas) in any two compared samples.

3.0 CONCLUSIONS AND RECOMMENDATIONS

Tritium continues to be the most abundant radionuclide detected in public drinking water supplies potentially impacted by the SRS. Tritium was detected in both groundwater and surface water systems. However, the observed tritium activities are low when compared to the USEPA MCL for Tritium in drinking water, which is an average of 20,000 pCi of tritium per liter of water, over the course of a year. Detections of gross alpha and non-volatile beta radionuclides of concern were all below their respective MCLs. Comparative analysis with DOE-SR for groundwater systems cannot be performed because DOE-SR does not sample groundwater systems off the Savannah River Site. Due to this fact, it is of great importance that SCDHEC continues to monitor these off-site public water systems in the event these wells are impacted by contaminated groundwater from the SRS (SRNS 2014).

The SCDHEC Drinking Water Monitoring Project continues to be an important source of essential data for assessing human health exposure pathways. Due to the extent of the surface water contamination on the SRS and its potential to migrate south/southwest and discharge to the Savannah River, SCDHEC will continue to monitor surface water quality to identify any future contaminant migration that could potentially impact drinking water systems downstream from the SRS. SCDHEC will continue sampling to provide the public with an independent source of radiological data for drinking water systems within the SRS study area.

SCDHEC will continue collecting background samples that will provide a better idea of what ambient radioactivity levels are present in South Carolina. The data from these samples will be used in statistical analyses with the routine samples.

Currently, additional drinking water systems in the area around the SRS are being considered for routine sampling. If these locations prove to be beneficial to the drinking water project, they will be added to the project and included in all future sampling events.

4.0 Map

Map 1. SCDHEC ESOP Drinking Water Network

5.0 Tables and Figures

Table 1. Drinking Water Systems Sampled by ESOP

System Number	System Name	Number of Taps	Population
0210001	Aiken	18,443	42,374
0210002	Jackson	1,309	3,602
0210007	New Ellenton	2,231	5,303
0220001	Langley Water District	367	838
0220002	College Acres Public Water District	529	1,350
0220003	Bath Water District	314	1,064
0220004	Beech Island	3,094	7,436
0220005	Talatha Water District	571	1,553
0220006	Breezy Hill Water District	5,080	12,495
0220008	Montmorenci Water District	1,396	3,428
0220012	Valley Public Service Authority	3,409	7,803
0310001	Allendale	1,521	4,052
0610001	Barnwell	2,494	6,727
0610002	Williston	1,650	3,307
0610003	Blackville	1,141	2,973
0610004	Hilda	131	466
0610005	Elko	150	462
0670075	Healing Springs	1	6*
0670918	SCAT Park	6	125
0210003F	North Augusta	12,022	31,506
0720003F	Chelsea B/J	44,227	133,353
0720004F	Purrysburg B/J		
SAVF	Savannah	35	10,619
	TOTAL	100,121	280,842
	Approximate Groundwater	43,837	105,364
	Approximate Surface Water	56,284	175,478

***** This information is likely higher due to public access to the natural spring.
Note: Data was obtained from SCDHEC Environmental Facility Information System database.

Tables and Figures

Table 2. Gamma Analyte Table

Radioisotope	Abbreviation
Actinium-228	Ac-228
Americium-241	Am-241
Berylium-7	Be-7
Cerium-144	Ce-144
Cobalt-58	Co-58
Cobalt-60	Co-60
Cesium-134	Cs-134
Cesium-137	Cs-137
Europium-152	Eu-152
Europium-154	Eu-154
Europium-155	Eu-155
Iodine-131	I-131
Potassium-40	K-40
Manganese-54	Mn-54
Sodium-22	Na-22
Lead-212	Pb-212
Lead-214	Pb-214
Radium-226	Ra-226
Ruthenium-103	Ru-103
Antimony-125	Sb-125
Thorium-234	Th-234
Yttrium-88	Y-88
Zinc-65	Zn-65
Zirconium-95	Zr-95

Table 3. DOE-SR and ESOP Data Comparisons

	ESOP Tritium	DOE-SR Tritium	ESOP Gross Alpha	DOE-SR Gross Alpha	ESOP NV Beta	DOE-SR NV Beta
North Augusta	277.00	173.00	12.30	0.14	<LLD	1.95
Chelsea B/J	528.00	460.00	2.98	0.14	4.84	2.37
Purrysburg B/J	484.00	422.00	7.89	0.07	4.64	1.89
Savannah	368.00	424.00	2.40	0.05	4.82	2.19
Average	402.38	369.75	6.39	0.10	4.77	2.10

Tables and Figures

Figure 1. ESOP Yearly Tritium Averages in Drinking Water Systems

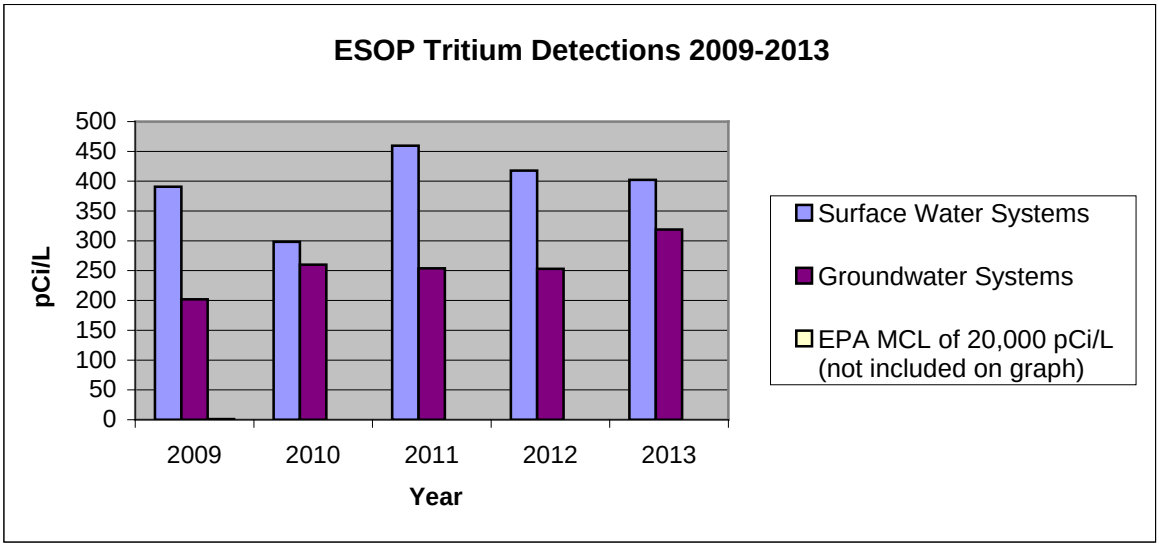
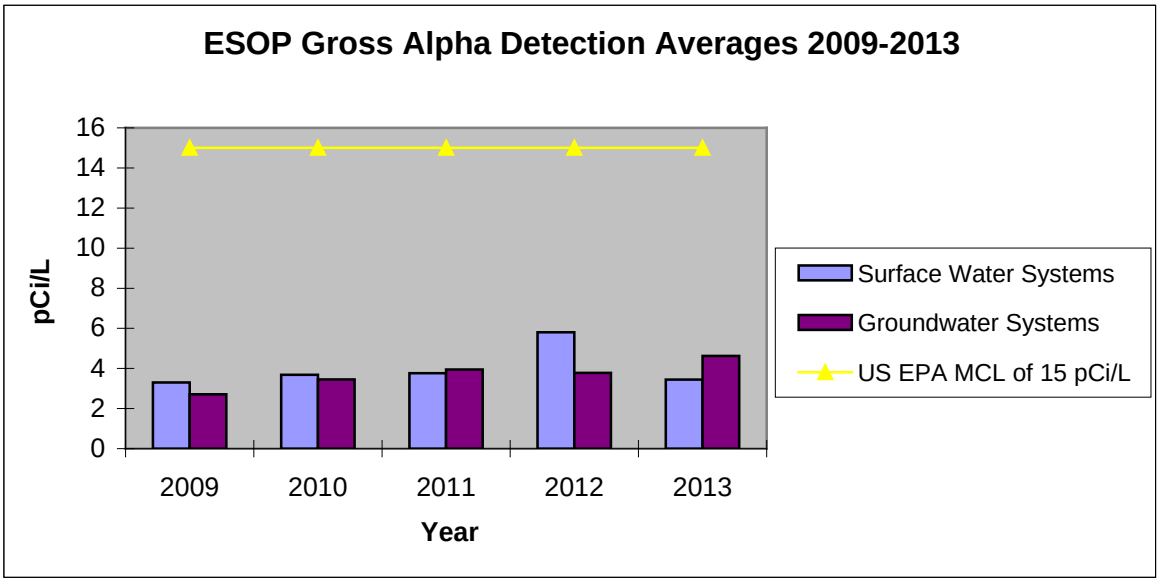
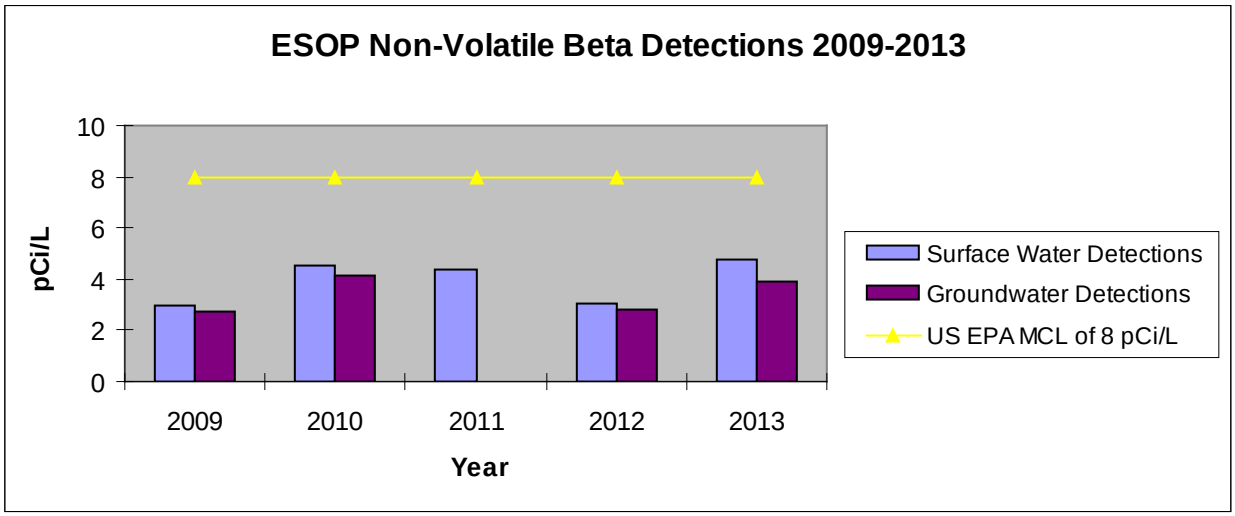


Figure 2. ESOP Yearly Gross Alpha Averages in Drinking Water Systems



Tables and Figures

Figure 3. ESOP Yearly Non-Volatile Beta Averages in Drinking Water Systems



Note: Missing bar for 2011 indicates no NV Beta Detection for that year.

Figure 4. DOE-SR Yearly Tritium Averages in Drinking Water Systems

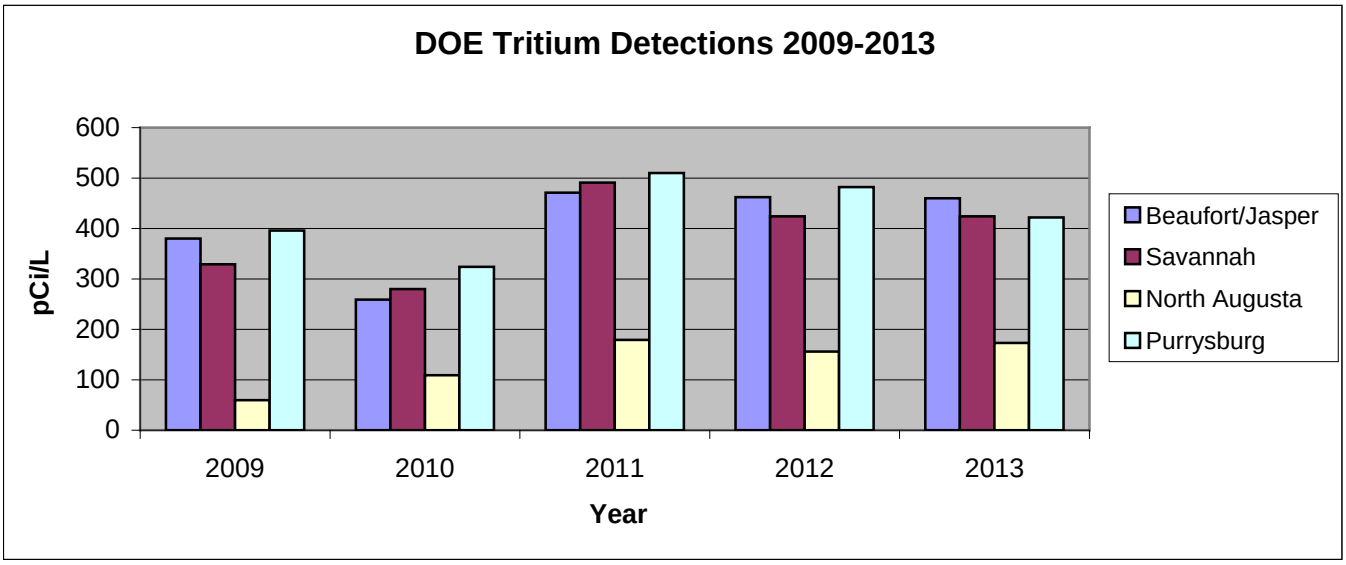


Figure 5a. ESOP/DOE-SR Comparison of 2013 Averages of Tritium in Drinking Water Systems

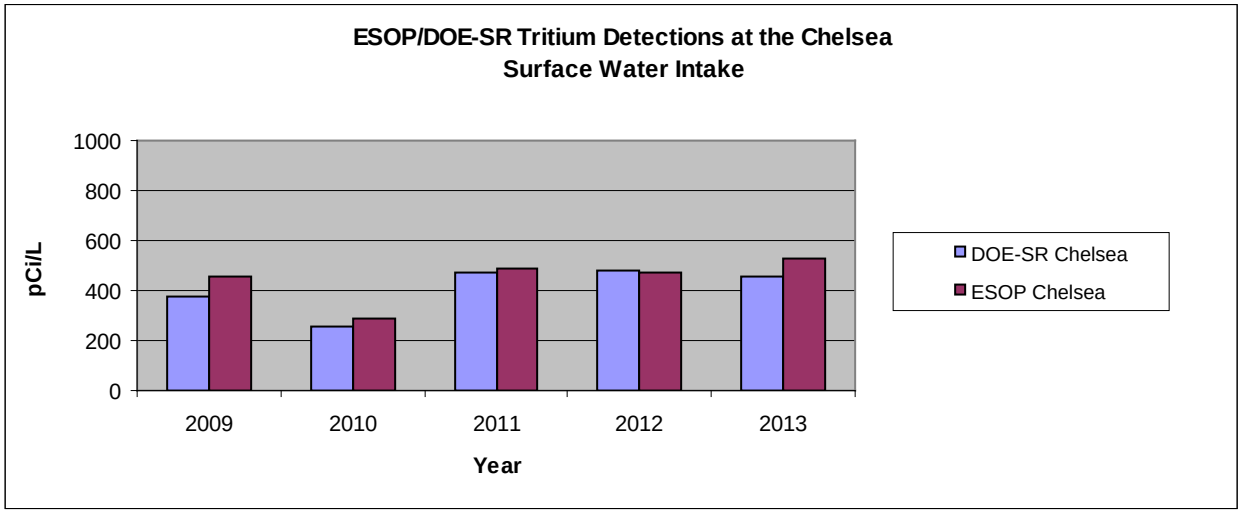


Figure 5b. ESOP/DOE-SR Comparison of 2013 Averages of Tritium in Drinking Water Systems

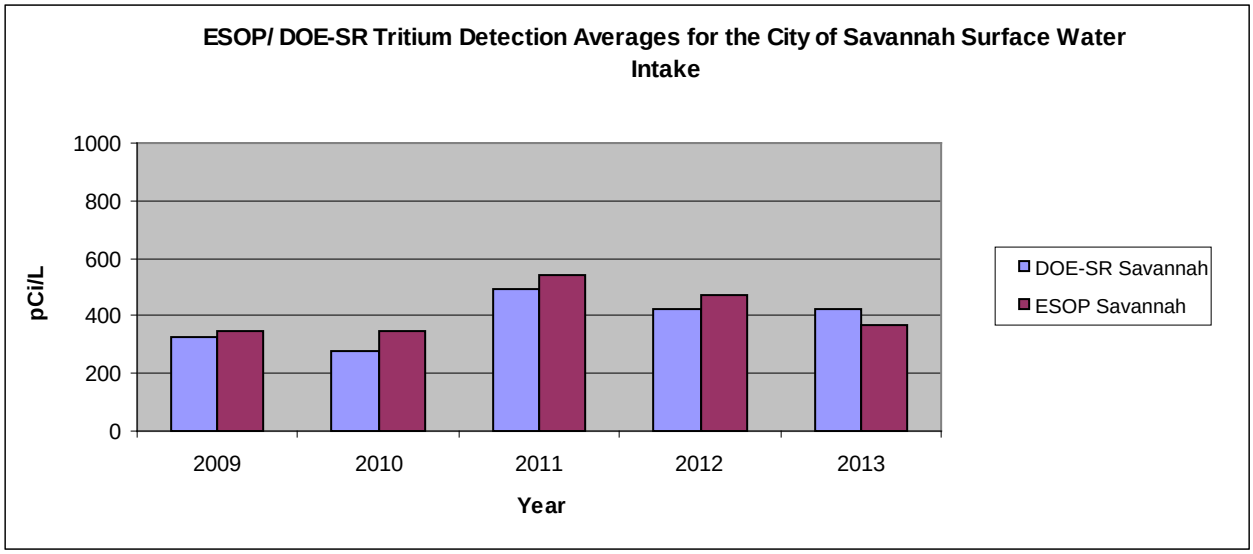


Figure 5c. ESOP/DOE-SR Comparison of 2013 Averages of Tritium in Drinking Water Systems

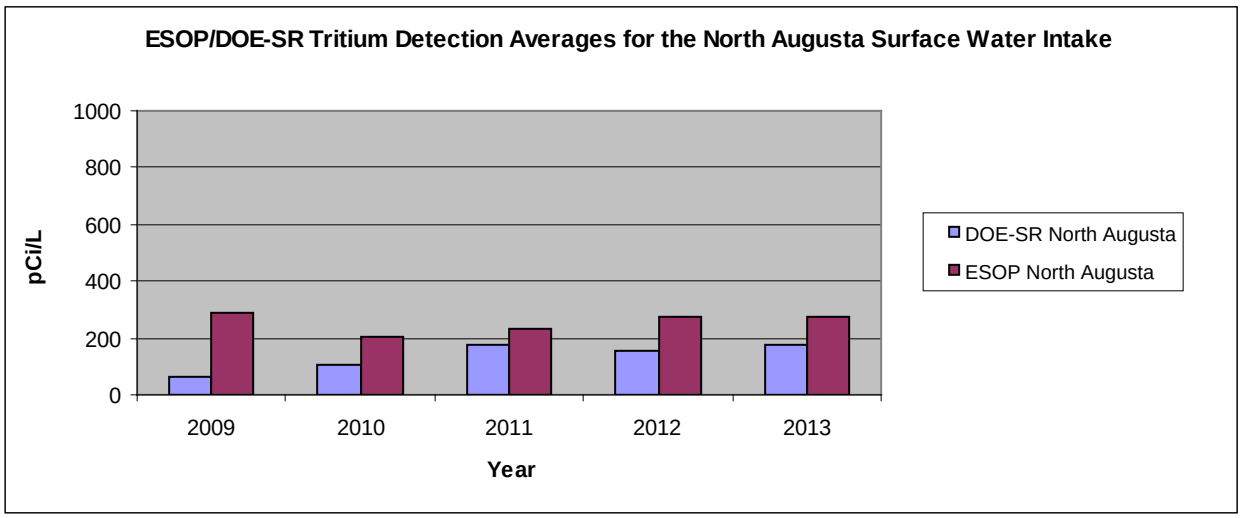
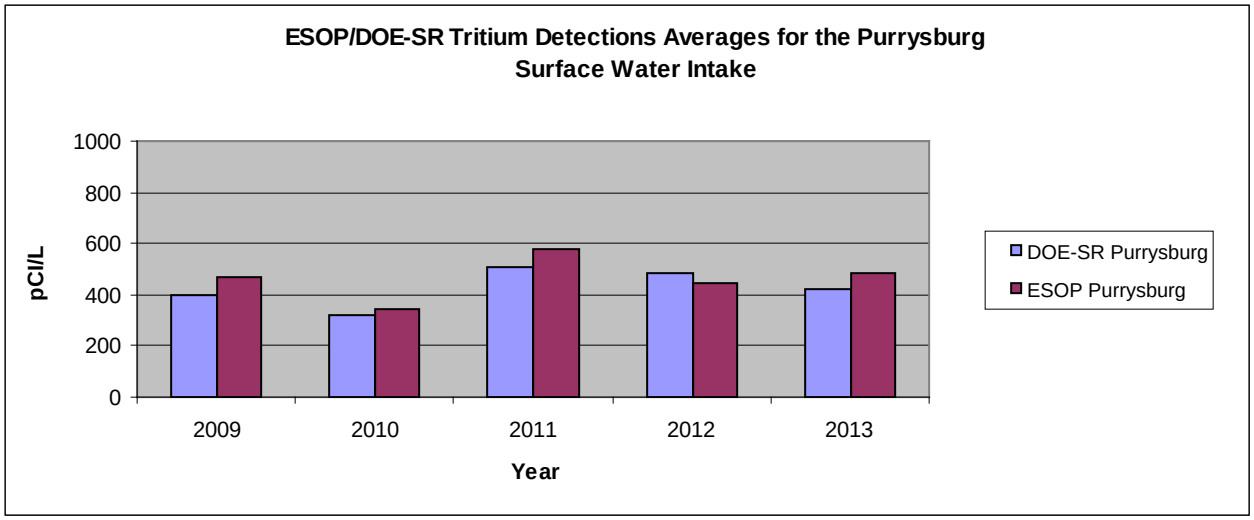


Figure 5d. ESOP/DOE-SR Comparison of 2013 Averages of Tritium in Drinking Water Systems



6.0 Summary Statistics

Notes:

1. N/A = Not Applicable
2. Min. = Minimum
3. Max. = Maximum
4. Num = Number of Detections
5. NV = Non-volatile
6. Avg. = Average
7. St. Dev. = Standard Deviation

2013 Surface Water Fed Summary Statistics

Radionuclide:	Gross Alpha (pCi/L)	Statistical Analysis					
System Name:	System Number:	Median	Avg.	St. Dev.	Max.	Min.	Num.
North Augusta SW	DW0210003F	12.30	12.30	N/A	12.30	12.30	1
Chelsea B/J SW	DW0720003F	2.98	2.98	N/A	2.98	2.98	1
City of Savannah	SAVF	2.4	2.4	1.32	12.3	2.06	2
Purrysburg SW	DW0720004F	7.89	7.89	N/A	7.89	7.89	1
Yearly Average of Detectable gross alpha			**6.39**				
Standard Deviation			**4.64**				

Radionuclide:	Gross NV Beta (pCi/L)	Statistical Analysis					
System Name:	System Number:	Median	Avg.	St. Dev.	Max.	Min.	Num.
North Augusta SW	DW0210003F	<LLD	<LLD	<LLD	<LLD	<LLD	0
Chelsea B/J SW	DW0720003F	4.84	4.84	N/A	4.84	4.84	1
City of Savannah	DWSAVF	4.82	4.82	0.34	5.06	4.58	2
Purrysburg B/J SW	DW0720004F	4.64	4.64	N/A	4.64	4.64	1
Yearly Average of Detectable non-volatile (NV) beta			**4.77**				
Standard Deviation			**0.11**				

Radionuclide:	Tritium (pCi/L)	Statistical Analysis					
System Name:	System Number:	Median	Avg.	St. Dev.	Max.	Min.	Num.
North Augusta SW	DW0210003F	257	277	46.93	331	244	3
Chelsea B/J SW	DW0720003F	517	528	229.65	923	221	9
City of Savannah	DWSAVF	262	368	167.86	741	234	11
Purrysburg B/J SW	DW0720004F	457	484	206.10	818	249	11
Yearly Average of Detectable tritium			**402.38**				
Standard Deviation			**113.68**				

2013 Groundwater Fed Summary Statistics

Radionuclide:	Gross Alpha (pCi/L)		Statistical Analysis				
System Name	System Number	Median	Avg.	St. Dev.	Max.	Min.	Num.
SCAT Park	0670918	4.86	4.86	4.57	8.09	1.63	2
Williston	0610002	2.64	2.64	N/A	2.64	2.64	1
New Ellenton	0210007	2.40	2.40	N/A	2.40	2.40	1
Hilda	0610004	6.17	6.17	N/A	6.17	6.17	1
Montmorenci	0220008	2.63	2.63	1.06	3.38	1.88	2
Healing Springs	0670075	6.53	6.53	N/A	6.53	6.53	1
Jackson	0210002	7.76	7.76	N/A	7.76	7.76	1
College Acres	0220002	3.96	3.96	0.04	3.98	3.93	2
Yearly Average of Detectable gross alpha			**4.62**				
Standard Deviation			**2.04**				

Radionuclide:	Gross NV Beta (pCi/L)		Statistical Analysis				
System Name	System Number	Median	Avg.	St. Dev.	Max.	Min.	Num.
Aiken	0210001	3.05	3.05	N/A	3.05	3.05	1
Jackson	0210002	5.70	5.70	N/A	5.70	5.70	1
Barnwell	0610001	2.93	2.93	N/A	2.93	2.93	1
Yearly Average of Detectable gross nv beta			**3.89**				
Standard Deviation			**1.57**				

Radionuclide:	Tritium (pCi/L)		Statistical Analysis				
System Name	System Number	Median	Avg.	St. Dev.	Max.	Min.	Num.
Talatha Water	0220005	319	319	96.17	387	251	2
Yearly Average of Detectable tritium			**319**				
Standard Deviation			**N/A**				

LIST OF ACRONYMS

B/J	Beaufort-Jasper
DOE-SR	Department of Energy - Savannah River
DWB	Drinking Water Background (sample)
ESOP	Environmental Surveillance and Oversight Program
LLD	Lower Limit of Detection
MCL	Maximum Contaminant Level
SCAT	South Carolina Advanced Technology
SCDHEC	South Carolina Department of Health and Environmental Control
SRS	Savannah River Site
USEPA	United States Environmental Protection Agency

UNITS OF MEASURE

pCi/L	Picocuries per liter
±	Plus or minus. Refers to one standard deviation unless otherwise stated
±2	Plus or minus 2 standard deviations.

REFERENCES

Argonne National Laboratory (ANL). 2007. Health-Based Radionuclide Concentrations in Drinking Water and Air. Human Health Fact Sheet.

Savannah River Nuclear Solutions, LLC (SRNS). 2014. Savannah River Site Environmental Report for 2013. Savannah River Site Aiken, SC. SRNS-STI-2014-00007.

Till, J.E., et al. 2001. Savannah River Site Environmental Dose Reconstruction Project, Phase II: Source Term Calculation and Ingestion Pathway Data Retrieval, Evaluation of Materials Released From the Savannah River Site. RAC Report No. 1-CDC-SRS-1999-Final. Risk Assessment Corporation (RAC).

United States Environmental Protection Agency (USEPA). 2002. National Primary Drinking Water Regulations. Title 40, Chapter 1, Part 141.

Washington Savannah River Company (WSRC). 1998. Assessment of Radionuclides in The Savannah River Site Environment-Summary (U), Environmental Protection Department, Environmental Monitoring Section, Aiken, South Carolina. WSRC-TR-98-00162.

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2013 Radiological Monitoring of Surface Water on and Adjacent to the Savannah River Site

Environmental Surveillance and Oversight Program

97RW002

Beth Cameron, Project Manager

January 01, 2013 - December 31, 2013

Midlands EQC Region - Aiken
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South Carolina Department of Health and Environmental Control

Table of Contents

1.0 PROJECT SUMMARY

The focus of the Radiological Monitoring of Surface Water (RSW) project is monitoring and surveillance of the streams and creeks on the Savannah River Site (SRS) as well as the Savannah River. This project is part of the South Carolina Department of Health and Environmental Control (SCDHEC) Environmental Surveillance and Oversight Program (ESOP). Since the Savannah River is the primary drinking water source for downstream communities, it is important to monitor radionuclide concentrations in the river. Surface water samples are collected and analyzed for radionuclides, and the results are compared to Department of Energy-Savannah River (DOE-SR) data. DOE-SR conducts surveillance and monitoring activities for the following purposes: determining concentrations and migration of radionuclides in the aquatic environment, detecting and verifying accidental releases, characterizing concentration trends, and determining associated impacts on human health and the environment. ESOP supports DOE-SR's objectives to ensure the primary goal of drinking water safety is established and met. These activities will allow the RSW project to generate independent data to compare with DOE-SR data. This data is shared with the public.

The RSW project analyzes water samples for many gamma-emitting radionuclides. Cesium-137 (Cs-137) continues to be the main gamma-emitting radionuclide detected in the SRS streams. The streams that were largely affected by Cs-137 are: Fourmile Branch, Pen Branch, Steel Creek, and Lower Three Runs Creek, with Steel Creek historically showing the highest activity (Till et al. 2001).

Alpha-emitting radionuclides were released to liquid effluent from M-Area, separation areas, and the reactor areas. The primary stream affected by the M-area releases was Tims Branch, which ultimately flows into Upper Three Runs Creek. Fourmile Branch is the stream most affected by releases coming from the separation areas. Releases from the reactor areas affected all streams with the exception of Upper Three Runs Creek (Till et al. 2001).

Beta-emitting radionuclides were released to liquid effluent from separation areas and the reactors. Fourmile Branch is the stream primarily affected by releases from the separations areas. Steel Creek, Pen Branch, and Lower Three Runs Creek were mainly affected by releases from the reactors. Strontium-90 is a main contributor of beta activity and came primarily from the reactors (Till et al. 2001).

The RSW project continues to collect surface water samples from 13 specific locations within and outside of the SRS boundary as part of an ambient sampling network (Section 4.0, Map). Section 5.0, Table 1 identifies sample ID, location, rationale, and frequency. Seven of these locations use ISCO™ automatic water samplers to collect aliquots every 30 minutes to produce a composite. Grab samples are collected from the remaining six locations. Samples are collected three days per week (Monday, Wednesday, and Friday) from the locations that have automatic water samplers. The composite sampler is utilized to collect composite samples over a 48-hour period (Monday through Wednesday and Wednesday through Friday) or a 72-hour period (Friday through Monday). One sample is poured from the composite for same day tritium analysis. Another sample is poured into a secondary bottle from the composite and combined for the whole week. This weekly composite sample is then combined in a tertiary container to be analyzed monthly for gross alpha, gross beta, and gamma (Table 1.). Some locations were

chosen because they are considered to be public access locations. The public access locations are downstream of SRS, with the exception of the background location of Jackson Boat Landing (SV-2010), providing a potential means for exposure to radionuclides.

Quarterly samples are collected for tritium analysis from the five creek mouths that flow from SRS directly into the Savannah River (Upper Three Runs Creek, Beaver Dam Creek, Fourmile Branch, Steel Creek, and Lower Three Runs Creek). Pen Branch is not sampled because the Savannah River Swamp interrupts the flow for this creek and there is no creek mouth access.

An enhanced surface water monitoring program is implemented to provide downstream drinking water customers with advance notice of the potential for increased tritium levels in the Savannah River due to an SRS release. This early detection facet is possible because of the continuous monitoring of the six SRS streams that flow to the Savannah River. Samples for tritium analysis are collected from the seven locations with automatic water samplers. Additionally, a grab sample is collected from Johnson's Boat Landing (SV-2080) and US Highway 301 at the Savannah River (SV-118). Sampling devices at SV-118 consist of an ISCO™ composite sampler and a 24-bottle carousel sampler. The carousel sampler provides hourly samples collected for the same respective time frame as the composite sampler. This gives ESOP a more accurate method for detecting potential tritium concentrations. Samples are analyzed at the Midlands EQC Region-Aiken Environmental Quality Control (EQC) tritium laboratory on the day of collection. Results from the tritium analysis are used to project tritium activity in the Savannah River. Results from the enhanced program are considered to be unofficial results and are used only for notification purposes.

An additional component of the RSW Project is the Supplemental Surface Water Monitoring Program implemented in 2005. The purpose of this sampling program is to monitor any potential releases of radionuclides. Sample locations are located along McQueen Branch, Upper Three Runs, Fourmile Branch, and Steel Creek. This monitoring was established for early detection of unplanned releases from SRS source term areas. Samples are collected on Tuesday, prepped the same day, and analyzed for gamma emitting radiolnuclides the next day as part of a quick scan early detection procedure. These samples are collected as unofficial results for notification purposes only.

In August of 2007, ESOP began collecting ambient grab samples from a location at SC Highway 125 and Lower Three Runs Creek. This sampling was conducted in response to elevated tritium levels detected in groundwater samples near the Energy Solutions (formerly Chem-Nuclear) facility in Snelling, SC. The purpose of adding this location was to differentiate any potential tritium contributions to Lower Three Runs from Energy Solutions from SRS activities. This sampling location was moved to a location (Lower Three Runs Creek and Patterson Mill Road, SV-328) closer to the Energy Solutions source in 2007.

Quarterly sampling for iodine-129 (I-129) and technetium-99 (Tc-99) was conducted at the ambient location on Fourmile Branch due to concerns that these are possible constituents related to effluent from the burial grounds.

The automatic water samplers located at SV-118 are powered by alternating current. This power source can be interrupted at times due to power outages most often associated with seasonal

thunderstorms. Although this interruption of power is infrequent, when it occurs, only a partial sample may be collected in the composite sampler. Additionally, the sampling program in the carousel sampler may be halted, resulting in missed samples during a sampling event. All but two of the other automatic water samplers are powered by solar panels and lead acid batteries. Solar panels will be purchased for the remaining two locations within the next year. Any missed composite samples are collected as grab samples.

2.0 RESULTS AND DISCUSSION

SCDHEC Surface Water Data

All monitoring data are in Appendix A-ESOP Data, and summary statistics are in Section 6.0. All established sampling locations are in Section 5.0, Table 1.

Tritium

In 2013, tritium activity was detected at all ambient locations where weekly samples were collected (Section 6.0, Summary Statistics). Average tritium activities at Jackson Boat Landing (SV-2010) and Upper Three Runs Creek at United States Forestry Service (USFS) Rd E-2 (SV-2027), were lower than average tritium activities at the other ambient sample locations. These locations are upstream from SRS impacts and considered background locations. The average detected tritium for these locations was 306 (±105) picocuries per liter (pCi/L) for SV-2010 and 356 (±389) pCi/L for SV-2027. Fourmile Branch at USFS Rd. 13.2 (SV-2039) and Pen Branch at USFS Rd. 13.2 (SV-2047) continue to yield the highest levels of tritium activity. SV-2039 had an average tritium activity of 40,348 (±9,941) pCi/L and SV-2047 had an average tritium activity of 19,611 (±7,435) pCi/L. Detected tritium activity at all locations ranged from 171 pCi/L at SV-2053 to 59,198 pCi/L at SV-2039**.** Section 5.0, Figure 1 shows trending for 2009-2013 tritium averages.

Tritium activity in the Savannah River at the creek mouths of the five SRS streams was monitored on a quarterly basis in 2013 (Section 6.0, Summary Statistics). Three samples were collected each quarter at Fourmile Branch (SV-2015): one from the creek mouth, one from 30 feet downstream of the creek mouth, and one from 150 feet downstream of the creek mouth. Samples were taken at these three intervals to show the effect of the mixing zone created by the Savannah River flow. Samples collected directly at the creek mouth of Fourmile Branch (SV-2015a) had the highest average tritium activity (25,611 (±15,545) pCi/L) of all creek mouth locations**.**

Gamma

As part of a gamma spectroscopy analysis, samples were analyzed for gamma-emitting radionuclides (Section 5.0, Table 2) at the Radiological Environmental Monitoring Division (REMD) Laboratory in Columbia, SC. Cesium-137 has been historically detected in samples collected from Fourmile Branch and Lower Three Runs Creek. These streams were affected by releases from reactor activities, so periodic Cs-137 detections are likely in samples collected from these locations (Till et al. 2001). Cobalt-60 (Co-60) and Americium-241 (Am-241) results were incorporated in the RSW project report for comparison purposes with DOE-SR data. All

Cs-137, Co-60, and Am-241 results from the gamma analysis in 2013 were below their respective Minimum Detectable Activities (MDA).

Alpha

In 2013, alpha-emitting radionuclides were detected at all but one of the locations where monthly composite samples were collected (Section 6.0, Summary Statistics). Average detected activity over all locations ranged from a single detection of 1.80 pCi/L at SV-2018 to a single detection of 17.50 pCi/L at SV-2053. SV-325 had detections in four of the 12 samples collected averaging 4.19 (± 1.47) pCi/L.

Historically, SV-325 yields detections for alpha activity (SCDHEC 2000-2013). Isotopic analysis performed by DOE-SR revealed the source to be natural uranium (SRNS 2011). This may contribute to the common occurrence of alpha detections at this location. The 2013 average alpha activity at SV-325 was below the United States Environmental Protection Agency (USEPA) Maximum Contaminant Level (MCL) for drinking water of 15 pCi/L (USEPA 2002). Beginning in 2009, samples collected at this location exhibited particles of sediment and detritus usually associated with rain events. This increase in turbidity seems to be related to storm events. Samples with high turbidity can have potential interferences during alpha/beta analysis. Alpha particles, and to a lesser extent, beta particles, are attenuated by salts and solids dried onto a planchet (USEPA 2010). This sampling location is monitored for turbidity to ensure it is not a concern in collected samples. Ambient monitoring average annual alpha trends for 2009-2013 are shown in Section 5.0, Figure 2.

Beta

Beta-emitting radionuclide activity was detected in seven of nine locations where monthly composite samples were collected (Section 6.0, Summary Statistics). The average activity ranged from a single detection of 2.95 pCi/L at SV-2047 to 6.09 (±2.14) pCi/L at SV-2039. Fourmile Branch (SV-2039) was primarily affected by releases from the separation areas, so gross beta detections can be expected at this location (Till et al. 2001). Ambient monitoring average annual beta trends for 2009-2013 are shown in section 5.0, Figure 3. USEPA has established a MCL of 4 millirem per year for beta particle and photon radioactivity from man-made radionuclides in drinking water. The USEPA screening MCL for gross beta-emitting particles for drinking water systems is 50 pCi/L minus natural K-40 (USEPA 2002), and all averages were below this limit.

Iodine-129 and Technetium-99

Iodine-129 and Technetium-99 sampling of the ambient location on Fourmile Branch was monitored on a quarterly basis. There was a Tc-99 detection in one of the four quarterly samples above the MDA of 2.65 (±1.00) pCi/L. There was a Tc-99 detection in one of the four quarterly samples of 5.17 (±2.72) pCi/L.

USEPA has established a MCL of 4 millirem per year for beta particle and photon radioactivity from man-made radionuclides in drinking water. Tc-99 would be covered under this MCL. The average concentration of Tc-99, which is assumed to yield 4 millirem per year, is 900 pCi/L.

The average concentration of I-129, which is assumed to yield 4 millirem per year, is 1 pCi/L. If other radionuclides, emitting beta particles and photon radioactivity are present in addition to Tc-99 and I-129, the sum of the annual dose from all the radionuclides shall not exceed 4 millirem/year (USEPA 2002).

SCDHEC/DOE-SR DATA COMPARISON

Data from 2013 reported in this project were compared to DOE-SR reported results (Section 5.0, Tables 3, 4, 5). The SCDHEC and DOE-SR colocated sampling sites were Tims Branch at Road C, Upper Three Runs Creek at Road A, Fourmile Branch at USFS Road 12.2, Pen Branch and USFS Road 13.2, Steel Creek at Road A, Lower Three Runs Creek at SRS Road B and at Patterson Mill Road, and the Savannah River at US Highway 301 Bridge. DOE-SR sampled at several other locations along these streams. However, the data comparisons are only for the colocated sample sites.

Tritium

DOE-SR reports all values, including values that are negative and ones that are below detection. Therefore, DOE-SR reports an average for all locations derived from detections and non-detection values. For the purpose of this report, the average, median, and standard deviation for all DOE-SR data were recalculated using detections only for a more accurate comparison. SCDHEC and DOE-SR had detections for tritium at all colocated sample locations (Section 5.0, Table 3). DOE-SR average tritium activities for all colocated sites were within one standard deviation (SD) of SCDHEC average tritium activities. SCDHEC and DOE-SR samples indicate that Fourmile Branch (40,348 (±9,941) pCi/L and 36,042 (±7,723) pCi/L, respectively) and Pen Branch (19,611 (±7,435) pCi/L and 16,515 (±6,168) pCi/L, respectively) have the highest average tritium activity of all SRS streams**.** The 2013 SCDHEC and DOE-SR tritium results appear to be consistent with historically reported data values (Section 5.0, Figures 4-9, SCDHEC 2008-2013, SRNS 2009-2014).

Gamma

DOE-SR reported a single detection of Am-241 (0.010 (±0.004) pCi/L (SRNS 2014) at the colocated sample site Fourmile Branch at Road A-12.2. DOE-SR reported another single detection of Am-241 (0.009 (±0.005) pCi/L (SRNS 2014) at Steel Creek at Road A colocated sample site. SCDHEC had no gamma detected above the MDA in 2013.

Alpha

DOE-SR detected gross alpha activity at all of the colocated sampling locations in 2013. SCDHEC detected gross alpha activity at all but one of the colocated sample locations (Section 5.0, Table 4). SCDHEC and DOE-SR samples collected from Tims Branch exhibited the highest gross alpha average activity (12.06 (±16.20) pCi/L and 9.76 (±18.40) pCi/L, respectively) (SRNS 2014). SCDHEC and DOE-SR samples collected from Tims Branch at Road C exhibited the highest single gross alpha concentration (41.00 pCi/L and 64.90 pCi/L, respectively) (SRNS 2014).

Beta

SCDHEC detected gross beta activity at five of the seven colocated sampling locations while DOE-SR detected activity at all seven colocated locations (Section 5.0, Table 5). SCDHEC did not detect gross beta activity at Upper Three Runs, or Steel Creek. SCDHEC and DOE-SR samples collected from Tims Branch exhibited the highest gross beta average activity (6.01 (±0.76) pCi/L and 3.25 (±3.65) pCi/L, respectively) (SRNS 2014).

Iodine-129 and Technetium-99

SCDHEC and DOE-SR do not have a collocated sampling site for Iodine-129 and Technitium-99. Therefore, these analytes were not compared.

3.0 CONCLUSIONS AND RECOMMENDATIONS

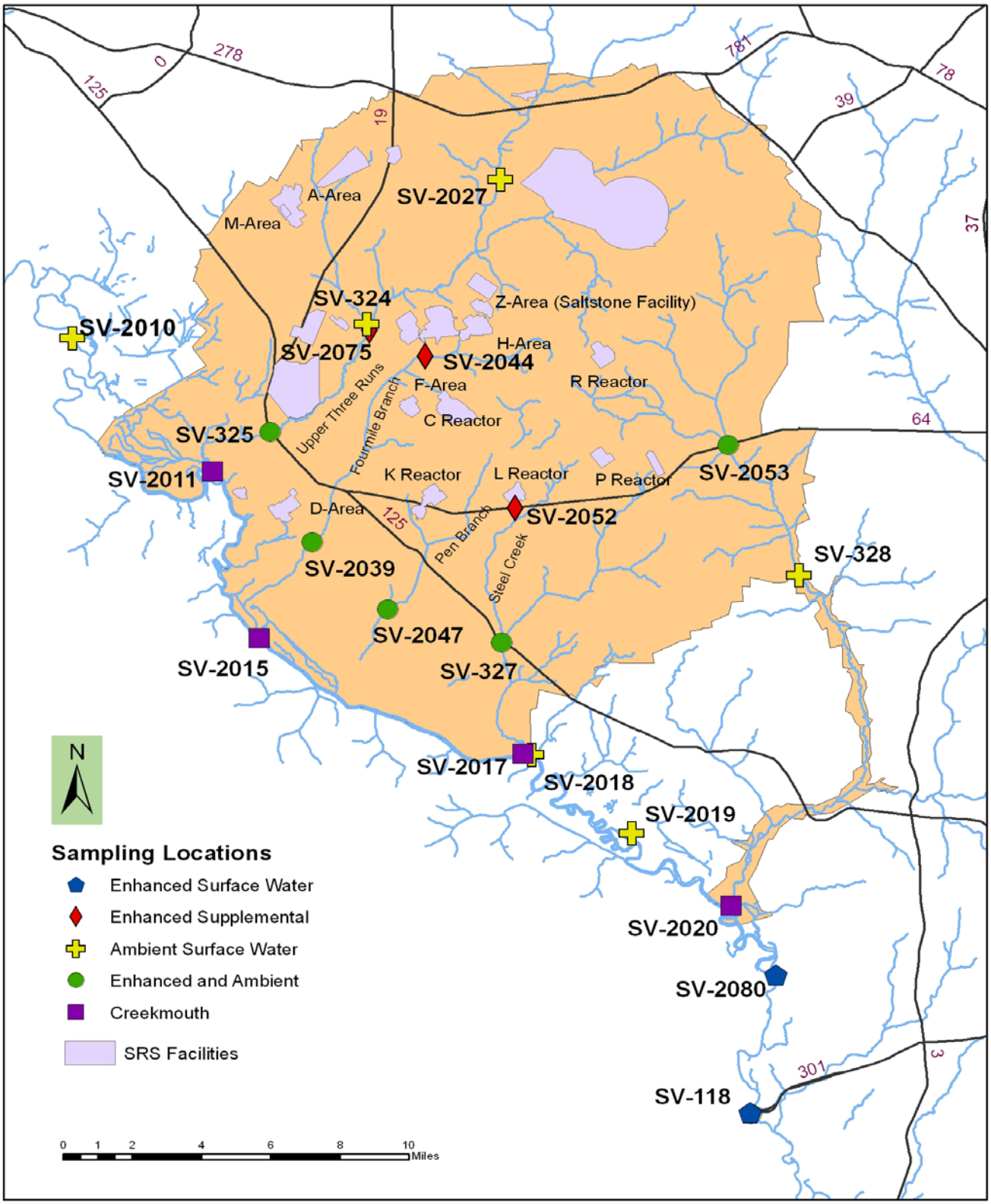
While tritium was detected at all public access locations, the results were below the USEPA MCL annual average of 20,000 pCi/L for drinking water, with the exception of the Fourmile Branch Creek Mouth (USEPA 2002). Data generated from samples collected at the mouth of Fourmile Branch (SV-2015) indicate that the public could come into contact with tritium activity greater than the MCL at that location.

Differences in average values between SCDHEC and DOE-SR could be attributed, in part, to the nature of the water medium and the specific point and time when the sample was collected.

The ESOP RSW project will continue to independently collect and analyze surface water on and adjacent to SRS. This monitoring effort will provide an improved understanding of radionuclide levels in SRS surface waters and valuable information relative to human health exposure pathways. The RSW project will periodically evaluate modifications of the monitoring activities to better accomplish the project's goals and objectives. Further refinement of the RSW project may result in additional sampling locations being incorporated into the ambient or enhanced monitoring regimes. Monitoring will continue as long as there are activities at SRS that create the potential for contamination entering the environment. Continued monitoring will provide an improved understanding of radionuclide activity in SRS surface waters and the Savannah River, which will provide valuable information to human health exposure pathways. This comparison of data results allows for independent data evaluation of DOE-SR monitoring activities.

4.0 Map

Map 1. Surface Water Sampling Locations for 2013



5.0 Tables and Figures

Table 1. 2013 Surface Water Sampling Locations and Frequency

Ambient Monitoring Locations

ID	Location	Rationale	Frequency
SV-2010	Savannah River at RM 170.5 (Jackson Boat Landing)	Accessible to public; Above all SRS operations; Near Jackson population center; Upriver control; River monitoring	Weekly H3 / Monthly AB, Gamma Composite
SV-325	Upper Three Runs Creek at SC 125 (SRS Road A)	Within SRS perimeter; Below SRS operations areas; Tributary monitoring	Weekly H3 / Monthly AB, Gamma Composite
SV-2012	Savannah River at TNX Boat Landing	Adjacent to SRS perimeter; River monitoring	Weekly H3
SV-2040	Beaver Dam Creek at D-Area	Within SRS perimeter; Below SRS operations areas; Tributary monitoring	Weekly H3 / Monthly AB, Gamma Composite
SV-2039	Fourmile Branch at Road A-13.2	Within SRS perimeter; Below SRS operations areas; Tributary monitoring	Weekly H3 / Monthly AB, Gamma Composite
SV-2047	Pen Branch at Road A-13.2	Within SRS perimeter; Below SRS operations areas; Tributary monitoring	Weekly H3 / Monthly AB, Gamma Composite
SV-327	Steel Creek at SC 125 (SRS Road A)	Within SRS perimeter; Below SRS operations areas; Tributary monitoring	Weekly H3 / Monthly AB, Gamma Composite
SV-2018	Savannah River at RM 141 (Steel Creek Boat Landing)	Accessible to public; Adjacent to SRS perimeter; Below SRS operations and tributaries; River monitoring	Weekly H3 / Monthly AB, Gamma Composite
SV-2019	Savannah River at RM 134.5 (Little Hell Boat Landing)	Accessible to public; Below SRS operations and tributaries; River monitoring	Weekly H3
SV-2080	Svannah River at RM 125 (Johnson's Boat Landing)	Accessible to public; Below SRS operations and tributaries; River monitoring	TriWeekly H3 Grab
SV-118	Savannah River at RM 118.8 (Highway 301 Bridge)	Accessible to public; Below SRS operations and tributaries; River monitoring	Weekly H3 / Monthly AB, Gamma Composite
SV-328	Lower Three Runs Creek at Patterson Mill Rd.	Within SRS perimeter; Below SRS operations areas and PAR pond; Tributary monitoring	Weekly H3
SV-2053	Lower Three Runs Creek at Road B	Within SRS perimeter; Below SRS operations areas and PAR pond; Tributary monitoring	Weekly H3 / Monthly AB, Gamma Composite
SV-2027	Upper Three Runs Creek at SRS Road 2-1	Within SRS perimeter; Upstream from SRS operations; Upstream control; Tributary monitoring	Weekly H3

Notes:
1. ID is Sampling Location Identification Code Number
2. RM is River Mile
3. H3 is Tritium
4. AB is Alpha/Beta
5. Tri-Weekly Enhanced sample data is not used for reporting purposes only for early detection

Tables and Figures

Table 1. (Cont.)

Creek Mouth Locations

ID	Location	Rationale	Frequency
SV-2011	Upper Three Runs Creek Mouth at RM 157.4	Accessible to public; Adjacent to SRS; Below SRS operations areas; Tributary monitoring	Quarterly H3
SV-2013	Beaver Dam Creek Mouth at RM 152.3	Accessible to public; Adjacent to SRS; Below SRS operations areas; Tributary monitoring	Quarterly H3
SV-2015a	Fourmile Branch at RM 150.6 (Creek Mouth)	Accessible to public; Adjacent to SRS; Below SRS operations areas; Tributary monitoring	Quarterly H3
SV-2015b	Fourmile Branch at RM 150.6 (30 ' downstream from Creek Mouth)	Accessible to public; Adjacent to SRS; Below SRS operations areas; Tributary monitoring	Quarterly H3
SV-2015c	Fourmile Branch at RM 150.6 (150' downstream from Creek Mouth)	Accessible to public; Adjacent to SRS; Below SRS operations areas; Tributary monitoring	Quarterly H3
SV-2017	Steel Creek Mouth at RM 141.5	Accessible to public; Adjacent to SRS; Downstream from SRS operations; Tributary monitoring	Quarterly H3
SV-2020	Lower Three Runs Creek Mouth at RM 129.1	Accessible to public; Adjacent to SRS; Downstream from SRS operations; Tributary monitoring	Quarterly H3

Supplemental Locations

ID	Location	Rationale	Frequency
SV-2069	McQueen Branch off Monroe Owens Rd.	Downstream from SRS operations; Z-Area	Weekly AB
SV-2071	Upper Three Runs Creek at Road C-4	Downstream from F- & H-Area HLW Tanks	Weekly AB
SV-2075	Upper Three Runs Creek at Road C	Downstream from F- & H-Area HLW Tanks	Weekly AB
SV-2039	Fourmile Branch at Road A-12.2	Downstream from F- & H-Area HLW Tanks	Weekly AB

Notes:
1. ID is Sampling Location Identification Code Number
2. RM is River Mile
3. H3 is Tritium
4. HLW is High Level Waste

Tables and Figures

Table 2. Radiological analytes for gamma spectroscopy analysis

Radioisotope	Abbreviation
Actinium-228	Ac-228
Americium-241	Am-241
Berylium-7	Be-7
Cerium-144	Ce-144
Cobalt-58	Co-58
Cobalt-60	Co-60
Cesium-134	Cs-134
Cesium-137	Cs-137
Europium-152	Eu-152
Europium-154	Eu-154
Europium-155	Eu-155
Iodine-131	I-131
Potassium-40	K-40
Manganese-54	Mn-54
Sodium-22	Na-22
Lead-212	Pb-212
Lead-214	Pb-214
Radium-226	Ra-226
Ruthenium-103	Ru-103
Antimony-125	Sb-125
Thorium-234	Th-234
Ytrium-88	Y-88
Zinc-65	Zn-65
Zirconium-95	Zr-95

Tables and Figures

Table 3. 2013 Tritium Data Comparison for SCDHEC and DOE-SR Colocated Sampling Locations

Sample Location	Sample ID	Average Concentration (pCi/L)	Standard Deviation (pCi/L)	Median (pCi/L)	Minimum Concentration (pCi/L)	Maximum Concentration (pCi/L)	Number of Samples	Number of Detects
Tims Branch at Road C	SV-324	405	150	328	240	1,062	50	47
	TB-5	703	284	1,220	630	389	12	8
Upper Three Runs Creek at Road A	SV-325	678	183	639	342	1,159	51	51
	U3R-4	1,168	746	962	589	3,220	12	11
Fourmile Branch at Road A-12.2	SV-2039	40,348	9,941	42,593	20,750	59,198	51	51
	FM-6	36,042	7,723	35,800	22,100	53,200	12	12
Pen Branch at Road 13.2	SV-2047	19,611	7,435	18,589	7,161	39,679	51	51
	PB-3	16,515	6,168	16,500	6,780	26,800	12	12
Steel Creek at Road A	SV-327	1,899	546	1,844	470	3,122	51	51
	SC-4	1,976	725	1,865	1,010	3,920	12	12
Highway 301 Bridge at River Mile 118.8	SV-118	630	541	435	194	2,248	51	48
	River Mile 118	600	366	500	197	1,790	49	47
Lower Three Runs Creek at Patterson Mill Road	SV-328	1,978	961	1,683	194	3,973	51	51
	L3R-2	2,228	882	2,165	1,200	3,350	12	12
Lower Three Runs Creek at Road B	SV-2053	391	338	321	171	2,468	51	44
	L3R-1A	613	259	619	330	1,020	12	9

Notes:
1. Shaded areas represent SCDHEC data and unshaded areas represent DOE-SR data
2. DOE-SR data is from the SRS Environmental Data Report for 2013 (SRNS 2014)

Tables and Figures

Table 4. 2013 Alpha Data Comparison for SCDHEC and DOE-SR Colocated Sampling Locations

Sample Location	Sample ID	Average Concentration (pCi/L)	Standard Deviation (pCi/L)	Median (pCi/L)	Minimum Concentration (pCi/L)	Maximum Concentration (pCi/L)	Number of Samples	Number of Detects
Tims Branch at Road C	SV-324	12.06	16.20	5.11	3.58	41.00	12	5
	TB-5	9.76	18.40	3.30	1.05	64.90	12	12
Upper Three Runs Creek at Road A	SV-325	4.19	1.47	4.36	2.30	5.75	12	4
	U3R-4	6.48	6.90	4.42	1.84	26.50	12	12
Fourmile Branch at Road A-12.2	SV-2039	3.44	NA	NA	3.44	3.44	12	1
	FM-6	1.87	2.03	1.05	0.62	7.35	12	10
Pen Branch at Road 13.2	SV-2047	3.66	0.69	3.66	3.17	4.15	12	2
	PB-3	0.91	NA	NA	0.91	0.91	12	1
Steel Creek at Road A	SV-327	ND	ND	ND	ND	ND	12	0
	SC-4	2.09	0.56	2.20	0.99	2.97	12	8
Highway 301 Bridge at River Mile 118.8	SV-118	9.47	10.37	9.47	2.14	16.80	12	2
	River Mile 118	1.49	0.25	1.44	1.38	1.66	48	4
Lower Three Runs Creek at Road B	SV-2053	17.50	NA	NA	17.50	17.50	12	1
	L3R-1A	1.04	0.31	1.04	0.82	1.26	12	2

Notes:
1. Shaded areas represent SCDHEC data and unshaded areas represent DOE-SR data
2. DOE-SR data is from the SRS Environmental Data Report for 2013 (SRNS 2014)
3. ND is No Detects
4. NA is Not Applicable

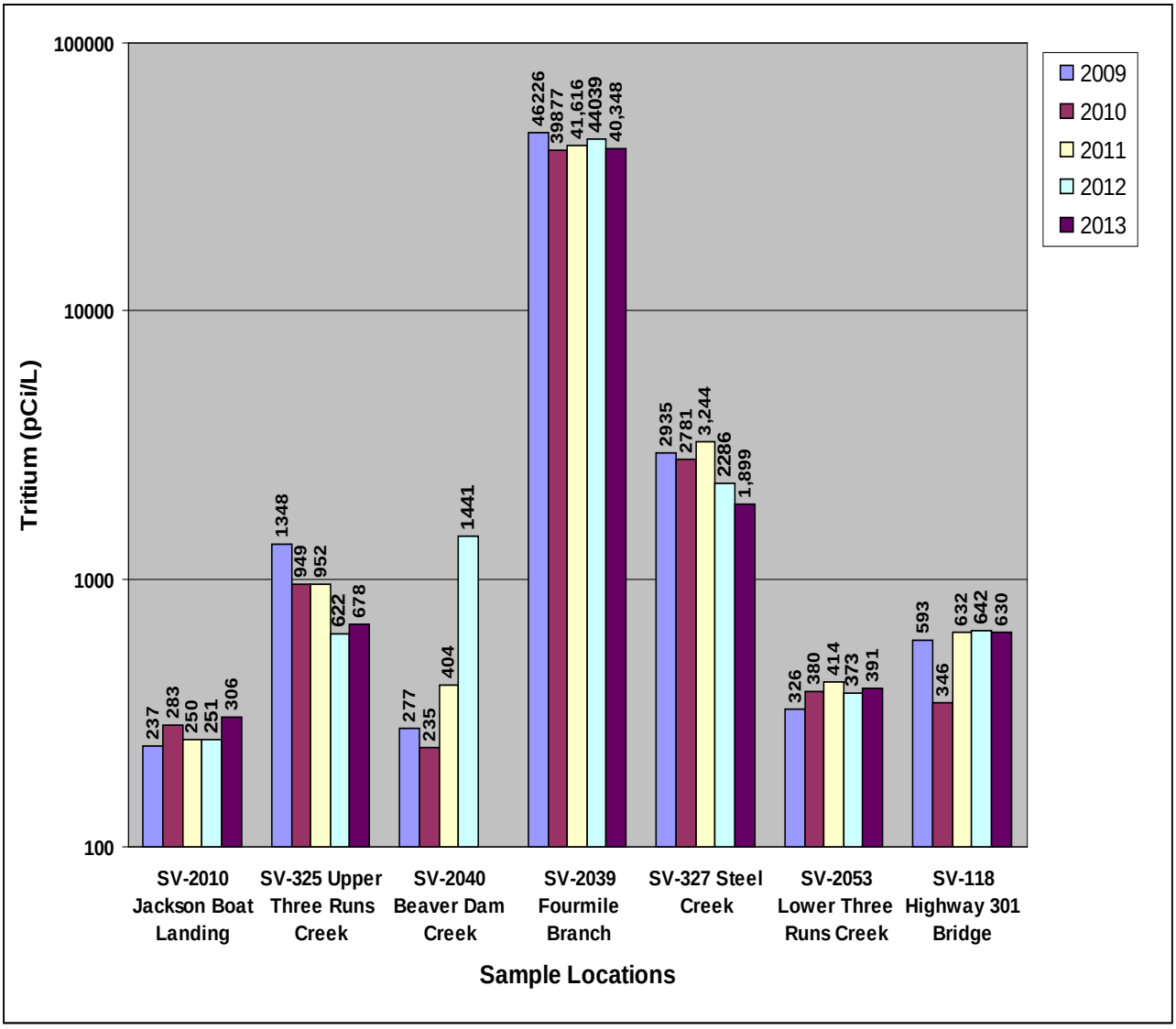
Table 5. 2013 Beta Data Comparison for SCDHEC and DOE-SR Colocated Sampling Locations

Sample Location	Sample ID	Average Concentration (pCi/L)	Standard Deviation (pCi/L)	Median (pCi/L)	Minimum Concentration (pCi/L)	Maximum Concentration (pCi/L)	Number of Samples	Number of Detects
Tims Branch at Road C	SV-324	6.01	0.76	6.13	5.20	6.71	12	3
	TB-5	3.25	3.65	1.76	1.14	13.20	12	12
Upper Three Runs Creek at Road A	SV-325	ND	ND	ND	ND	ND	12	0
	U3R-4	4.41	3.50	2.75	2.50	9.65	12	4
Fourmile Branch at Road A-12.2	SV-2039	6.09	2.14	5.18	4.40	9.97	12	6
	FM-6	5.76	1.79	5.51	3.16	10.40	12	12
Pen Branch at Road 13.2	SV-2047	2.95	NA	NA	2.95	2.95	12	1
	PB-3	1.83	NA	NA	1.83	1.83	12	1
Steel Creek at Road A	SV-327	ND	ND	ND	ND	ND	12	0
	SC-4	1.68	0.56	1.56	0.95	2.62	12	12
Highway 301 Bridge at River Mile 118.8	SV-118	5.28	1.04	5.28	4.54	6.01	12	2
	River Mile 118	2.45	0.64	2.38	0.40	3.92	48	36
Lower Three Runs Creek at Road B	SV-2053	5.82	NA	NA	5.82	5.82	12	1
	L3R-1A	2.47	0.61	2.22	1.93	3.76	12	8

Notes:
1. Shaded areas represent SCDHEC data and unshaded areas represent DOE-SR data
2. DOE-SR data is from the SRS Environmental Data Report for 2013 (SRNS 2014)
3. ND is No Detects
4. NA is Not Applicable

Tables and Figures

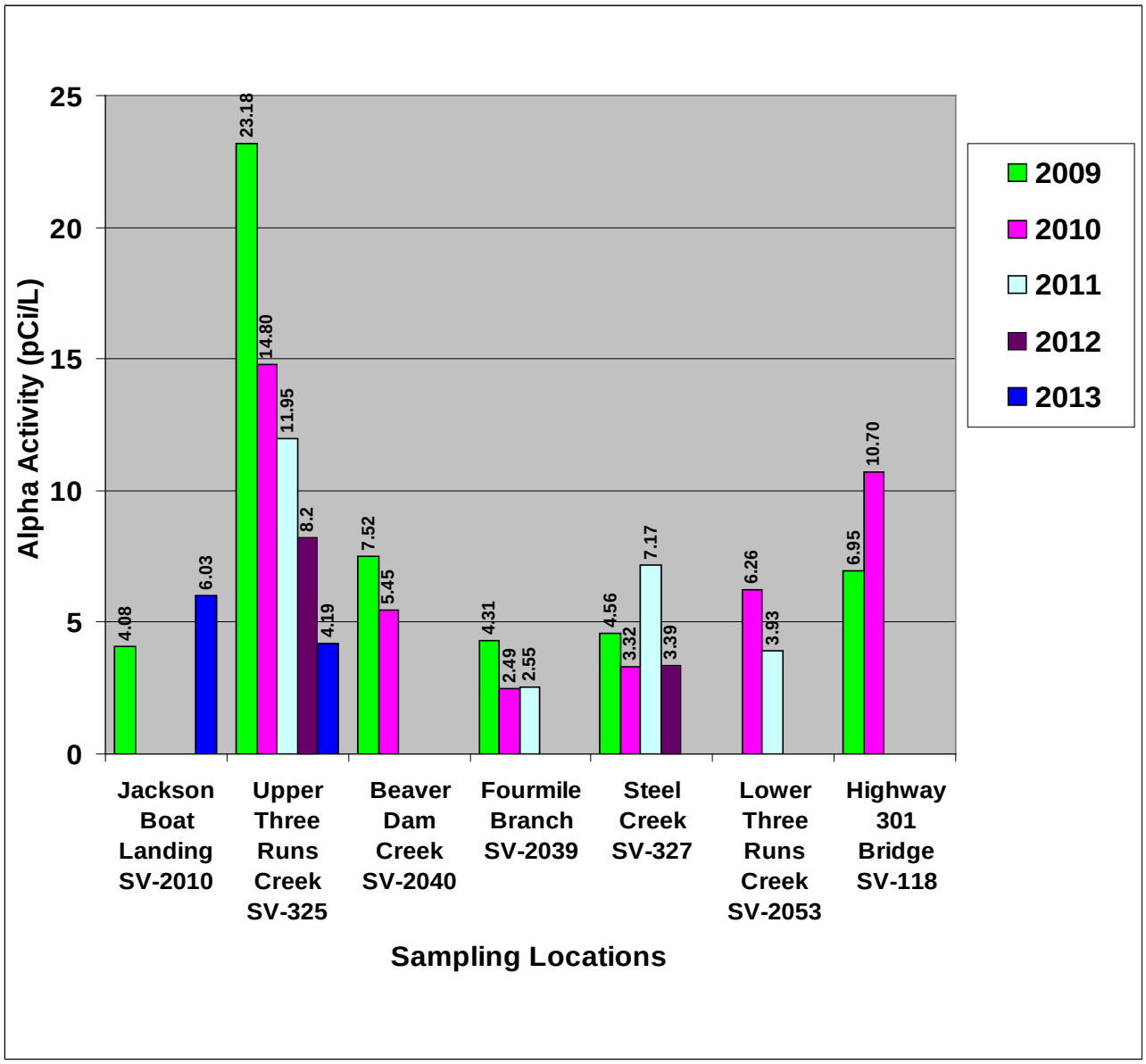
Figure 1. SCDHEC Average Tritium Trends for 2009-2013 (SCDHEC 2009-2013)



Notes:
1. Jackson Boat Landing is a background location.
2. Beaver Dam Creek was discontinued in 2013 due to no flow.

Tables and Figures

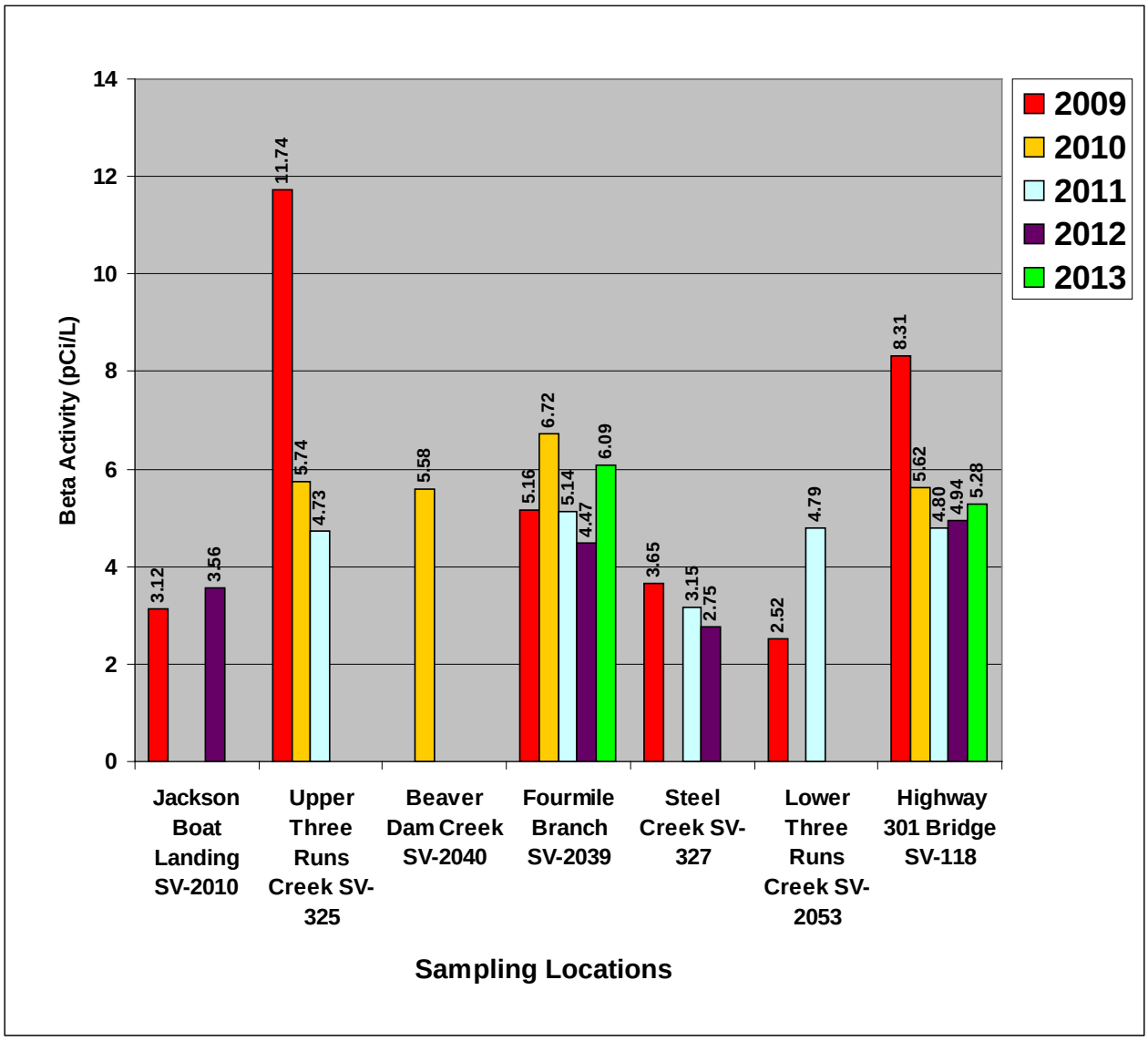
Figure 2. SCDHEC 2009-2013 Average Alpha Data (SCDHEC 2009-2013)



Notes:
1. No detections at Jackson Landing in 2010, 2011, and 2012
2. No detections at Beaver Dam Creek 2011, and 2012 and discontinued in 2013 due to no flow
3. No detections at Fourmile Branch in 2012 and 2013
4. No detections at Lower Three Runs Creek in 2009, 2012, and 2013
5. No detections at Highway 301 Bridge in 2011, 2012, and 2013
6. The USEPA screening level MCL for Alpha is 15 pCi/L for drinking water

Tables and Figures

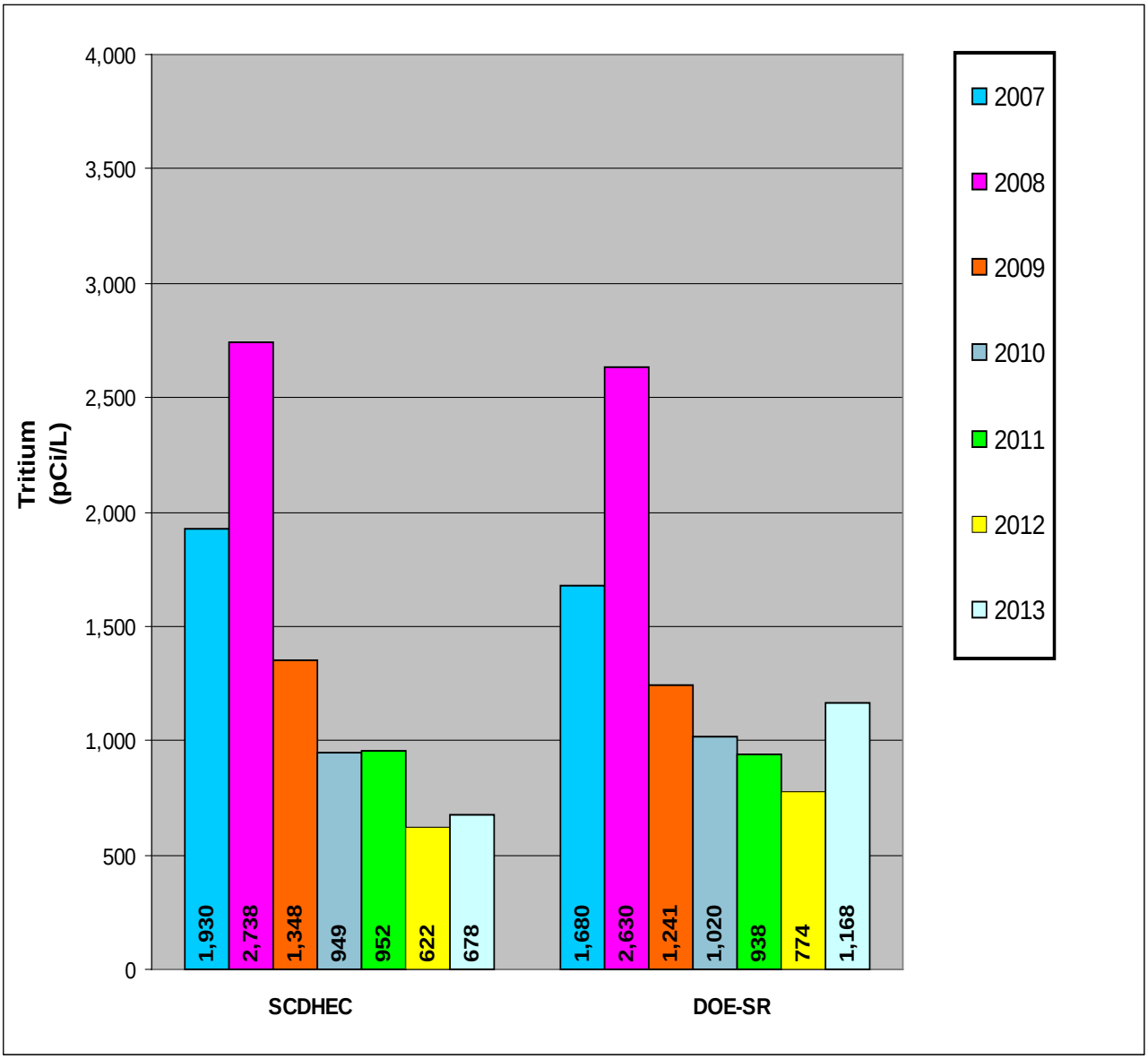
Figure 3. SCDHEC 2009-2013 Average Beta Data (SCDHEC 2009-2013)



Notes:
1. The USEPA screening level MCL for gross beta particles is 50 pCi/L for drinking water
2. No detections at Beaver Dam Creek in 2009 and 2011 and discontinued in 2013 due to no flow
3. No detections at Jackson Boat Landing, Steel Creek or Lower Three Runs in 2010
4. No detections at Highway 301 Bridge in 2011 and 2012
5. No detections at Upper Three Runs, Beaver Dam Creek, and Lower Three Runs in 2012

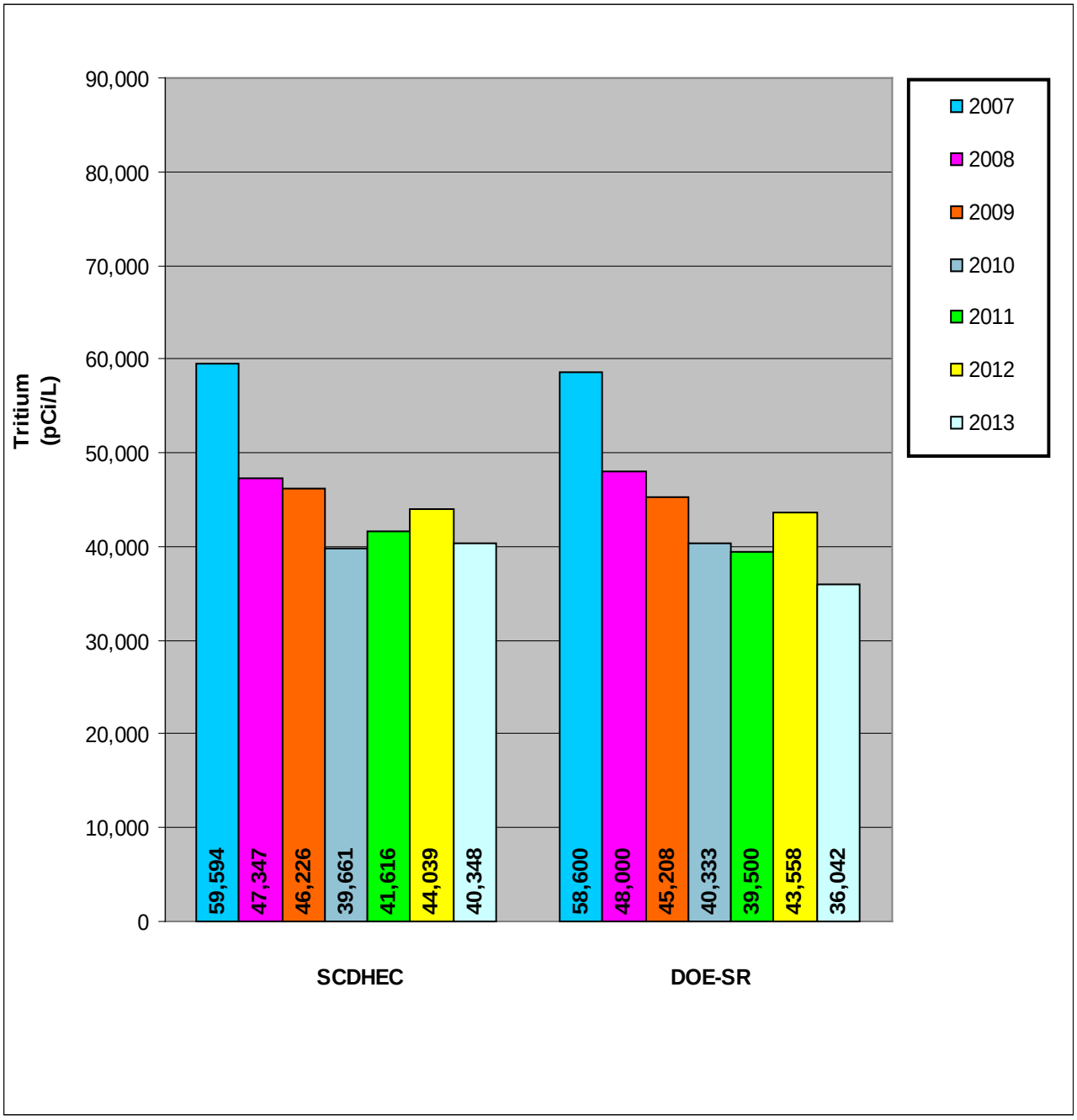
Tables and Figures

Figure 4. 2007-2013 Average Tritium Data Trends For SCDHEC and DOE-SR at Upper Three Runs Creek and SC Highway 125 (WSRC 2008, SRNS 2009-2014, SCDHEC 2007-2013).



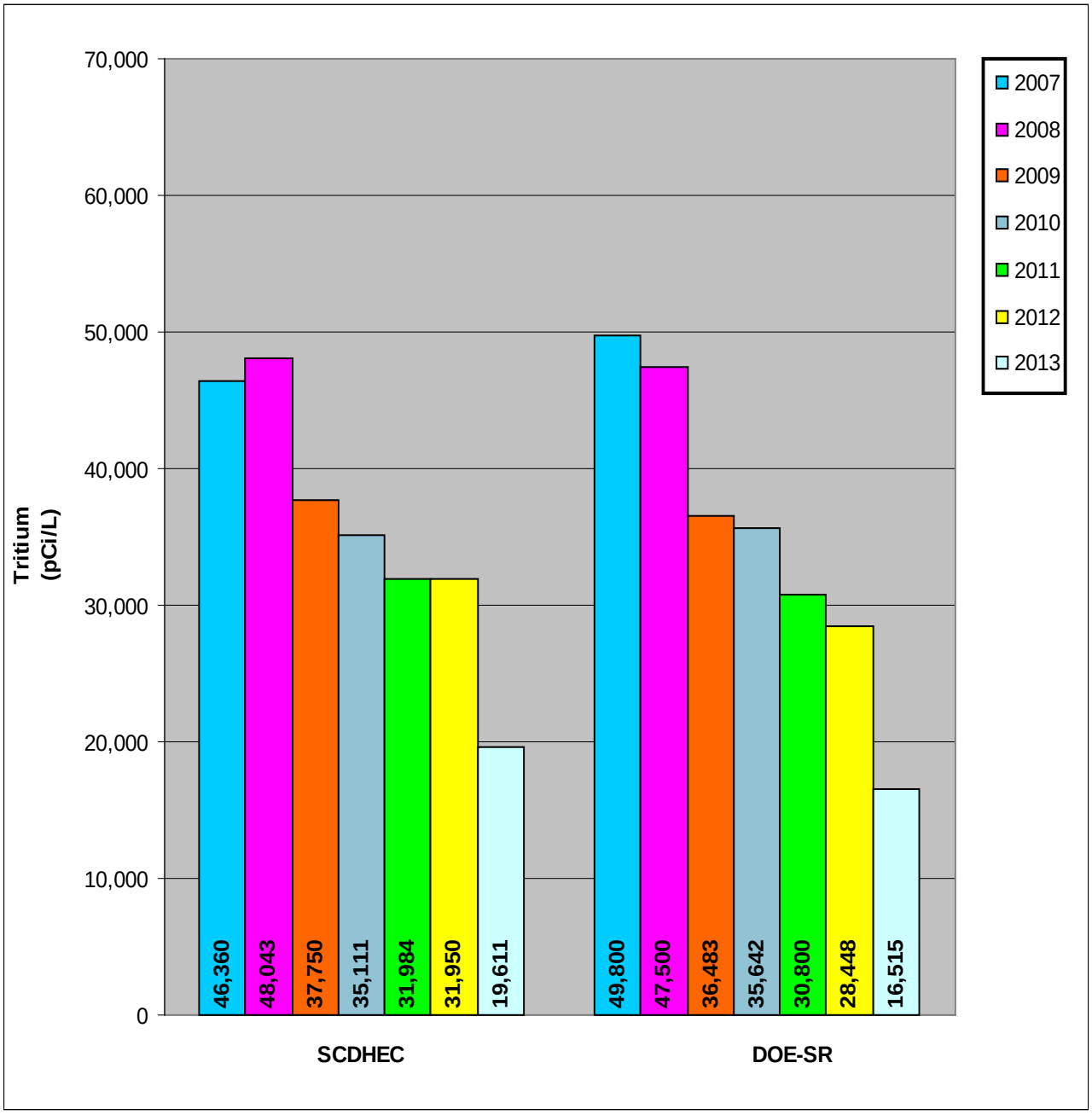
Tables and Figures

Figure 5. 2007-2013 Average Tritium Data Trends For SCDHEC and DOE-SR at Fourmile Branch and USFS Road 12.2 (WSRC 2008, SRNS 2009-2014, SCDHEC 2007-2013).



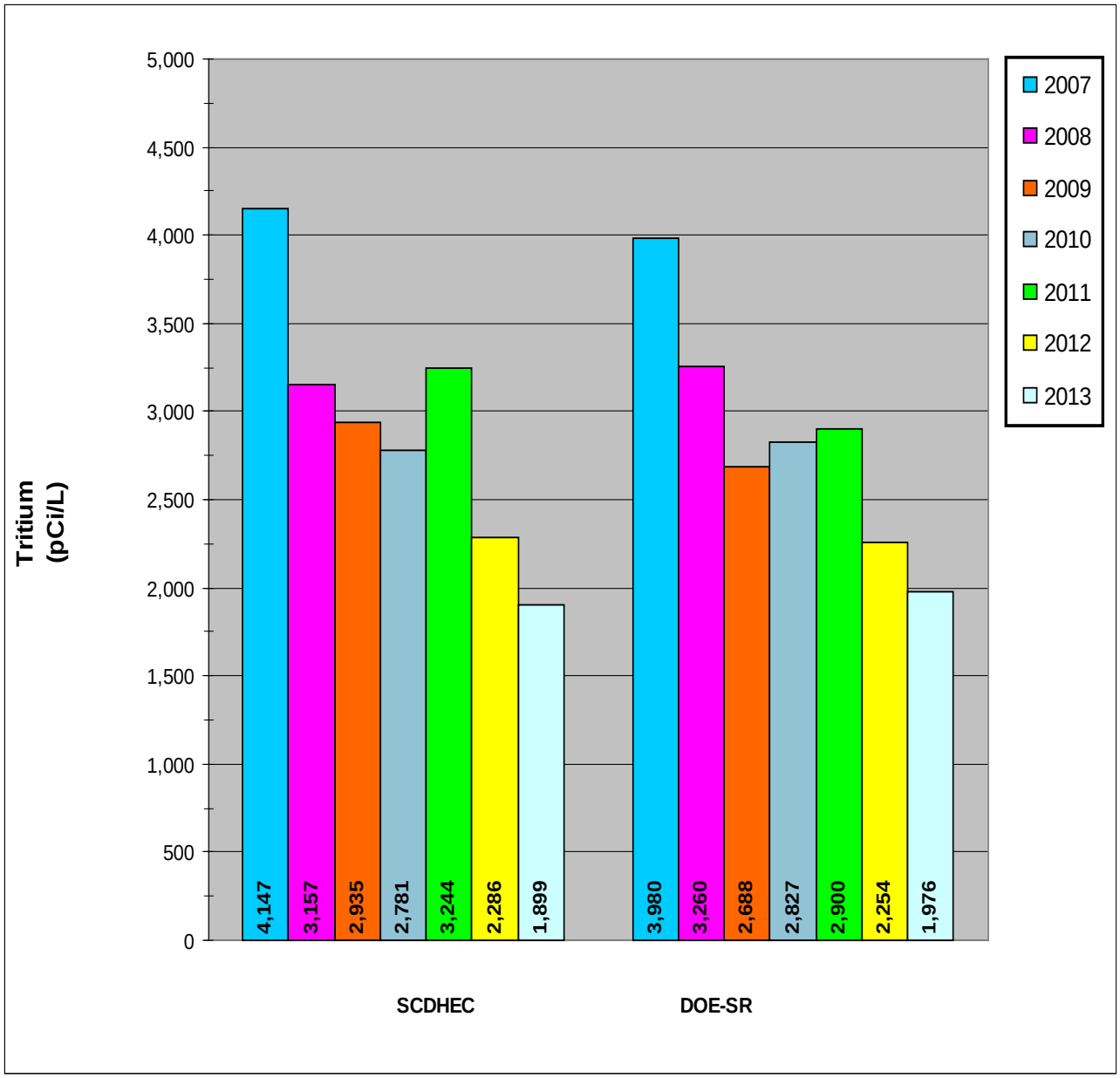
Tables and Figures

Figure 6. 2007-2013 Average Tritium Data Trends For SCDHEC and DOE-SR at Pen Branch and USFS Road 13.2 (WSRC 2008, SRNS 2009-2014, SCDHEC 2007-2013).



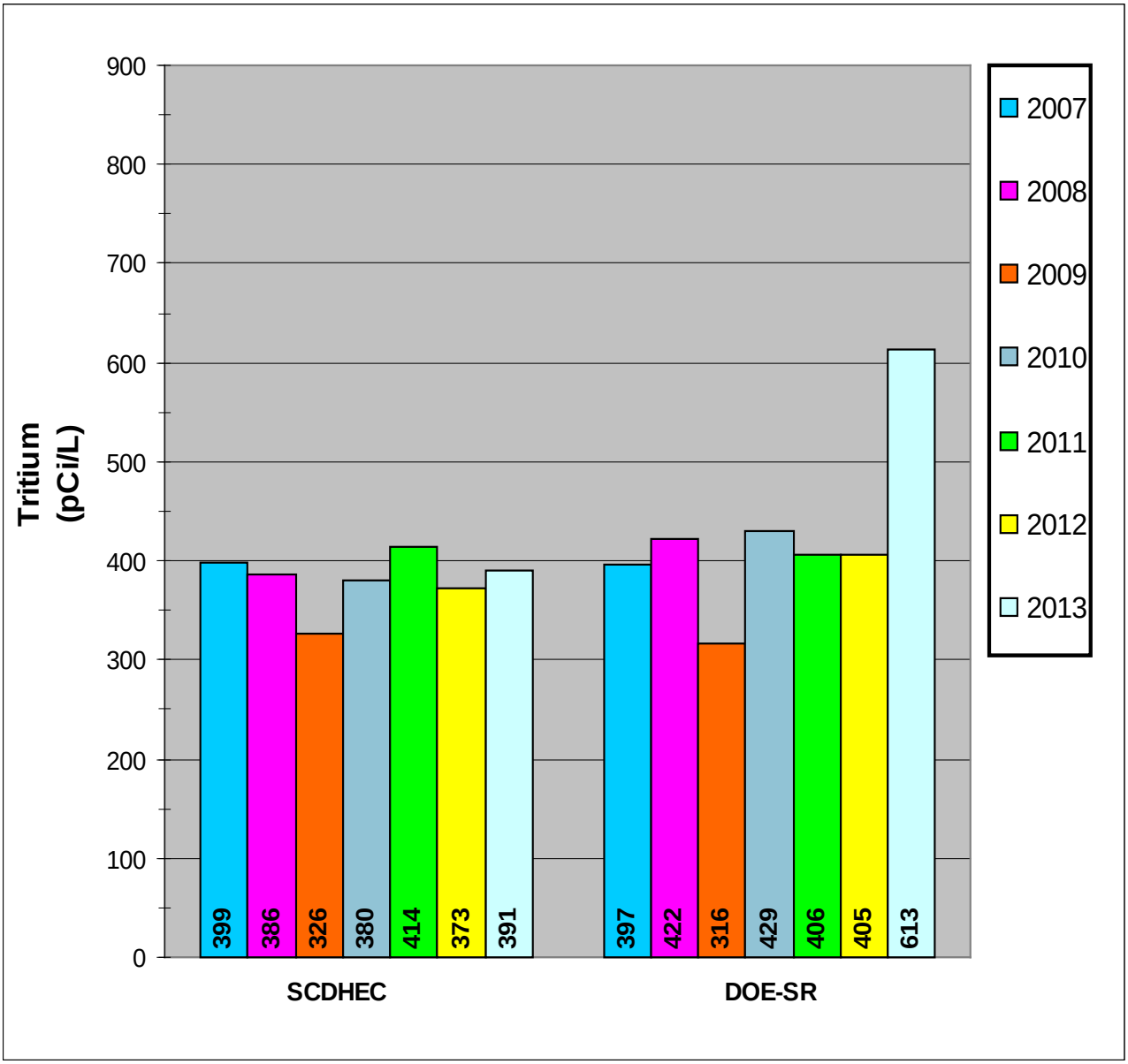
Tables and Figures

Figure 7. 2007-2013 Average Tritium Data Trends For SCDHEC and DOE-SR at Steel Creek and SC Highway 125 (WSRC 2008, SRNS 2009-2014, SCDHEC 2007-2013).



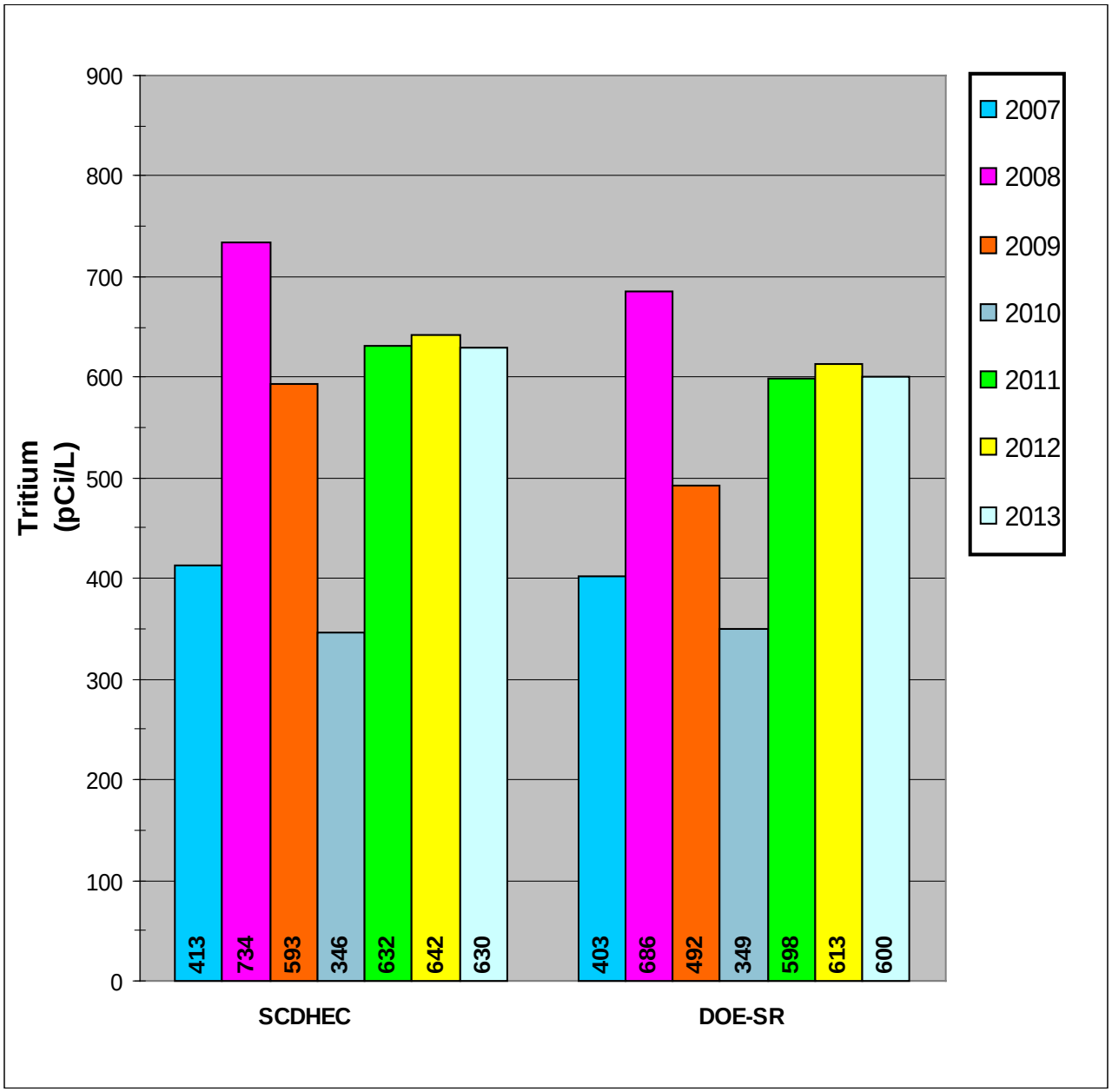
Tables and Figures

Figure 8. 2007-2013 Average Tritium Data Trends For SCDHEC and DOE-SR at Lower Three Runs Creek and SRS Road B (WSRC 2008, SRNS 2009-2014, SCDHEC 2007-2013).



Tables and Figures

Figure 9. 2007-2013 Average Tritium Data Trends For SCDHEC and DOE-SR at the Savannah River and US Highway 301 Bridge (WSRC 2008, SRNS 2009-2014, SCDHEC 2007-2013).



6.0 Summary Statistics

Notes:
1. pCi/L is picocuries per Liter
2. ND is No Detection
3. NA is Not Applicable
4. NS is No Sample

Summary Statistics

2013 Ambient Monitoring Data-Tritium

Sample Location	Average Concentration (pCi/L)	Standard Deviation	Median	Maximum Concentration (pCi/L)	Minimum Concentration (pCi/L)	Number of Samples	Number of Detects
Jackson Landing (SV-2010)	306	105	271	564	213	51	15
Tims Branch (SV-324)	405	150	389	1,062	240	50	47
Upper Three Runs Creek (SV-325)	678	183	639	1,159	342	51	51
Fourmile Branch (SV-2039)	40,348	9,941	42,593	59,198	20,750	51	51
Pen Branch (SV-2047)	19,611	7,435	18,589	39,679	7,161	51	51
Steel Creek (SV-327)	1,899	546	1,844	3,122	470	51	51
Steel Creek Boat Landing (SV-2018)	977	883	513	3,260	228	51	46
Little Hell Landing (SV-2019)	602	596	334	2,840	201	51	43
Highway 301 Bridge (SV-118)	630	541	435	2,248	194	51	48
Lower Three Runs Creek and Patterson Mill Rd. (SV-328)	1,978	961	1,683	3,973	194	51	51
Lower Three Runs Creek (SV-2053)	391	338	321	2,468	171	51	44
Upper Three Runs Creek (SV-2027)	356	389	256	1,646	200	50	13

2013 Creek Mouth Data-Tritium

Sample Location	Average Concentration (pCi/L)	Standard Deviation	Median	Maximum Concentration (pCi/L)	Mimimum Concentration (pCi/L)	Number of Samples	Number of Detects
Upper Three Runs Creek Creek Mouth (SV-2011)	482	83	460	573	411	4	3
Beaver Dam Creek Creek Mouth (SV-2013)	695	205	585	932	569	4	3
Fourmile Branch Creek Mouth (SV-2015 a)	25,611	15,545	24,149	43,364	10,782	4	4
Fourmile Branch (SV-2015 b) 30' downstream from Creek Mouth	9,202	2,224	9,202	10,775	7,629	4	2
Fourmile Branch (SV-2015 c) 150' downstream from Creek Mouth	2,837	NA	NA	2,837	2,837	4	1
Steel Creek Creek Mouth (SV-2017)	2,575	1,978	2,620	4,481	580	4	4
Lower Three Runs Creek Creek Mouth (SV-2020)	412	243	315	771	249	4	4

Summary Statistics

2013 Ambient Monitoring Data-Alpha

Sample Location	Average Concentration (pCi/L)	Standard Deviation	Median	Minimum Concentration (pCi/L)	Maximum Concentration (pCi/L)	Number of Samples	Number of Detects
Jackson Landing (SV-2010)	6.03	3.34	6.03	3.66	8.39	12	2
Tims Branch (SV-324)	12.06	16.20	5.11	3.58	41.00	12	5
Upper Three Runs Creek (SV-325)	4.19	1.47	4.36	2.30	5.75	12	4
Fourmile Branch Creek (SV-2039)	3.44	NA	NA	3.44	3.44	12	1
Pen Branch (SV-2047)	3.66	0.69	3.66	3.17	4.15	12	2
Steel Creek (SV-327)	ND	ND	ND	ND	ND	12	0
Steel Creek Boat Landing (SV-2018)	1.80	NA	NA	1.80	1.80	12	1
Highway 301 Bridge (SV-118)	9.47	10.37	9.47	2.14	16.80	12	2
Lower Three Runs Creek (SV-2053)	17.50	NA	NA	17.50	17.50	12	1

2013 Ambient Monitoring Data-Beta

Sample Location	Average Concentration (pCi/L)	Standard Deviation	Median	Minimum Concentration (pCi/L)	Maximum Concentration (pCi/L)	Number of Samples	Number of Detects
Jackson Landing (SV-2010)	3.71	NA	NA	3.71	3.71	12	1
Tims Branch (SV-324)	6.01	0.76	6.13	5.20	6.71	12	3
Upper Three Runs Creek (SV-325)	ND	ND	ND	ND	ND	12	0
Fourmile Branch (SV-2039)	6.09	2.14	5.18	4.40	10.0	12	6
Pen Branch (SV-2047)	2.95	NA	NA	2.95	2.95	12	1
Steel Creek (SV-327)	ND	ND	ND	ND	ND	12	0
Steel Creek Boat Landing (SV-2018)	5.22	2.58	5.22	3.39	7.04	12	2
Highway 301 Bridge (SV-118)	5.28	1.04	5.28	4.54	6.01	12	2
Lower Three Runs Creek (SV-2053)	5.82	NA	NA	5.82	5.82	12	1

List of Acronyms

Am-241	Americium-241
CDC	Centers for Disease Control and Prevention
Co-60	Cobalt-60
Cs-137	Cesium-137
DOE-SR	Department of Energy - Savannah River
ESOP	Environmental Surveillance and Oversight Program
ETF	Effluent Treatment Facility
EQC	Environmental Quality Control
H3	Tritium
I-129	Iodine-129
LLD	Lower Limit of Detection
MCL	Maximum Contaminant Level
MDA	Minimum Detectable Activity
MDC	Minimum Detectable Concentration
NA	Not Applicable
ND	No Detection
NS	No Sample
REMD	Radiological Environmental Monitoring Division
RSW	Radiological Surface Water
SCDHEC	South Carolina Department of Health and Environmental Control
SD	Standard Deviation
SRS	Savannah River Site
SRNS	Savannah River Nuclear Solutions
Sr-90	Strontium-90
Tc-99	Technitium-99
U	Uranium
USEPA	United States Environmental Protection Agency
USFS	United States Forestry Service
WSRC	Washington Savannah River Company (formerly Westinghouse Savannah River Company)

Units of Measure

mL	milliliter
pCi/L	picocuries/liter
±	plus or minus one standard deviation
±2	plus or minus two standard deviations, represents uncertainty in single detects

References

Centers for Disease Control and Prevention (CDC). 2006. Phase III of the SRS Dose Reconstruction Project.

Murphy, C.C., Jr., L.R. Bauer, D.W. Hayes, W.L. Marter, C.C. Zeigler, D.E. Stephenson, D.D. Hoel, and D.H. Hamby. 1991. Tritium in the Savannah River Site Environment. WSRC-RP-9-0-424-1 Rev. 1. SRS Phase II Database MJC1994051310. May.

Murphy, C.E., Jr. and W.H. Carlton. 1991. Tritium in the Savannah River Environment Addendum to WSRC-RP-9-0-424-1, Rev. 1. SRS Phase II Database MJC1994051311.

Savannah River Nuclear Solutions, LLC (SRNS). 2009. Savannah River Site Environmental Report for 2008. Savannah River Site Aiken, SC. SRNS-STI-2009-00190.

SRNS. 2010. Savannah River Site Environmental Report for 2009. Savannah River Site Aiken, SC SRNS-STI-2011-00059.

SRNS. 2011. Savannah River Site Environmental Report for 2010. Savannah River Site Aiken, SC SRNS-STI-2011-00175.

SRNS. 2012. Savannah River Site Environmental Report for 2011. Savannah River Site Aiken, SC. SRNS–STI–2012-00564.

SRNS. 2013. Savannah River Site Environmental Report for 2012. Savannah River Site Aiken, SC. SRNS-STI-2013-00024.

SRNS. 2014. Savannah River Site Environmental Report for 2013. Savannah River Site Aiken, SC. SRNS-STI-2014-00006.

Savannah River Site. 2008. Historical History Web Interface URL: http://www.srs.gov/general/about/history1.htm.

Savannah River Site. 2009. Savannah River Site Web Interface URL: http://www.srs.gov/general/programs/solidification/index.htm.

South Carolina Department of Health and Environmental Control (SCDHEC). 2000-2012. South Carolina Department of Health and Environmental Control Environmental Data Report, Bureau of Environmental Services, Environmental Surveillance and Oversight Program, Aiken, SC.

Till JE, et al. 2001. Savannah River Site Environmental Dose Reconstruction Project, Phase II: Source Term Calculation and Ingestion Pathway Data Retrieval, Evaluation of Materials Released From the Savannah River Site. RAC Report No. 1-CDC-SRS-1999-Final. Risk Assessment Corporation (RAC).

United States Environmental Protection Agency (USEPA) 2002. "List of Drinking Water Contaminants & MCLs", EPA 816-F-02-013 (July 2002).

USEPA. 2008a. USEPA website
URL: http://www.epa.gov/radiation/radionuclides/tritium.html#where.

USEPA. 2008b. USEPA website
URL: http://www.epa.gov/radiation/radionuclides/cesium.html.

USEPA. 2010. USEPA website
URL: http://www.epa.gov/wastes/hazard/testmethods/sw846/pdfs/9310.pdf.

WSRC. 2003. Savannah River Site Environmental Report for 2002, WSRC-TR-2003-00026/CD, Environmental Monitoring & Analysis, Environmental Services Section, Aiken, SC.

WSRC. 2004. Savannah River Site Environmental Report for 2003, WSRC-TR-2004-00015/CD, Environmental Monitoring & Analysis, Environmental Services Section, Aiken, SC.

WSRC. 2005. Savannah River Site Environmental Report for 2004, WSRC-TR-2005-00005/CD, Environmental Monitoring & Analysis, Environmental Services Section, Aiken, SC.

WSRC. 2006. Savannah River Site Environmental Report for 2005, WSRC-TR-2006-00007/CD, Environmental Monitoring & Analysis, Environmental Services Section, Aiken, SC.

WSRC. 2007. Savannah River Site Environmental Report for 2006, WSRC-TR-2007-00008/CD, Environmental Monitoring & Analysis, Environmental Services Section, Aiken, SC.

WSRC. 2008. Savannah River Site Environmental Report for 2007, WSRC-STI-2008-00057/CD, Environmental Monitoring & Analysis, Environmental Services Section, Aiken, SC.

Zeigler, C.C, I.B. Lawrimore, and W.E. O'Rear. 1985. Environmental Monitoring at the Savannah River Plant, Annual Report 1984. DPSPU-85-302. Health Protection Department, Savannah river Plant, Du Pont. SRS Phase II Database MJC1994051722.

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2013 Nonradiological Monitoring of Ambient Surface Water at the Savannah River Site

Environmental Surveillance and Oversight Program

97NW004

Adam R. Waller, Project Manager

January 1, 2013 – December 31, 2013

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D H E C
PROMOTE PROTECT PROSPER
South Carolina Department of Health and Environmental Control

Table of Contents

1.0 PROJECT SUMMARY

The streams located on the Savannah River Site (SRS) receive a wide variety of permitted point source discharges and non-point source run-off from on-site facilities and operations. These discharges specifically include, but are not limited to, industrial storm water, utility water, treated industrial and sanitary wastewater, and run-off from land disturbing activities. Data from SRS Environmental Reports and South Carolina Department of Health and Environmental Control's (SCDHEC) Environmental Surveillance and Oversight Program (ESOP) is used to monitor the ambient water quality of streams on SRS.

ESOP assessed the surface water quality for nonradiological parameters in 2013 at SRS by sampling the on-site streams for inorganic and organic contaminants. The streams on SRS are tributaries to the Savannah River and are classified as Freshwater (FW) by SCDHEC's Bureau of Water (SCDHEC 2008a). As an indication of possible water quality issues, ESOP data was compared to the FW standard guidelines in SCDHEC's Water Classifications and Standards, Regulation 61-68. These guidelines give numeric criteria for specific parameters and narrative criteria that indicate conditions of biological integrity and water quality for aquatic life and human health (SCDHEC 2008b). The fact that a stream does not meet the specified numeric standards for a particular parameter does not mean the stream is polluted or of poor quality. Natural conditions can cause streams to exceed the standards. Where appropriate, ESOP results were also compared to the Savannah River watershed data collected by SCDHEC's Bureau of Water from 2008 through 2012 (SCDHEC 2013). This data includes averages and data ranges for all streams in the entire Savannah River Basin.

Nine ESOP sample locations were strategically chosen to monitor ambient surface water conditions and detect the nonradiological impact from the Department of Energy – Savannah River (DOE-SR) operations. See Section 4.0 for a map of ESOP sample locations. The stream sample locations were selected based on accessibility and their proximity upstream and downstream of DOE-SR operations before flowing into the publicly accessible Savannah River (Section 5.0, Table 1). Six of the ESOP sample locations were co-located with DOE-SR sample locations to provide data comparisons (Section 5, Table 3).

Streams were tested for the following parameters on a monthly interval: pH, dissolved oxygen (DO), temperature, alkalinity, turbidity, biochemical oxygen demand (BOD), total suspended solids (TSS), E. coli, total Kjeldahl nitrogen (TKN), ammonia, nitrate/nitrite, total phosphorous, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, and zinc. Volatile organic compounds (VOCs), pesticides, and polychlorinated biphenyls (PCBs) were sampled biannually. These are standard parameters used to indicate water quality in freshwater streams throughout South Carolina (SCDHEC 2011). In all, over 3500 individual analyses were performed with 162 of these individual parameters exceeding South Carolina or United States Environmental Protection Agency (USEPA) standards or other recommended guidelines. Data from SCDHEC surface water locations were compared to DOE-SR data where

sample points were co-located (SCDHEC 2012). All surface water data can be found in Appendix A, and surface water statistical analyses can be found in Section 6.0.

2.0 RESULTS AND DISCUSSION

pH Results

Many chemical and biological processes in surface waters can be affected by pH, a measurement that indicates the alkalinity or acidity of a substance (USEPA 1997). The streams encountered at SRS are typical of southeastern streams characterized as blackwater. A blackwater stream is a stream with a deep, slow moving channel that flows through forested swamps and wetlands. Decaying vegetation in the water results in the leaching of tannins from the vegetation resulting in transparent, acidic water that is darkly stained, resembling tea or coffee. Low pH is typical for blackwater streams such as those sampled at SRS (USGS 2000).

The pH standard for all South Carolina freshwater streams is between 6.0 and 8.5 standard units (su), although lower pH is typical for blackwater streams (SCDHEC 2008b). ESOP personnel measured and recorded the pH at each sample location during the sampling event. There were 45 individual measurements at seven locations that were outside of the pH standard, including locations downstream and upstream of SRS operations (Section 6.0, Summary Statistics, Appendix A-ESOP Data). Three of these locations had yearly averages that were below the pH standard; NWSV-324 (5.67 (±0.52) su) and NWSV-2027 (5.25 (±0.78) su), and NWSV-2061 (5.78 (±0.64) su). These are typical results for blackwater streams. The Savannah River Basin's pH averaged 6.69, and ranged from 4.6 to 8.61 (SCDHEC 2013). All ESOP sample measurements were within this range. See Section 5.0, Figure 1 for a comparison of ESOP and DOE-SR data for co-located samples; there were no significant differences (SRNS 2014).

DO and BOD Results

Oxygen is cycled through the environment and is both produced and consumed in streams. The amount of oxygen in its dissolved form in water is the DO. The BOD is the amount of oxygen consumed by microorganisms in stream water. Water quality is diminished when the BOD is high, which depletes the oxygen in the water. Low DO means less oxygen to sustain higher forms of aquatic life (USEPA 1997).

Dissolved oxygen was measured and recorded in the field as part of each ESOP sampling event, and samples were collected for BOD analysis. The South Carolina freshwater standard for DO is a daily average no less than 5.0 milligrams per liter (mg/L) with a minimum of 4.0 mg/L (SCDHEC 2008b). The monthly sampling frequency employed by ESOP is insufficient for strict interpretation related to the standards. The ESOP grab sample method is considered to be representative and provides an indication of water quality relative to DO. One 2013 sample was below 5.0 mg/L, NWSV-324 (4.79 mg/L) for June (Section 6.0, Summary Statistics, Appendix A-ESOP Data). The SCDHEC Bureau of Water Savannah River Basin's DO averaged 8.83 mg/L, and ranged from 0.66 mg/L to 15.4 mg/L (SCDHEC 2013). All ESOP sample measurements were within this

range. See Section 5.0, Figure 2 for a DO comparison of ESOP and DOE-SR data for co-located samples; there were no significant differences (SRNS 2014).

There are no numeric criteria in the South Carolina freshwater standards for a maximum BOD level; however, all 2013 ESOP samples were near or below the lower limit of detection (LLD) of 2.0 mg/L (Section 6.0, Summary Statistics, Appendix A-ESOP Data). The only sample above the LLD was at NWSV-327 for August, 2.6 mg/L. These results show no indication of water quality issues relative to BOD in SRS streams. The Savannah River Basin results ranged from <LLD to 6.4 mg/L. All ESOP samples results were within this range. DOE-SR did not collect BOD samples in 2013; therefore, no comparison was made for BOD.

Temperature Results

Temperature can affect biological and chemical processes in a stream. All aquatic organisms can be negatively impacted by temperature that varies from the naturally occurring range (USEPA 1997). The South Carolina freshwater standards state the temperature of free flowing freshwater shall not be increased more than 2.8°C above natural temperature conditions and shall not exceed a maximum of 32.2°C (SCDHEC 2008b).

ESOP field personnel measured and recorded the temperature during each sampling event in 2013. All streams were below the maximum. ESOP did not collect temperature data above and below every possible point of impact; therefore, the results were insufficient for strict interpretation related to the standard. However, ESOP data showed that the stream temperatures at each sampling event were comparable to each other, including samples representative of natural conditions that were upstream of most SRS operations (Section 6.0, Summary Statistics, Appendix A-ESOP Data). Overall the results do not indicate any water quality issues relative to temperature. No comparisons were made between ESOP results and the Savannah River watershed or DOE-SR results due to the high variability in temperature dependent on the day and the time of day samples were collected.

Alkalinity Results

Alkalinity is important for aquatic life in freshwater systems because it buffers pH changes that occur naturally or as a result of anthropogenic sources. Components of alkalinity, such as carbonate and bicarbonate, will incorporate some toxic heavy metals and reduce their toxicity (USEPA 1997). There are no numeric criteria in the South Carolina freshwater standards for alkalinity; however, the National Technical Advisory Committee recommends a minimum alkalinity of 20 mg/L and that natural alkalinity not be reduced by more than 25 percent (National Academy of Sciences (NAS) 1974). Waters having insufficient alkalinity due to natural conditions do not have to be supplemented with artificially added materials to increase the alkalinity. Alkalinity resulting from naturally occurring materials, such as carbonate and bicarbonate, is not considered a health hazard in drinking water supplies. Naturally occurring maximum

levels up to approximately 400 mg/L, as calcium carbonate, are not considered a problem to human health (NAS 1974).

ESOP sampled each location monthly in 2013 for alkalinity. Seventy-five individual samples at eight locations were below the recommended minimum level (Section 6.0, Summary Statistics, Appendix A-ESOP Data). Seven of these locations had yearly averages below the recommended level; NWSV-324 (4.2 (±1.3) mg/L), NWSV-325 (3.1 (±1.29) mg/L), NWSV-2027 (1.13 (±0.18) mg/L), NWSV-2039 (11 (±3.6) mg/L), NWSV-2047 (19 (±8.5) mg/L), NWSV-2055 (17 (±6.7) mg/L), and NWSV-2061 (5 (±1.9) mg/L). The low alkalinity, as related to pH, in SRS streams may be due to the presence of naturally low buffering compounds in the streams. These conditions were consistent even in the samples upstream of most SRS operations, represented by NWSV-2027 and NWSV-2061. The Savannah River Basin's alkalinity averaged 24.69 mg/L, and ranged from 1 mg/L to 160 mg/L (SCDHEC 2013). All ESOP sample results were within this range. DOE-SR did not sample for alkalinity in 2013; therefore no comparison was made.

Turbidity and TSS Results

Turbidity is a measure of water clarity or the amount of light that passes through the water. The freshwater quality standard for turbidity in South Carolina streams is not to exceed 50 nephelometric turbidity units (NTU) provided existing uses are maintained (SCDHEC 2008b). All ESOP monitored streams were below the standard for turbidity in 2013 (Section 6.0, Summary Statistics, Appendix A-ESOP Data). The ESOP sample results ranged from 0.90 mg/L to 15 mg/L. This is comparable to the Savannah River Basin's turbidity ranging from 0.8 mg/L to 320 mg/L (SCDHEC 2013). All ESOP sample results were within this range. DOE-SR did not sample for turbidity in 2013; therefore, no comparison was made.

Turbidity is directly affected by the water's TSS, which refers to the amount of material suspended in the water (USEPA 1997). There is no freshwater quality standard for TSS. The ESOP sample results ranged from 1.0 mg/L to 22 mg/L (Section 6.0, Summary Statistics, Appendix A-ESOP Data). This is comparable to the Savannah River Basin's TSS ranging from 1 mg/L to 43 mg/L (SCDHEC 2013). All ESOP sample results were within this range. See Section 5.0, Figure 3 for a TSS comparison of ESOP and DOE-SR data for co-located samples; there were no significant differences (SRNS 2014).

E. coli Results

In 2013, SCDHEC switched from sampling for fecal coliform to E. coli. This is a species of coliform bacteria that is only found in human and other mammal waste, and is the best indicator of human health risk. The South Carolina freshwater E. coli standard is a daily maximum of 349 Most Probable Number (MPN) per 100ml. ESOP field personnel collected monthly surface water samples for E. coli analysis at each location in 2013. There were 19 individual samples at eight locations that exceeded 349 MPN per 100ml. Two locations also had yearly averages above the standard; NWSV-325 (356 (± 315)

MPN) and NWSV-2055 (384 (±218) MPN). The ESOP sample results ranged from 34 MPN to 1120 MPN. This is comparable to the Savannah River Basin's E. coli ranging from 4 MPN to 6931.6 MPN (SCDHEC 2013). All ESOP sample results were within this range. DOE-SR did not collect samples for fecal coliform in 2013; therefore, no comparison was made.

Nutrient Results

Phosphorous and nitrogen are essential nutrients for the plants and animals that make up the aquatic food web; however, in excess they can cause significant water quality problems. Phosphorous and nitrogen cycle through the environment in a variety of forms, and can indirectly impact DO and other water quality indicators (USEPA 1997). In 2013, ESOP sampled for total phosphorous and various forms of nitrogen, including nitrite/nitrate, TKN, and ammonia. There are no numeric criteria in the South Carolina freshwater standard for any of these parameters.

ESOP uses the most conservative of the federally established drinking water standards for nitrate/nitrite levels to indicate ambient water quality in freshwater streams for nutrients. The USEPA drinking water standards for nitrate/nitrite levels are 10 mg/L and 1 mg/L, respectively, and are designed to protect the public from consumption (USEPA 2009). To provide a conservative approach, ESOP uses the maximum of 1 mg/L as an indication of possible water quality issues. There were no individual samples in 2013 that exceeded 1 mg/L, while there was one that equaled the 1 mg/L limit, NWSV-2039 (Appendix A-ESOP Data). This stream typically has nitrogen levels higher than other SRS streams due to an upstream wastewater treatment plant or to groundwater beneath F-Area and H-Area seepage basins outcropping into Four Mile Branch (RAC 1999). However, no location, including NWSV-2039, had a 2013 yearly average that exceeded the drinking water standard (Section 6.0, Summary Statistics, Appendix A-ESOP Data).

The ESOP results for total phosphorous ranged from <LLD to 0.14 mg/L. The Savannah River Basin results ranged from <LLD to 2.7 mg/L. All ESOP total phosphorous results were within this range.

The ESOP nitrate/nitrite results ranged from <LLD to 1.1 mg/L. The Savannah River Basin results ranged from <LLD to 7.6 mg/L. All ESOP nitrate/nitrite results were within this range.

The ESOP TKN results ranged from <LLD to 3.00 mg/L. The Savannah River Basin results ranged from <LLD to 2.4 mg/L. All ESOP TKN results, except one (NWSV-328 for July), were within this range.

The ESOP ammonia results ranged from <LLD to 0.22 mg/L. The Savannah River Basin results ranged from <LLD to 0.39 mg/L. All ESOP ammonia results were within this range.

Overall the nutrient levels on SRS are similar to the levels found throughout the Savannah River Basin. DOE-SR did not sample for TKN or ammonia in 2013; therefore,

no comparison was made. See Section 5.0, Figure 4 and Figure 5 for a comparison of ESOP and DOE-SR data from co-located samples for total phosphorous and nitrate/nitrite, respectively. There were no significant differences (SRNS 2014).

Metals Results

Most metals are considered to be pollutants, including some that are toxic or known carcinogens. In 2013, ESOP personnel collected monthly samples at each sample location for the following metals: cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, and zinc. All metals data is included in Appendix A-ESOP Data. Yearly averages were calculated for all metals; however, many of these averages are based on a single detection (Section 6.0, Summary Statistics, Appendix A-ESOP Data). Due to the potential health effects of some metals, a yearly average, even if based on a single detection that exceeds the freshwater standards, may indicate a water quality issue. All of these metals, except iron and manganese, have numeric criteria for the protection of human health and aquatic life in the South Carolina freshwater quality standards.

Iron and manganese are naturally occurring metals that do not have state freshwater standards. Iron has a recommended USEPA limit in freshwater streams of 1 mg/L (USEPA 2008). Twenty-one individual ESOP samples at six locations had iron above this recommended level. One location had a yearly average above the recommended level, NWSV-324 (3.2 (±1.0) mg/L). DOE-SR results for co-located samples indicated the same location, in addition to NWSV-2039 and NWSV-2047, had yearly averages above the recommended level for iron (SRNS 2014).

The ESOP sample results for iron ranged from <LLD to 4.8 mg/L. The Savannah River Basin's iron levels ranged from 0.03 mg/L to 7.9 mg/L (SCDHEC 2013). All ESOP sample results were within this range. The EPA recommended limit for iron is 1 mg/L. ESOP detected iron in each of the co-located sample locations with one location, NWSV-324, averaging above this limit. DOE-SR also detected iron in each co-located sample location, with three above the recommended limit.

The ESOP manganese sample results ranged from 0.012 mg/L to 0.19 mg/L. The Savannah River Basin's manganese levels ranged from 0.01 mg/L to 5.4 mg/L (SCDHEC 2013). All ESOP sample results were within this range. ESOP and DOE-SR detected manganese in each of the co-located sample locations. There is no standard for this analyte. See Section 5.0, Figure 6 and Figure 7 for an iron and manganese comparison of ESOP and DOE-SR data for co-located samples; there were no significant differences (SRNS 2014). Due to the lack of numeric data, none of the other metals results were compared to the Savannah River watershed data. Comparison figures to DOE-SR data were also not included.

The freshwater quality standard for cadmium in South Carolina streams is not to exceed 0.00010 mg/L (SCDHEC 2008b). Three individual ESOP samples at two locations had cadmium levels above the standard. These two sample locations had yearly averages above the standard; NWSV-325 had one detection of 0.00011 mg/L and NWSV-2039

(0.00013 (± 0.00001) mg/L). DOE-SR detected cadmium above the standard at five of the six co-located sample locations in 2013. (SRNS 2014). See Section 5.0, Figure 8 for a comparison of ESOP and DOE-SR cadmium data.

The freshwater quality standards for chromium, copper, and nickel in South Carolina streams are not to exceed 0.011 mg/L, 0.0029 mg/L and 0.016 mg/L, respectively (SCDHEC 2008b). There were no ESOP detections of chromium in 2013. DOE-SR detected chromium in five of the six co-located sample locations with one above the standard. ESOP did not detect copper in 2013. DOE-SR detected copper above the standard in at least one sample from every co-located sample location; however, only one DOE-SR yearly average was above the standard. The DOE-SR copper detections were found at levels below ESOP LLD. ESOP did not detect nickel in 2013. DOE-SR detected nickel in each of the co-located sample locations, with none averaging over the standard.

The freshwater quality standard for lead in South Carolina streams is not to exceed 0.00054 mg/L (SCDHEC 2008b). Due to laboratory limitations, ESOP has an LLD higher than the standard at 0.0020 mg/L; therefore, any detection of lead is over the standard. There were no ESOP detections in 2013. DOE-SR detected lead above the standard at two of the co-located sample locations (SRNS 2014).

The freshwater quality standard for mercury in South Carolina streams is not to exceed 0.00091 mg/L (SCDHEC 2008b). Mercury was not detected above the LLD of 0.00020 mg/L in any of the ESOP samples in 2013; therefore, all SCDHEC monitored streams met the standard for this parameter. DOE-SR has a mercury detection limit of 0.00002 mg/L. DOE-SR detected mercury at levels below the SCDHEC LLD in several of the co-located samples. None of these detections were over the freshwater quality standard (SRNS 2014).

The freshwater quality standard for zinc in South Carolina streams is not to exceed 0.037 mg/L (SCDHEC 2008b). All of the 2013 ESOP detections for zinc were below the standard for this parameter. DOE-SR detected zinc above the standard in at least one sample from each co-located sample location; however, no yearly average was above the standard. See Section 5.0, Figure 9 for a zinc comparison of ESOP and DOE-SR yearly averages for co-located samples, there were no significant differences (SRNS 2014).

VOCs, PCBs and Pesticide Results

Most VOCs, PCBs, and pesticides are considered to be pollutants including some that are toxic. Most have numeric criteria for the protection of human health and aquatic life in the South Carolina freshwater quality standards. ESOP field personnel collected surface water samples for VOC, PCB, and pesticides at each location biannually. ESOP sampled for 59 individual VOC, PCB, and pesticide parameters at each location during the Spring and Fall of 2013. All data is included in Appendix A-ESOP Data. There were no ESOP detections of VOC, PCB, or pesticide contaminants in 2013. DOE-SR did not detect any other VOC, PCB, or pesticide parameters in 2013 (SRNS 2014).

SCDHEC and DOE-SR Data Comparison

Six of the nine SCDHEC sampling locations were co-located with DOE-SR sampling locations: NWSV-324, NWSV-325, NWSV- 327, NWSV-328, NWSV-2039, and NWSV-2047 (SRNS 2014). Section 5.0, Table 1 defines the geographic locations of the ESOP sampling locations and Section 5.0, Table 2 defines the sampling schedule for ESOP. Section 5.0, Table 3 defines the geographic locations of all the DOE-SR sampling locations. Comparisons were made for each parameter individually in the text above. Some comparisons include graphs located in Section 5 that show data from the seven co-located samples to determine if there were any significant statistical differences in the following parameters: pH (Figure 1), DO (Figure 2), TSS (Figure 3), total phosphorous (Figure 4), nitrate/nitrite (Figure 5), iron (Figure 6), manganese (Figure 7), cadmium (Figure 8), and zinc (Figure 9). Small discrepancies in data between DOE-SR and SCDHEC may be attributed to differences in sample collection date, sample collection time, sample preservation, and lab analysis. Differences in statistical calculations, such as the yearly averages, may also attribute to dissimilarities. All data less than the LLD were left out of ESOP statistical calculations due to the lack of numeric data.

3.0 CONCLUSIONS/RECOMMENDATIONS

The parameters identified that were above or below USEPA or SCDHEC standards or recommended levels for particular streams will continue to be monitored to establish trends that may warrant further investigation. Overall, the nonradiological water quality on the SRS in 2013 compared favorably with the South Carolina Freshwaters Standard or other recommendations for the parameters and locations monitored in this study. The 2013 ESOP results for most parameters were similar to the SCDHEC's Bureau of Water data for the Savannah River watershed as a whole. ESOP will continue to sample on a monthly and biannual basis for routine parameters. ESOP will continue to evaluate water quality based on the independent nonradiological monitoring and surveillance of SRS surface water. Monitoring is required due to continued land disturbance from clean-up activities, new facility construction, logging, and new missions. The locations, number of samples, sample frequencies, and monitoring parameters are reviewed annually and modified as needed to maximize available resources and address SRS mission changes.

4.0 MAP

Map 1. Nonradiological Surface Water Monitoring Sample Locations

5.0 TABLES AND FIGURES

Table 1. SCDHEC Surface Water Sample Locations

Sample Location	Location Description	Location Rationale
NWSV-2027	Upper Three Runs at Road 2-1	Upstream of most SRS Operations
NWSV-2061	Tinker Creek at Road 2-1	Upstream of most SRS Operations
NWSV-324	Tims Branch at Road C	Downstream from M- & A-Areas
NWSV-325	Upper Three Runs at Road A	Downstream from F-Area
NWSV-2055	Meyers Branch at Road 9	Downstream from P-Area
NWSV-2039	Fourmile Branch at Road A-13.2	Downstream from F- and H-Areas
NWSV-2047	Pen Branch at Road A-13.2	Downstream from K-Area
NWSV-327	Steel Creek at Road A	Downstream from L-Lake
NWSV-328	Lower Three Runs at Patterson Mill Road	Downstream from Par Pond

Table 2. Water Quality Parameter Analyses for SCDHEC

Laboratory	Frequency	Parameter
SCDHEC Lab Aiken, SC	Monthly	Turbidity, BOD, E. Coli, and TSS.
SCDHEC Lab Columbia, SC	Monthly	Alkalinity, Ammonia, Nutrients, Mercury, and Metals
	Semi-annually	VOCs, Pesticides, and PCBs.
Field	Monthly	Temperature, pH, and DO.

Table 3. DOE-SR Surface Water Sample Locations

SRS Stream Locations	Savannah River Locations
Tinker Creek near Northeast Site Boundary	River Mile 160
Tims Branch at Road C*	River Mile 150.4
Upper Three Runs at Road 1-A	River Mile 141.5
Upper Three Runs at Road A*	River Mile 129.1
Beaver Dam Creek at D-Area	River Mile 118.8
Four Mile Creek at Road E	
Four Mile Creek at Road C	
Four Mile Creek adjacent to D-Area*	
Pen Branch at Road A-13.2*	
Steel Creek at Road A*	
Lower Three Runs at Patterson Mill Road*	

*Co-located with DHEC sample locations.

Figure 1. pH Comparison

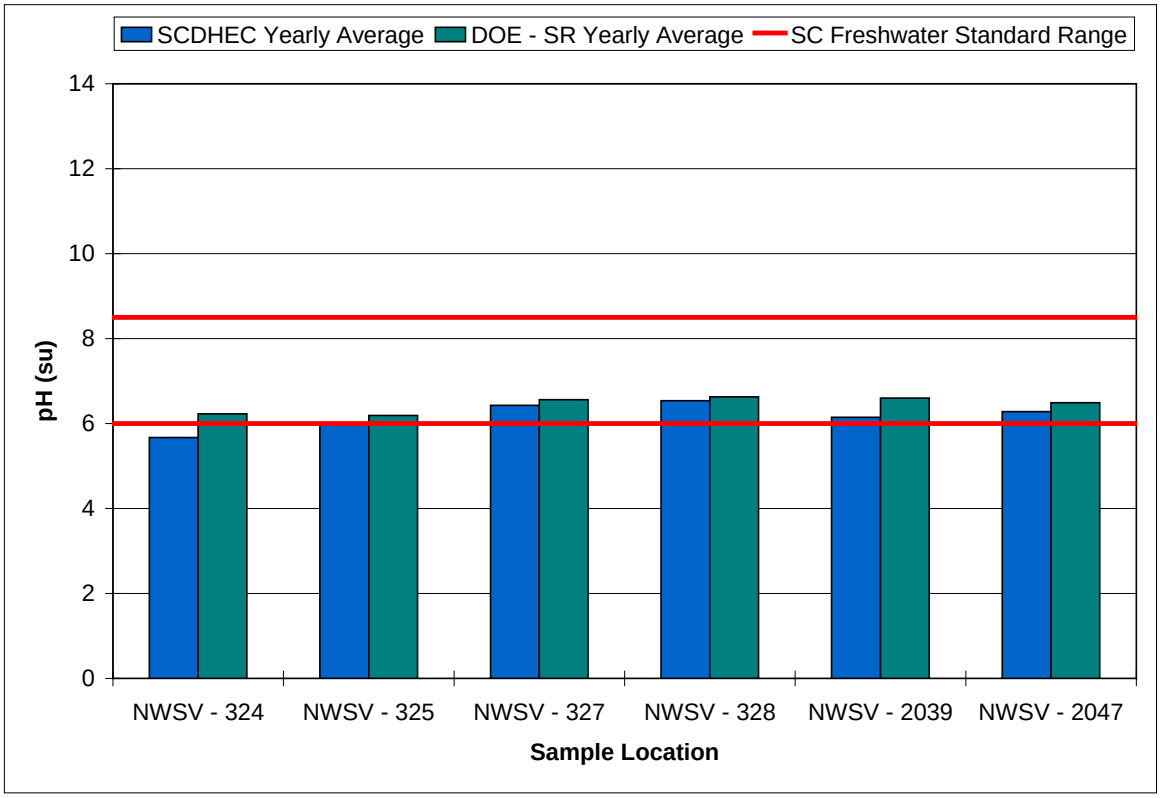


Figure 2. DO Comparison

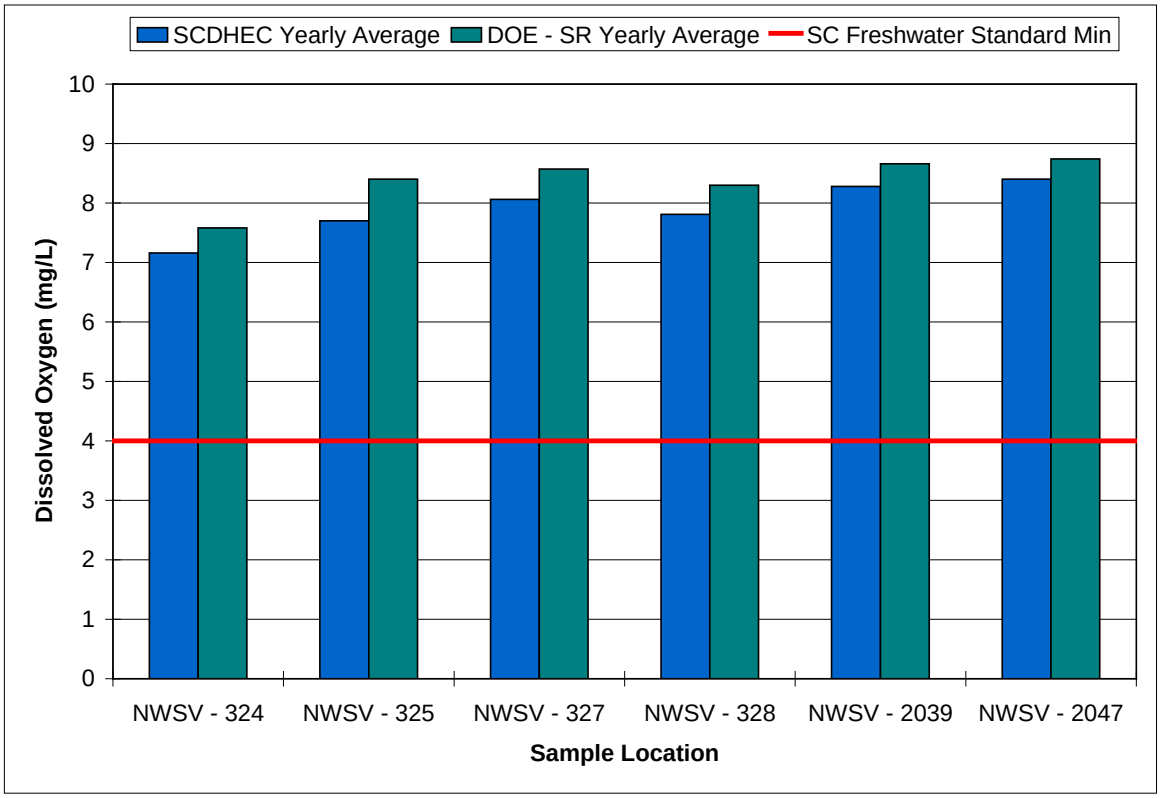


Figure 3. TSS Comparison

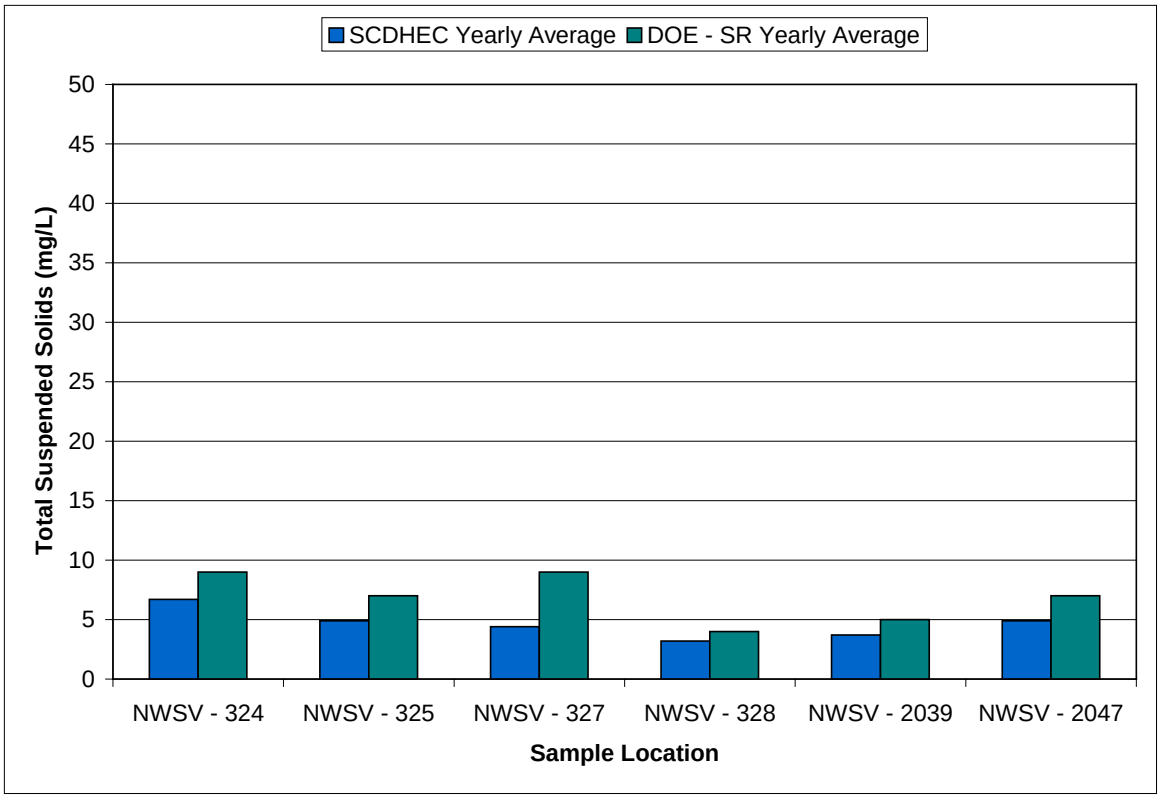


Figure 4. Total Phosphorous Comparison

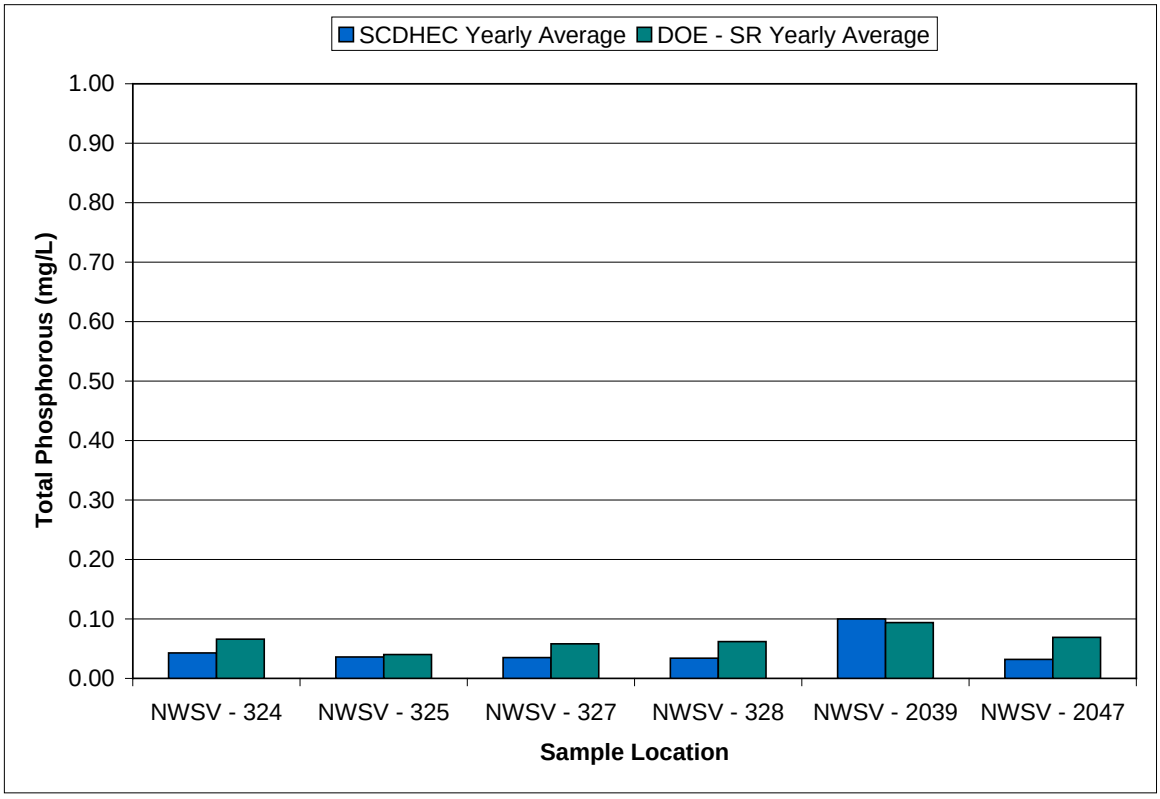


Figure 5. Nitrate/Nitrite Comparison

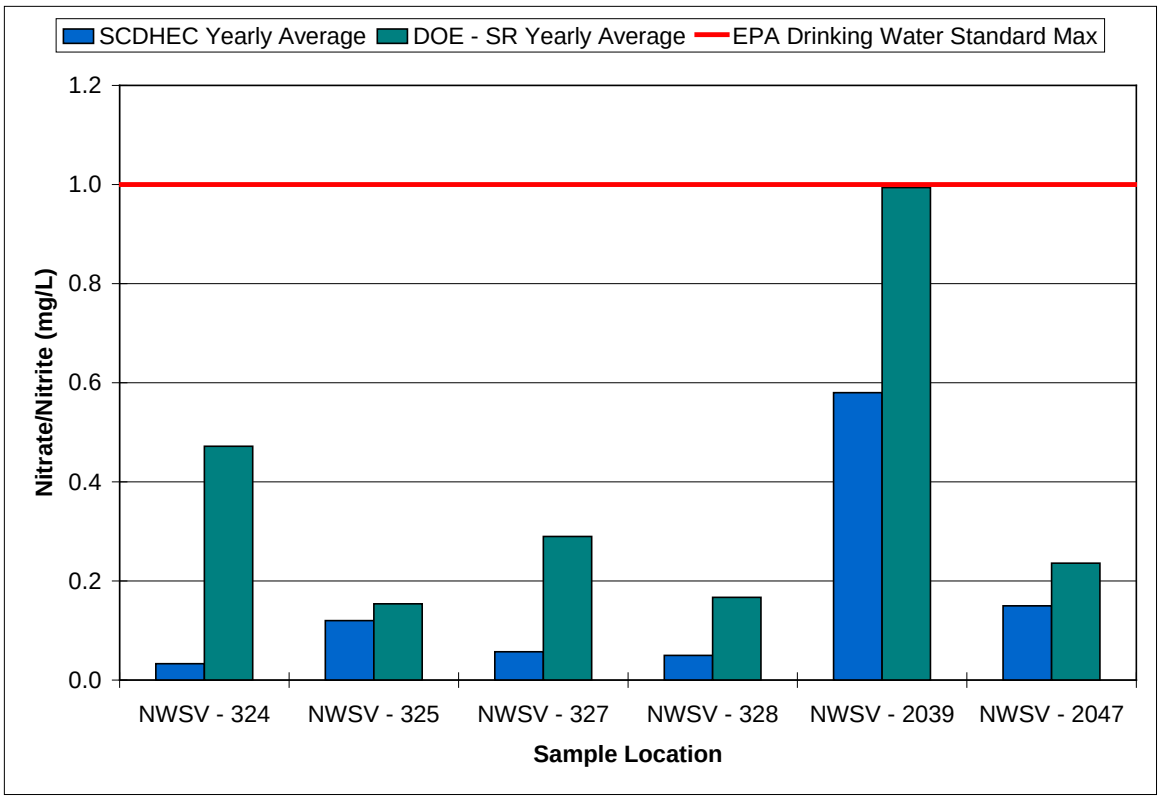


Figure 6. Iron Comparison

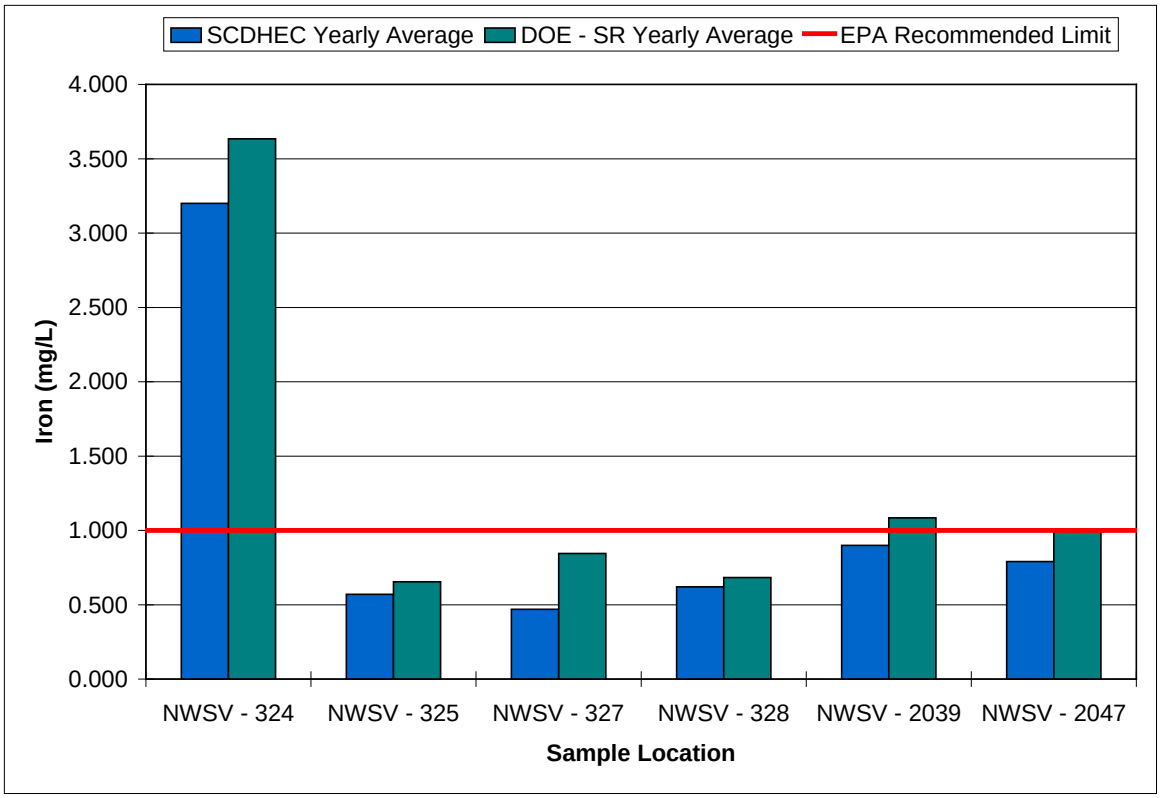


Figure 7. Manganese Comparison

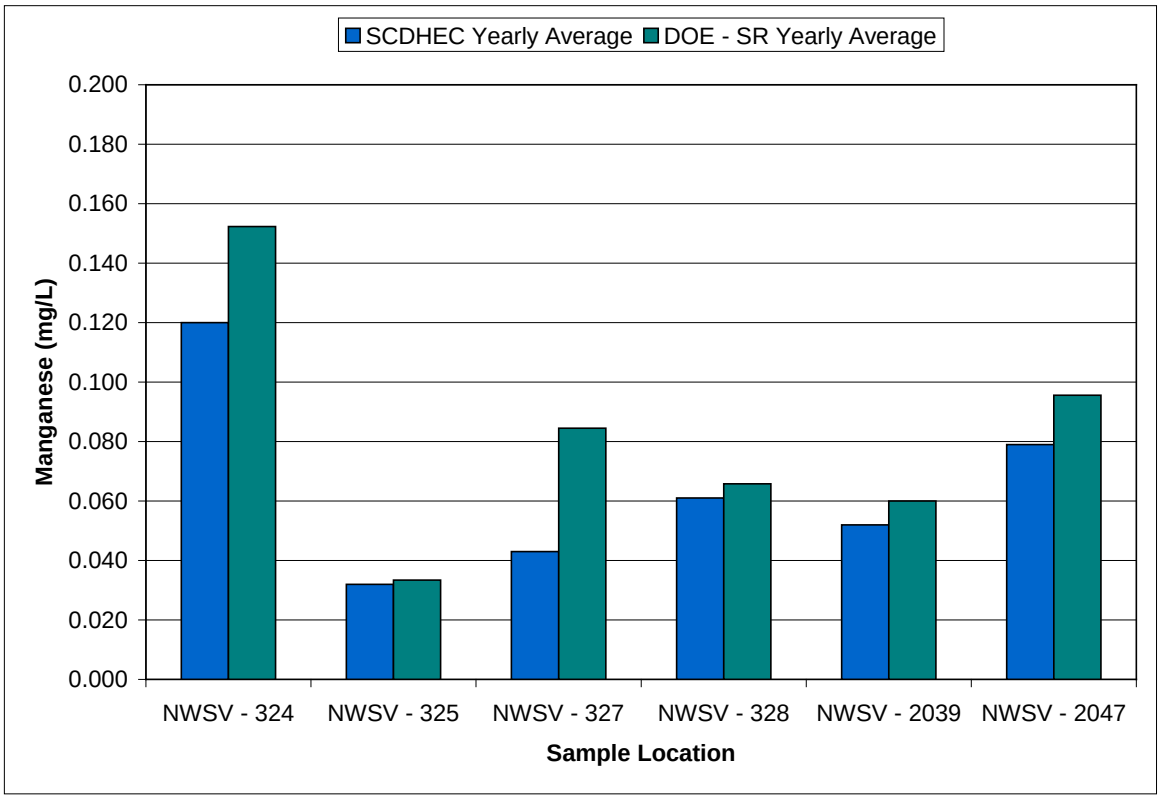


Figure 8. Cadmium Comparison

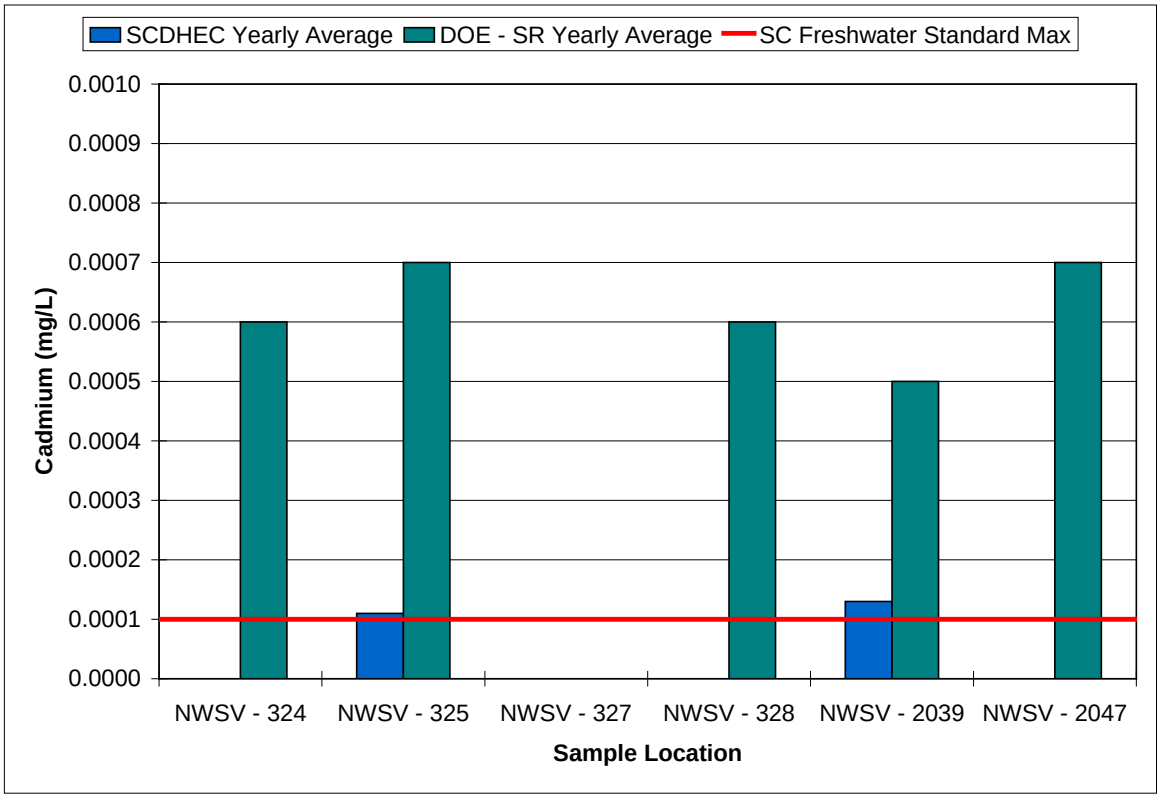
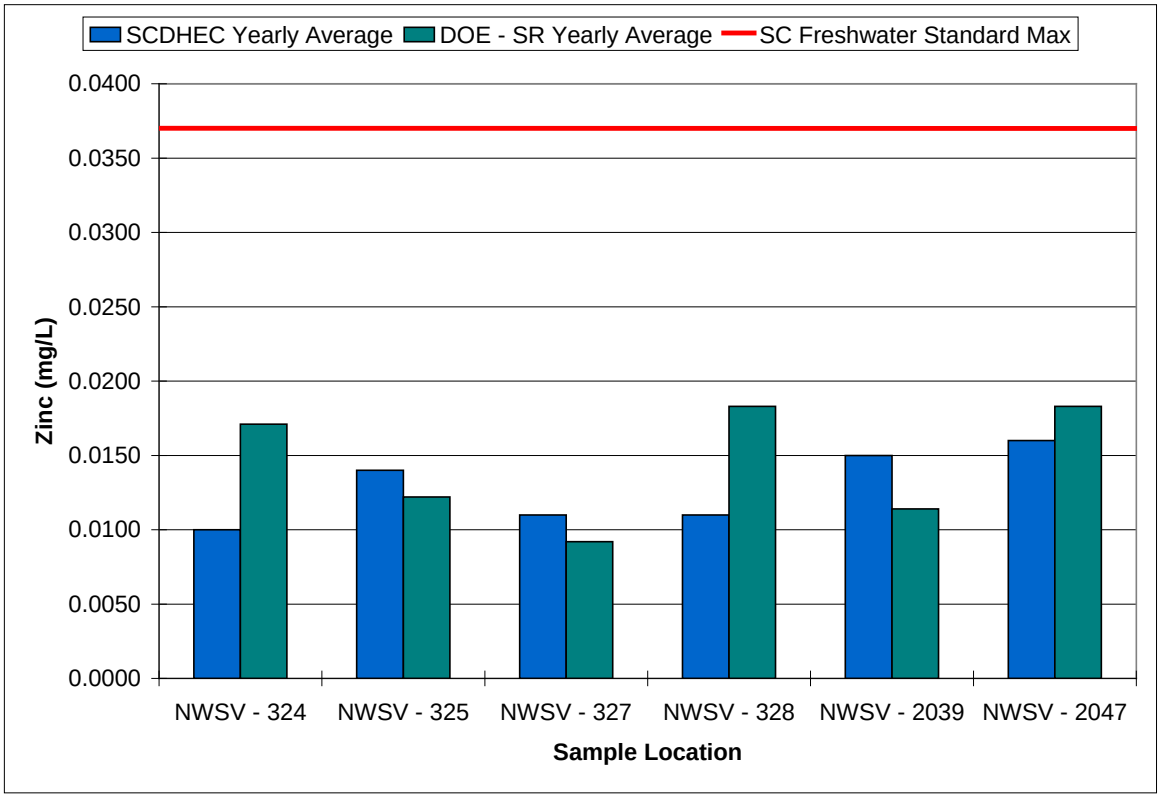


Figure 9. Zinc Comparison



6.0 SUMMARY STATISTICS

Summary Statistics for Nonradiological Monitoring of Ambient Surface Water at SRS

Notes:

1. N/A = Not Applicable
2. AVG = Average
3. STDEV = Standard Deviation
4. MIN = Minimum
5. MAX = Maximum
6. N = Number of Detections

All summary statistics are rounded to two significant figures.

Summary Statistics

Sample Location	NWSV-324	Tims Branch at Road C					
Statistical Analysis		AVG	STDEV	Median	Min	Max	N
Field Parameters	pH	5.67	0.52	5.53	5.04	6.61	12
	DO	7.16	1.29	7.16	4.79	9.72	12
	Water Temp	17.89	4.21	17.53	12.38	23.70	12
Lab Parameters	Alkalinity	4.21	1.33	3.80	2.20	6.30	12
	Turbidity	6.28	2.29	5.85	4.00	11.00	12
	BOD	N/A	N/A	N/A	N/A	N/A	0
	TSS	6.74	1.94	6.50	3.40	10.00	12
	E. Coli	132.52	52.52	138.28	50.40	209.80	12
	TKN	0.64	0.23	0.63	0.32	1.10	11
	Ammonia	0.10	0.056	0.09	0.053	0.22	11
	Nitrate/Nitrite	0.033	0.009	0.034	0.021	0.050	8
	Total Phosphorus	0.043	0.010	0.041	0.030	0.058	12
	Cadmium	N/A	N/A	N/A	N/A	N/A	0
	Chromium	N/A	N/A	N/A	N/A	N/A	0
	Copper	N/A	N/A	N/A	N/A	N/A	0
	Iron	3.17	1.00	3.10	1.50	4.80	12
	Lead	N/A	N/A	N/A	N/A	N/A	0
	Manganese	0.12	0.039	0.11	0.061	0.19	12
	Nickel	N/A	N/A	N/A	N/A	N/A	0
	Zinc	0.01	0.002	0.01	0.012	0.02	3
	Mercury	N/A	N/A	N/A	N/A	N/A	0

Sample Location	NWSV-325	Upper Three Runs at Road A					
Statistical Analysis		AVG	STDEV	Median	Min	Max	N
Field Parameters	pH	6.01	0.88	6.07	4.59	7.59	12
	DO	7.70	1.02	7.81	5.84	9.18	12
	Water Temp	17.22	3.78	16.31	12.35	22.61	12
Lab Parameters	Alkalinity	3.10	1.29	3.60	0.00	4.50	11
	Turbidity	5.28	3.46	3.85	2.20	12.00	12
	BOD	N/A	N/A	N/A	N/A	N/A	0
	TSS	4.91	2.26	4.35	2.40	11.00	12
	E. Coli	355.66	314.64	220.38	103.90	1119.90	12
	TKN	0.44	0.25	0.48	0.11	0.90	11
	Ammonia	0.059	0.006	0.057	0.054	0.065	3
	Nitrate/Nitrite	0.124	0.055	0.115	0.037	0.250	12
	Total Phosphorus	0.036	0.011	0.038	0.021	0.051	11
	Cadmium	0.00011	N/A	0.00011	0.00011	0.00011	1
	Chromium	N/A	N/A	N/A	N/A	N/A	0
	Copper	N/A	N/A	N/A	N/A	N/A	0
	Iron	0.57	0.27	0.47	0.37	1.30	12
	Lead	N/A	N/A	N/A	N/A	N/A	0
	Manganese	0.032	0.024	0.023	0.014	0.093	12
	Nickel	N/A	N/A	N/A	N/A	N/A	0
	Zinc	0.014	0.004	0.013	0.010	0.022	7
	Mercury	N/A	N/A	N/A	N/A	N/A	0

Summary Statistics

Sample Location	NWSV-327	Steel Creek at Road A					
Statistical Analysis		AVG	STDEV	Median	Min	Max	N
Field Parameters	pH	6.43	0.39	6.51	5.46	7.00	12
	DO	8.06	1.47	7.87	6.11	10.01	12
	Water Temp	17.73	5.09	15.62	11.65	26.65	12
Lab Parameters	Alkalinity	23.50	3.85	24.50	17.00	29.00	12
	Turbidity	3.57	2.05	2.95	1.50	9.20	12
	BOD	2.60	N/A	2.60	2.60	2.60	1
	TSS	4.42	5.66	3.10	1.00	22.00	12
	E. Coli	213.42	169.40	186.00	34.10	686.70	12
	TKN	0.52	0.22	0.505	0.24	0.94	12
	Ammonia	0.085	0.036	0.071	0.063	0.150	5
	Nitrate/Nitrite	0.057	0.028	0.062	0.021	0.110	10
	Total Phosphorus	0.035	0.0101	0.040	0.023	0.041	3
	Cadmium	N/A	N/A	N/A	N/A	N/A	0
	Chromium	N/A	N/A	N/A	N/A	N/A	0
	Copper	N/A	N/A	N/A	N/A	N/A	0
	Iron	0.47	0.22	0.43	0.19	0.96	12
	Lead	N/A	N/A	N/A	N/A	N/A	0
	Manganese	0.043	0.020	0.042	0.021	0.096	12
	Nickel	N/A	N/A	N/A	N/A	N/A	0
	Zinc	0.011	N/A	0.011	0.011	0.011	1
	Mercury	N/A	N/A	N/A	N/A	N/A	0

Sample Location	NWSV-328	Lower Three Runs at Patterson Mill Road					
Statistical Analysis		AVG	STDEV	Median	Min	Max	N
Field Parameters	pH	6.54	0.29	6.59	5.95	7.04	12
	DO	7.81	1.30	8.12	5.74	9.52	12
	Water Temp	17.31	4.30	16.23	12.24	24.43	12
Lab Parameters	Alkalinity	40.83	10.51	42.00	24.00	58.00	12
	Turbidity	3.07	1.63	2.70	1.50	7.50	12
	BOD	N/A	N/A	N/A	N/A	N/A	0
	TSS	3.18	1.55	3.80	1.00	5.40	11
	E. Coli	325.46	230.88	287.68	91.00	727.00	12
	TKN	0.69	0.79	0.50	0.25	3.00	11
	Ammonia	0.069	0.015	0.066	0.051	0.098	7
	Nitrate/Nitrite	0.050	0.017	0.048	0.028	0.081	10
	Total Phosphorus	0.034	0.0129	0.029	0.022	0.057	10
	Cadmium	N/A	N/A	N/A	N/A	N/A	0
	Chromium	N/A	N/A	N/A	N/A	N/A	0
	Copper	N/A	N/A	N/A	N/A	N/A	0
	Iron	0.62	0.34	0.51	0.34	1.40	12
	Lead	N/A	N/A	N/A	N/A	N/A	0
	Manganese	0.061	0.021	0.055	0.037	0.100	12
	Nickel	N/A	N/A	N/A	N/A	N/A	0
	Zinc	0.011	N/A	0.011	0.011	0.011	1
	Mercury	N/A	N/A	N/A	N/A	N/A	0

Summary Statistics

Sample Location	NWSV-2027	Upper Three Runs at Road 2-1					
Statistical Analysis		AVG	STDEV	Median	Min	Max	N
Field Parameters	pH	5.25	0.78	5.22	4.14	6.72	12
	DO	8.04	1.09	8.28	6.48	9.43	12
	Water Temp	17.45	2.69	17.37	13.45	21.22	12
Lab Parameters	Alkalinity	1.13	0.18	1.05	1.00	1.40	6
	Turbidity	2.02	0.80	1.85	0.90	3.90	12
	BOD	N/A	N/A	N/A	N/A	N/A	0
	TSS	2.49	0.97	2.55	1.10	4.40	12
	E. Coli	238.58	147.28	175.60	110.60	590.90	12
	TKN	0.40	0.18	0.42	0.13	0.65	10
	Ammonia	0.069	0.027	0.053	0.053	0.100	3
	Nitrate/Nitrite	0.265	0.084	0.245	0.180	0.520	12
	Total Phosphorus	0.026	N/A	0.026	0.026	0.026	1
	Cadmium	N/A	N/A	N/A	N/A	N/A	0
	Chromium	N/A	N/A	N/A	N/A	N/A	0
	Copper	N/A	N/A	N/A	N/A	N/A	0
	Iron	0.35	0.126	0.33	0.19	0.64	12
	Lead	N/A	N/A	N/A	N/A	N/A	0
	Manganese	0.016	0.004	0.015	0.012	0.022	4
	Nickel	N/A	N/A	N/A	N/A	N/A	0
	Zinc	0.01	0.001	0.01	0.01	0.01	4
	Mercury	N/A	N/A	N/A	N/A	N/A	0

Sample Location	NWSV-2039	Fourmile Branch at Road A-13.2					
Statistical Analysis		AVG	STDEV	Median	Min	Max	N
Field Parameters	pH	6.15	0.50	6.15	5.48	7.06	12
	DO	8.28	1.27	8.45	6.30	10.10	12
	Water Temp	17.07	4.40	16.11	11.39	23.23	12
Lab Parameters	Alkalinity	11.46	3.56	11.50	5.30	18.00	12
	Turbidity	5.31	3.34	4.30	2.60	15.00	12
	BOD	N/A	N/A	N/A	N/A	N/A	0
	TSS	3.71	1.75	3.15	1.80	7.30	12
	E. Coli	183.70	107.40	142.70	87.80	461.10	12
	TKN	0.57	0.19	0.58	0.21	0.86	11
	Ammonia	0.058	0.010	0.052	0.050	0.075	7
	Nitrate/Nitrite	0.584	0.218	0.605	0.210	1.000	12
	Total Phosphorus	0.10	0.022	0.095	0.059	0.14	12
	Cadmium	0.00013	0.00001	0.00013	0.00012	0.00013	2
	Chromium	N/A	N/A	N/A	N/A	N/A	0
	Copper	N/A	N/A	N/A	N/A	N/A	0
	Iron	0.90	0.27	0.81	0.58	1.5	12
	Lead	N/A	N/A	N/A	N/A	N/A	0
	Manganese	0.052	0.011	0.049	0.037	0.076	12
	Nickel	N/A	N/A	N/A	N/A	N/A	0
	Zinc	0.015	0.001	0.015	0.013	0.017	5
	Mercury	N/A	N/A	N/A	N/A	N/A	0

Summary Statistics

Sample Location	NWSV-2047	Pen Branch at Road A-13.2					
Statistical Analysis		AVG	STDEV	Median	Min	Max	N
Field Parameters	pH	6.28	0.64	6.37	5.15	7.17	12
	DO	8.40	1.37	8.68	6.20	10.26	12
	Water Temp	16.73	4.33	15.56	11.36	22.99	12
Lab Parameters	Alkalinity	18.56	8.51	19.00	5.70	29.00	12
	Turbidity	6.08	3.42	4.75	2.30	14.00	12
	BOD	N/A	N/A	N/A	N/A	N/A	0
	TSS	4.88	2.99	3.85	1.20	10.00	12
	E. Coli	212.43	121.25	192.80	71.20	488.40	12
	TKN	0.60	0.34	0.51	0.24	1.20	12
	Ammonia	0.098	0.039	0.086	0.053	0.150	7
	Nitrate/Nitrite	0.151	0.090	0.140	0.086	0.420	12
	Total Phosphorus	0.032	0.0076	0.032	0.024	0.042	11
	Cadmium	N/A	N/A	N/A	N/A	N/A	0
	Chromium	N/A	N/A	N/A	N/A	N/A	0
	Copper	N/A	N/A	N/A	N/A	N/A	0
	Iron	0.79	0.31	0.71	0.35	1.40	12
	Lead	N/A	N/A	N/A	N/A	N/A	0
	Manganese	0.079	0.037	0.077	0.024	0.150	12
	Nickel	N/A	N/A	N/A	N/A	N/A	0
	Zinc	0.016	0.007	0.012	0.010	0.029	6
	Mercury	N/A	N/A	N/A	N/A	N/A	0

Sample Location	NWSV-2055	Meyers Branch at Road 9					
Statistical Analysis		AVG	STDEV	Median	Min	Max	N
Field Parameters	pH	6.42	0.45	6.51	5.64	7.04	12
	DO	8.49	1.21	8.77	6.72	9.84	12
	Water Temp	16.79	3.88	16.08	11.99	22.40	12
Lab Parameters	Alkalinity	16.68	6.68	15.50	7.40	27.00	12
	Turbidity	3.82	1.93	3.75	1.20	7.10	12
	BOD	N/A	N/A	N/A	N/A	N/A	0
	TSS	3.38	1.54	3.15	1.20	6.50	12
	E. Coli	383.98	217.68	328.15	90.80	727.00	12
	TKN	0.45	0.27	0.41	0.20	1.20	12
	Ammonia	0.096	0.052	0.074	0.054	0.19	6
	Nitrate/Nitrite	0.094	0.056	0.084	0.039	0.230	12
	Total Phosphorus	0.033	0.006	0.033	0.028	0.037	2
	Cadmium	N/A	N/A	N/A	N/A	N/A	0
	Chromium	N/A	N/A	N/A	N/A	N/A	0
	Copper	N/A	N/A	N/A	N/A	N/A	0
	Iron	0.55	0.27	0.44	0.25	1.10	12
	Lead	N/A	N/A	N/A	N/A	N/A	0
	Manganese	0.047	0.0208	0.044	0.017	0.088	12
	Nickel	N/A	N/A	N/A	N/A	N/A	0
	Zinc	0.012	0.0013	0.012	0.011	0.014	4
	Mercury	N/A	N/A	N/A	N/A	N/A	0

Summary Statistics

Sample Location	NWSV-2061	Tinker Creek at Road 2-1					
Statistical Analysis		AVG	STDEV	Median	Min	Max	N
Field Parameters	pH	5.78	0.64	6.00	4.49	6.56	12
	DO	8.22	1.20	8.49	6.41	9.95	12
	Water Temp	17.63	3.98	17.12	12.64	23.33	12
Lab Parameters	Alkalinity	5.04	1.85	5.60	2.20	7.60	11
	Turbidity	3.77	1.00	3.85	1.80	5.00	12
	BOD	N/A	N/A	N/A	N/A	N/A	0
	TSS	4.44	1.53	4.15	1.80	7.50	12
	E. Coli	237.14	117.00	225.80	86.00	410.60	12
	TKN	0.42	0.20	0.44	0.17	0.71	10
	Ammonia	0.061	0.007	0.060	0.051	0.069	6
	Nitrate/Nitrite	0.045	0.016	0.045	0.020	0.063	11
	Total Phosphorus	0.058	0.018	0.053	0.032	0.098	12
	Cadmium	N/A	N/A	N/A	N/A	N/A	0
	Chromium	N/A	N/A	N/A	N/A	N/A	0
	Copper	N/A	N/A	N/A	N/A	N/A	0
	Iron	0.53	0.16	0.51	0.33	0.80	12
	Lead	N/A	N/A	N/A	N/A	N/A	0
	Manganese	0.031	0.0116	0.028	0.018	0.051	12
	Nickel	N/A	N/A	N/A	N/A	N/A	0
	Zinc	0.014	0.0013	0.014	0.013	0.016	5
	Mercury	N/A	N/A	N/A	N/A	N/A	0

List Of Acronyms

BOD	Biochemical Oxygen Demand
DO	Dissolved Oxygen
DOE-SR	Department of Energy - Savannah River
ESOP	Environmental Surveillance and Oversight Program
FW	Freshwater
LLD	Lower Limit of Detection
MPN	Most Probable Number
NAS	National Academy of Sciences
PCB	Polychlorinated Biphenyls
SCDHEC	South Carolina Department of Health and Environmental Control
SRS	Savannah River Site
TKN	Total Kjeldahl Nitrogen
TSS	Total Suspended Solid
USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compounds

Units Of Measure

C	temperature in Celsius
mg/L	milligrams per liter
mL	milliliter
NTU	Nephelometric Turbidity Unit
su	standard units
±	plus or minus one standard deviation unless otherwise noted

References

National Academy of Sciences (NAS), National Academy of Engineering, 1974. Water quality criteria, 1972. U.S. Government Printing Office, Washington, D.C.

Radiological Assessments Corporation (RAC), 1999. Savannah River Site Environmental Dose Reconstruction Project. Phase II: Source Term Calculation and Ingestion Pathway Data Retrieval Evaluation of Materials Released from the Savannah River Site. RAC Report No. 1-CDC-SRS-1999-Final.

South Carolina Department of Health and Environmental Control (SCDHEC), 2008a. *Classified Waters* (Regulation 61-69), Bureau of Water, Division of Water Quality Assessment and Enforcement, Columbia, South Carolina.

SCDHEC, 2008b. *Water Classifications and Standards* (Regulation 61-68), Bureau of Water, Division of Water Quality Assessment and Enforcement, Columbia, South Carolina.

SCDHEC, 2011. *State of South Carolina Monitoring Strategy*, Technical Report No. 01J-11, Bureau of Water, Water Quality Monitoring Section, Columbia, South Carolina.

SCDHEC, 2012. *Nonradiological Ambient Surface Water Quality Monitoring Project Plan*, Bureau of Environmental Services - Environmental Surveillance and Oversight Program. Aiken, South Carolina.

SCDHEC, 2013. *South Carolina Water Quality Atlas 2008 through 2012*. Unpublished internal document, Bureau of Water (David Chestnut and Bryan Rabon, September 17, 2013). Columbia, South Carolina.

Savannah River Nuclear Solutions, LLC (SRNS), 2014. *Savannah River Site Environmental Report for 2013*. Savannah River Site, Aiken, South Carolina. SRNS-STI-2014-00006.

United States Environmental Protection Agency (USEPA), 1997. *Monitoring Water Quality*, EPA 841-B-97-003. Office of Water, Washington DC.

USEPA, 2008. *National Recommended Water Quality Criteria,* EPA-Section 304(a) Clean Water Act.

USEPA, 2009. *National Primary Drinking Water Standards*, EPA-816-F-09-004. Office of Water, Washington DC.

United States Geological Survey (USGS), 2000. *Water Quality in the Santee River Basin and Coastal Drainages, North and South Carolina,* 1995-1998: U.S Geological Survey Circular 1206, 32p., http://pubs.water.usgs.gov/circ1206/ .

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2013 Radiological and Nonradiological Monitoring of Sediments

Environmental Surveillance and Oversight Program

06SM001
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January 01, 2013 – December 31, 2013

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Table of Contents

1.0 PROJECT SUMMARY

The accumulation of radiological and nonradiological contaminants in sediment can have direct impacts on aquatic organisms that can result in human exposure. Point source and nonpoint source pollutants impact water bodies through direct discharge, atmospheric fallout, or through runoff. These accumulated contaminants may become resuspended in streams and rivers. Contaminants dispersed downstream potentially impact drinking water supplies and fish consumed by the public. The high mobility of sediments is a complicated issue; stream flow changes can redistribute contaminants or bury them as part of the natural sedimentation process. Patterns of sediment contamination are strongly affected by hydrologic factors and the physical and chemical characterization of the sediment (USEPA 1987).

Savannah River Site (SRS) streams receive surface water runoff and water from permitted discharges. Stormwater basins may receive runoff and atmospheric fallout from diffuse and fugitive sources (USDOE 1995). Cesium-137 (Cs-137) contamination occurs along the entire length of Lower Three Runs, Steel Creek on SRS, and the private property of Creek Plantation. This contamination was created by accidental releases of nuclear material from past operations.

Although DOE-SR conducted sediment remediation along Lower Three Runs creek in 2012, Lower Three Runs and Steel Creek watersheds still represent a possible pathway for release of contamination from SRS activities to both on-site and off-site receptors in the environment (WSRC 2002). Flooding and dam releases from Par Pond and L-Lake scour creek bottoms that may result in the resuspension of contaminated sediments. SRS is within the Savannah River watershed, with five major streams feeding into the Savannah River. Dispersal of any contaminants from these streams has the potential to impact the publicly accessible Savannah River.

Cesium-137 is an artificially produced fission product. Atmospheric Cs-137 was released from the separation areas and was a key radionuclide released to water and air, mainly from F-Area and H-Area (CDC 2006). The liquid releases were also from the reactors as a result of leaking fuel elements in the 1950s and 1960s (WSRC 1998). Current Cs-137 releases at facilities such as Z-area (Saltstone) Z001 outfall warrants the need for Cs-137 monitoring as it obvious that unplanned releases are not only of historical concern but also a current concern. The largest single source of Cs-137 was fallout from atmospheric nuclear weapons tests in the 1950s and 1960s, which dispersed and deposited Cs-137 world-wide. However, much of the Cs-137 from testing has now decayed. Due to its half-life of 30 years, Cs-137 still has an impact on the SRS environment. Additionally, the biological behavior of Cs-137 is similar to potassium, which is essential to the function of living cells (USEPA 2009a). Therefore, the potential for Cs-137 uptake into humans is important considering the potential health effects.

Americium-241 (Am-241) is a man-made transuranic nuclide produced during the fission process. With a half-life of 432 years, this radionuclide may be a legacy of past nuclear fallout events. Previous studies indicate that Am-241 was released in significant quantities from the SRS. Therefore, this warrants the sampling of Am-241 to detect any potential impacts from the significant quantities of Am-241 released from SRS (Till et. al. 2001). Along with Cs-137, Am-241 was released to the air from SRS (CDC 2006).

Alpha-emitting radionuclides were released to liquid effluent from M-Area, F-Area, H-Area, and the reactor areas. The primary stream affected by the M-Area releases was Tims Branch, which ultimately flows into Upper Three Runs Creek. Fourmile Branch is the stream most affected by releases coming from the separation areas. Releases from the reactor areas affected all streams with the exception of Upper Three Runs Creek (Till et al. 2001).

Beta-emitting radionuclides were released to liquid effluent from F-Area, H-Area, and the reactors. Fourmile Branch is the stream primarily affected by releases from the separations areas. Steel Creek, Pen Branch, and Lower Three Runs Creek were mainly affected by releases from the reactors. Strontium-90 (Sr-90) is a main contributor of beta activity and came primarily from the reactors (Till et al. 2001).

Plutonium releases at SRS occurred primarily through the discharge of liquid effluent. Plutonium was manufactured on SRS in H-Area from fuel rods and in F-Area from targets (Till et al. 2001). Iodine-129 (I-129) is a fission product of reactor fuel that has a very long (~16 million year) half-life. Most releases occurred during fuel processing (Till et al. 2001). Technetium-99 (Tc-99) was produced in SRS production reactors as a fission byproduct of uranium and plutonium. This radionuclide was released to the environment from the separation areas ventilation systems, the aqueous environment from liquid waste in waste tanks, and the Solid Waste Disposal Facility (WSRC 1993a). Technetium-99 has also been released to the environment from atmospheric weapons tests, nuclear reactor airborne emissions, nuclear fuel reprocessing plant airborne emissions, and facilities that treat or store radioactive waste (USEPA 2009b). Although historical fallout from weapons testing has been the most important man-made contributor to radioactive contamination of the global environment, there are other anthropogenic sources such as SRS operations. Also, some radionuclides occur naturally in the environment. Separating radioactivity contributed by releases from the SRS from weapons fallout is difficult for some radioisotopes (Till et al. 2001).

Ten metals were analyzed in creek mouth and boat landing samples collected in 2013. A complete list of all nonradiological analytes can be found in Section 5.0, Table 3.

Barium has been a constituent of the H-Area Hazardous Waste Management Facility (WSRC 1993b). Beryllium is a strong, lightweight metal used in nuclear weapons work (Till et al. 2001). Cadmium enters the atmosphere through fuel and coal combustion (Till et al. 2001). Chromium solutions were used at the SRS as corrosion inhibitors. Chromium was a part of wastewater solutions resulting from dissolving stainless steel. It was also used in cleaning solutions in the separation areas (Till et al. 2001). Copper, while naturally occurring, can also be released to the environment through the combustion of wood, coal, and oil (Alloway 1995). These mechanisms are possible sources of elevated copper in the sediments. Atmospheric emissions of lead from SRS occurred through coal and fuel combustion (Till et al. 2001). Lead can deposit in sediment, due to its immobility, and have a long residence time when compared to other pollutants (Alloway 1995). Manganese has been released in the separations area processes and discharged to liquid waste tanks. It is also a byproduct of coal burning (Till et al. 2001). Mercury in sediment may be attributed to atmospheric fallout. SRS facilities such as F-Area and H-Area, tritium facilities, waste tanks, and the coal-fired power plants have emitted mercury to the atmosphere (Till et al. 2001). Nickel was released to Tims Branch from M-Area

processes (Till et al. 2001). Upper Three Runs creek is the receptor of effluent from Tims Branch. Zinc was released in relatively small amounts to the separations area seepage basins as well as the M-Area seepage basin (Till et al. 2001).

The South Carolina Department of Health and Environmental Control (SCDHEC) Environmental Surveillance and Oversight Program (ESOP) provides independent evaluation of the Department of Energy-Savannah River (DOE-SR) environmental monitoring programs. ESOP personnel independently evaluated sediment samples for radionuclide and nonradionuclide contaminant concentrations in SRS streams, SRS stormwater basins, creek mouths along the boundary of SRS, the Savannah River, and publicly accessible sites in the SRS vicinity. Background locations are sampled to compare ambient levels of radionuclides from offsite locations to determine potential impacts due to SRS operations. Sediment samples on SRS are routinely split with DOE-SR in order to compare results.

The ESOP ambient sediment monitoring project changed in 2007 to include more background sediments (those greater than 50 miles from the SRS center point) within the boundaries of the state of South Carolina. This sampling program was implemented to allow statistical comparisons of the SRS perimeter and South Carolina background contaminant levels in sediment.

ESOP sampled 16 locations at SRS in 2013 with the cooperation of DOE-SR personnel. SRS sediment sampling locations are illustrated in Section 4.0, Map 1. Split samples were collected from eight stream locations on SRS, and from three SRS stormwater basins. These locations are not publicly accessible. Creek mouth sediment samples at five publicly accessible locations along the Savannah River were also co-sampled (Section 5.0, Table 1). The Pen Branch creek mouth was not sampled because it flows into a swamp area where there is no creek mouth access. Ten sediment samples were also collected from publicly accessible boat landings. In addition, ESOP independently sampled six random background sediments.

All SRS split samples were analyzed for gross alpha, gross beta, and gamma. Additionally, SRS creek mouths, and publicly accessible boat landings were analyzed for metals. All samples collected from random background locations were analyzed for gross alpha, gross beta, and gamma. Additionally, isotopic analysis was conducted on five SRS accessible creek mouths, and two SRS stream locations. Evaluation of radiological and nonradiological contaminants in sediment is necessary to detect any impact from DOE-SR operations beyond historically impacted areas. Radionuclide detections in sediment are typically the result of accumulation over many years and do not represent yearly depositions.

The continuation of sediment sampling and analysis, along with trending of data, is necessary to closely monitor SRS sediments. Cs-137 releases from Z-Area have the potential to contaminate tributaries of McQueen Branch and possibly contaminate Upper Three Runs. The impact for possible contamination warrants long-term monitoring by ESOP along SRS streams and the publicly accessible Savannah River.

2.0 RESULTS AND DISCUSSION

Radiological Parameter Results

SCDHEC 2013 radiological data can be found in Appendix A and statistical data can be found in Section 6.0.

Sediments were evaluated for gross alpha and gross non-volatile beta as well as a suite of 24 gamma-emitting radionuclides. Selected samples were also analyzed for plutonium-238 (Pu-238) and plutonium-239/240 (Pu-239/240). A complete list of gamma-emitting radionuclides that SCDHEC analyzed for in 2013 can be found in Section 5.0, Table 3.

Gamma spectroscopy analysis led to detections of man-made radionuclides. Cesium-137 activity trends highest at the SRS stormwater basins, followed by SRS on-site streams, and SRS creek mouths. Figure 1 in Section 5.0 illustrates Cs-137 activity in sediment samples collected from SRS stormwater basins, SRS streams, SRS creek mouths and publicly accessible boat landings.

Samples collected from seven of the eight on-site non-publicly accessible SRS stream sample locations had Cs-137 detections averaging 0.80 (±01.3) picocuries per gram (pCi/g) and ranged from less than minimum detectable activity (MDA) to 3.4 pCi/g at Lower Three Runs (SMSV-175). All of the three SRS stormwater basins had detections of Cs-137 at an average of 1.05 (±1.62) pCi/g.

Cesium-137 was detected at all five publicly accessible SRS creek mouth locations (Section 5.0, Figure 2). The Cs-137 averaged 0.40 (± 0.50) pCi/g and ranged from 0.09 pCi/g at Beaver Dam Creek mouth (SMSV-2013) to 1.34 pCi/g at Steel Creek mouth (SMSV-2017). Cesium-137 was detected at seven of the ten publicly accessible boat landing locations at an average of 0.30 (± 0.40) pCi/g and ranged from less than MDA to 1.18 pCi/g.

The concentration of background terrestrial radionuclides varies from place to place in much the same way that mineral deposits can be expected to vary from geologic processes that occur over time. The average value of background will fluctuate from site to site and its value is dependent on the data collected at a particular site.

Five out of six background samples had Cs-137 detections (Section 5.0, Table 2). The random background sample detection average was 0.14 (±0.07) pCi/g. The random background samples had detections ranging from less than MDA to 0.25 pCi/g. Cesium-137, on average, was highest in the SRS stormwater basins samples followed by SRS on-site streams.

There were detections of actinium-228, potassium-40, lead-212, lead-214, and radium-226. These are Naturally Occurring Radioactive Material (NORM) decay products that account for the remaining gamma detections (Section 5, Table 3). All other gamma-emitting radionuclides had no detections above their respective MDA.

Gross alpha activity was detected in four of the eight on-site non-publicly accessible SRS stream samples locations averaging 30.3(±14.9) pCi/g and ranging from less than MDA to 50.0 pCi/g.

The highest detection was located at Upper Three Runs (SMSV-325). Gross alpha activity was detected in one of the three SRS stormwater basin sample locations (SME-002). Gross alpha activity was not detected in any of the six background locations. Gross alpha activity was detected in three of the ten publicly accessible boat landings averaging 15.2 (±1.5) pCi/g and ranging from less than MDA to 16.3 pCi/g at Johnson's Landing (SMJL13). Gross alpha activity was detected in two of the five creek mouth samples averaging 22.8 (±5.3) pCi/g and ranging from less than MDA to 41.8 pCi/g at Beaver Dam Creek mouth (SMSV-2013). These results can be found in Section 5.0 Figure 3.

Gross non-volatile beta was detected in three of the eight on-site SRS stream locations averaging 20.3(±.86) pCi/g. Activities ranged from less than MDA to 50.0 pCi/g. The highest detection was located at Upper Three Runs (SMSV-325). Four out of the five creek mouth locations had gross non-volatile beta detections averaging 16.0 (±5.0) pCi/g. Activities ranged from less than MDA to 22.9 pCi/g. The highest detection was located at Beaver Dam creek mouth (SMSV-2011). Gross non-volatile beta was detected at two of the five SRS stormwater basins averaging 22.8 (±18.3) pCi/g and ranging from less than MDA to 35.8 pCi/g at SME-002 basin (Section 5.0 Figure 3).

Gross-beta was detected in one of the background locations (SMABB13).

Isotopic analysis of Pu-238 and Pu-239/240 was performed on samples from the five SRS creek mouths and four on-site SRS stream locations. Plutonium-238 was detected in all of the sampling locations. Activities ranged from 0.001 pCi/g to 0.056 pCi/g at SMSV-2069. Plutonium-239/240 was detected in all of sampling locations. Activities ranged from 0.001 to 0.034 pCi/g at SMSV-2069.

Nonradiological Parameter Results

A United States Environmental Protection Agency (USEPA) Target Analyte List of ten metals was analyzed in all of the SRS creek mouth locations and the public boat landings in 2012. Metals data can be found in Section 5.0, Figure 5. Comparisons were made to the Ecological Screening Value (ESV) for sediment which does not represent remediation goals or cleanup levels, but is used to identify constituents of potential concern (WSRC 2005). The South Carolina state averages are from "Elements in South Carolina Inferred Background Soil and Stream Sediment Samples" (Canova 1999).

Barium (Ba) was detected above the ESV of 20 milligrams per kilogram (mg/kg) in all of the five SRS creek mouth locations collected. The SRS creek mouth average was 70 (±46) mg/kg with a minimum of 24 mg/kg at Upper Three Runs Creek mouth (SMSV-2011) and a maximum of 140 mg/kg at Beaver Dam Creek mouth (SMSV-2013). The public boat landing average was 53 (±18) mg/kg with a minimum of 19 mg/kg at River View Park Boat landing (SMRVP13) and a maximum of 75 mg/kg at Steel Creek Boat landing (SMSCL13).

Beryllium (Be) was detected above the ESV of 0.5 mg/kg at only one of the five SRS creek mouth locations at a concentration of 0.52 mg/kg at SMSV-2013. Beryllium was detected above the ESV of 0.5 mg/kg at three of the ten public boat landing locations.

Cadmium (Cd) was found above the ESV of 0.6 mg/kg in three of the five SRS creek mouth locations collected. The SRS creek mouth average was 1.5(±0.4) mg/kg with a minimum of 1.2 mg/kg at Steel Creek mouth (SMSV-2017) and a maximum of 1.9 mg/kg at Beaver Dam Creek mouth (SMSV-2013). The public boat landing average was 1.2 (±.21) mg/kg ranging from less than 1 to a maximum of 1.6 mg/kg at Fury's Ferry Boat landing (SMFF13).

Chromium (Cr) was detected in all of the five SRS creek mouth locations and none were above the ESV of 36 mg/kg. The SRS creek mouth average was 8.8(±4.8) mg/kg with a minimum of 2.9 mg/kg at Upper Three Runs Creek mouth (SMSV-2011) and a maximum of 14 mg/kg at Beaver Dam Creek mouth (SV-2013). The public boat landing average was 11.5 (±5.0) mg/kg and ranged from of 4.7 mg/kg to 18 mg/kg at Fury's Ferry Boat landing (SMFF13)

Only one of the 2013 samples was above the ESV of 18.7 mg/kg for copper (Cu). The SRS creek mouth average was 3.9 (±2.1) mg/kg with a minimum of 1.2 mg/kg at SMSV-2011 and a maximum of 6.4 mg/kg a Beaver Dam Creek mouth (SMSV-2013). The public boat landing average was 7.0 (±5.6) mg/kg with a minimum of 2.0 mg/kg at Riverview Park Boat landing (SMRVP13) and a maximum of 20 mg/kg at Stokes Bluff Boat landing (SMSBL13).

All 2013 samples were below the ESV of 30.2 mg/kg for lead. Lead (Pb) was detected in three of the five SRS creek mouth samples at an average of 6.7 (±1.6) mg/kg with a minimum of 5.2 mg/kg at Steel Creek mouth (SMSV-2017) and a maximum of 8.4 mg/kg at Beaver Dam Creek mouth (SMSV-2013). Nine of the ten public boat landings yielded detections for lead. The average was 8.0 (±1.6) mg/kg with a minimum of 5.4 mg/kg at Jackson Boat landing (SMJBL13) and a maximum of 20 mg/kg at Stokes Bluff Boat landing (SMSBL13).

Six of the 2013 samples exceeded the ESV of 630 mg/kg for manganese. Manganese (Mn) was detected in all SRS creek mouths and public boat landing samples. SRS creek mouth samples had an average of 822 (±800) mg/kg with a minimum of 140 mg/kg at Upper Three Runs Creek mouth (SMSV-2011) and a maximum of 2100 mg/kg at Beaver Dam Creek mouth (SMSV-2013). The public boat landing average was 596 (±605) mg/kg with a minimum of 49 mg/kg at Johnsons Boat landing (SMJL13) and a maximum of 1800 mg/kg at Little Hell Boat landing (SMLHL13).

Mercury (Hg) was not detected above the MDC in any samples collected in 2013.

All 2013 samples were below the ESV of 15.9 mg/kg for nickel. Nickel (Ni) was detected in all of the five SRS creek mouth samples. The SRS creek mouth average was 4.1 (±0.1.5) mg/kg with a minimum of 2.7 mg/kg at Steel Creek mouth (SMSV-2017) and a maximum of 6.2 mg/kg at Beaver Dam Creek mouth (SMSV-2013). The public boat landing average was 4.6 (±2.0) mg/kg with a minimum of 2.0 mg/kg River View Park Boat landing (SMRVP13) and a maximum of 8.6 mg/kg at Stokes Bluff Boat landing (SMSBL13)

All 2013 samples were below the ESV of 98 mg/kg for zinc. Zinc (Zn) was detected in all of the SRS creek mouth samples. The SRS creek mouth average was 24 (±14) mg/kg with a minimum of 12 mg/kg at Four Mile Creek mouth (SMSV-2015) and a maximum of 44 mg/kg at Beaver Dam Creek mouth (SMSV-2013). The public boat landing average was 26 (±10) mg/kg with a

minimum of 11 mg/kg at River View Park Boat landing (SMRVP13) and maximum of 37 mg/kg at Fury's Ferry Boat landing (SMFF13). SCDHEC nonradiological sediment data can be found in ESOP Data- Appendix A and nonradiological statistical data can be found in Section 6.0.

SCDHEC and DOE-SR Data Comparison

Radiological data comparison of 2013 sediment samples from SCDHEC and DOE-SR resulted in similar findings. SCDHEC Cs-137 data from the SRS creek mouths were trended for 2009-2013 (Section 5.0, Figure 4). Average Cs-137 levels trend lower in the subsequent years of 2009-2013. Due to flooding disturbances in sediments and other media characteristics, variability in sediment samples can be anticipated.

DOE-SR and SCDHEC split eight SRS stream sediment and three stormwater basin sediment samples in 2013. All SCDHEC samples were analyzed for gross alpha and gross beta-emitting particles and gamma-emitting radionuclides. Select samples were also analyzed for Pu-238, Pu-239/40.

Both agencies detected Cs-137 concentrations in SRS streams, SRS stormwater basins and Savannah River locations. DOE-SR Cs-137 activity ranged from less than minimum detectable concentration (MDC) to 497 pCi/g at R-Canal (100-R Location). This location is not accessible to the public. The publicly accessible Savannah River and SRS creek mouths averaged 0.40 (±.50) pCi/g in the SCDHEC data. DOE-SR detected Cs-137 above MDC at 6 locations along the Savannah River and creek mouths at an average of 0.24 (±.20) pCi/g. Cs-137 was detected at all of the three basins sampled by SCDHEC averaging 1.05(± 1.62). The DOE-SR on site stormwater basins results ranged from less than MDC to a maximum Cs-137 concentration of 2880 (± 3.0) pCi/g at the Z-Area Basin.

SCDHEC had no detections of Am-241 in sediment samples collected in 2013. The on-site DOE-SR stream sediments Am-241 detections ranged from less than MDC to 1.84 pCi/g R-Area Downstream of R-1. DOE-SR detected Am-241 in two Savannah River and SRS creek mouths samples above MDC. The average MDA for the 2013 SCDHEC sediment samples was 0.156 pCi/g, which is much higher than the DOE-SR MDC of 0.0039 pCi/g (SRNS 2014). Since DOE-SR has a much lower MDC, this may explain why the SCDHEC data does not report more detections above the MDA. Also, values less than the MDC are included in the DOE-SR data (SRNS 2014). Only detections are averaged from the SCDHEC data.

DOE-SR detected Pu-238 above the MDC in two of the Savannah River sediment samples averaging .002 (±0004) pCi/g. SCDHEC detected Pu-238 at the five creek mouth locations averaging 0.008 (± 0.002) pCi/g. DOE-SR detected Pu-239 above the MDC in two of the Savannah River sediment samples averaging .004 (±0001) pCi/g. SCDHEC detected Pu-239/240 at the five creek mouth locations averaging 0.002 (± 0.001) pCi/g.

3.0 CONCLUSIONS AND RECOMMENDATIONS

The creek mouths of SRS are a conduit for the dispersal of radionuclides into publicly accessible water. Cesium-137, Pu-238, and Pu-239/240 were found in the sediment within several creek mouths at the Savannah River.

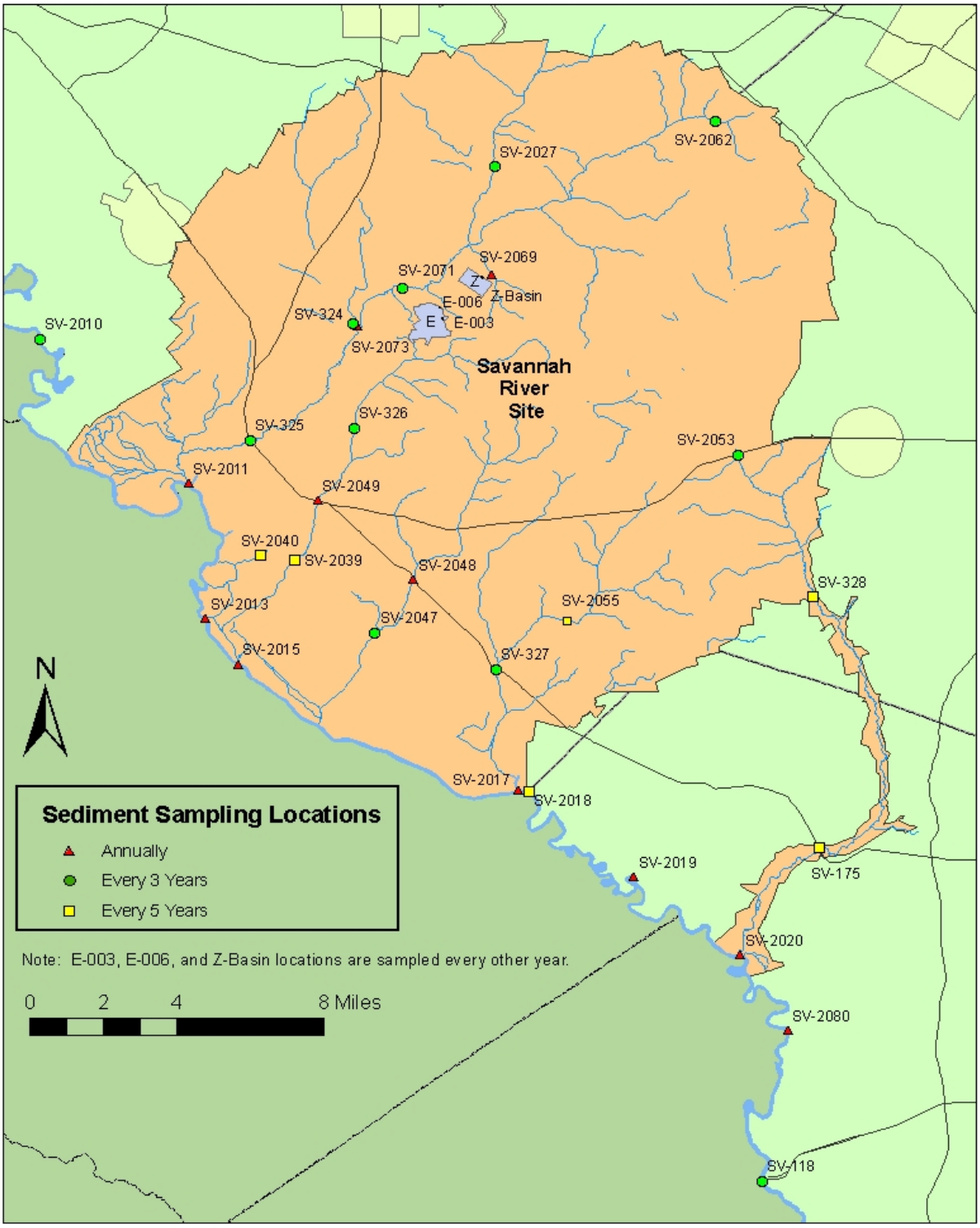
Cesium-137 is the most abundant anthropogenic radionuclide found in the sediment samples. Cesium-137 levels of 2013 from all the samples collected outside of SRS boundaries are within the expected range consistent with previous SCDHEC background data and may be attributed, in part, to fallout from past nuclear events in the 1950s and 1960s. The highest average level of Cs-137 from all 2013 sediment samples occurred in the SRS stormwater basin samples.

Metals in sediment can be naturally occurring or a result of man-made processes such as those used in SRS operations, which have released elevated amounts into streams on the SRS. Re-distribution of sediment from flooding can mobilize contaminants to downstream locations. Geological factors in the Savannah River basin contribute to the levels of metals through erosion and sediment deposition. All 2013 samples were below the ESV for beryllium, chromium, copper, mercury, nickel, zinc and lead.

SRS sediments should continue to be monitored due to current releases and the potential for future discharges from SRS operations, legacy wastes, and clean-up activities. Year-to-year data comparisons are difficult to interpret due to the nature of sediment. Differences among samples may be due to the fraction of clays that most effectively retain radionuclides. There is also difficulty in replicating the exact sampling point due to the movement of sediment. Monitoring of on-site sediments is of great importance as streams are a migration route for radionuclides to enter waters and sediment outside of the SRS boundary. ESOP will continue independent monitoring of SRS and Savannah River sediments and will periodically evaluate modification of the monitoring activities to better accomplish project goals and objectives. Continued monitoring will provide an improved understanding of radionuclide and non-radionuclide levels in SRS sediments and the Savannah River sediments which will impart valuable information to human health exposure pathways. Trending of data over multiple years demonstrates whether radionuclide concentrations in the SRS area are declining due to radioactive decay or possibly increasing due to disturbances on SRS. The comparison of data results allows for independent data evaluation of DOE-SR monitoring activities. To compare the environmental monitoring programs of ESOP and DOE-SR, the sediment samples from SRS will be collected in cooperation with DOE-SR personnel. Each program will then independently analyze the samples for radiological and nonradiological parameters and results will be compared in the 2013 ESOP Data Report. Cooperation between DOE-SR and SCDHEC provides credibility and confidence in the information being provided to the public.

4.0 Radiological and Nonradiological Monitoring of Sediments

Map 1. SRS Sediment Sampling Locations



5.0 Tables and Figures
Radiological and Nonradiological Monitoring of Sediments

Table 1a. Locations of SRS Sediment Samples

2013 ESOP Sediment Sample Locations on SRS		
Sample Location	**Location Description**	**Stream Abbr.**
	SRS Creek Mouth Samples	
SV-2011	Upper Three Runs Mouth @ RM 157.4	UTR
SV-2013	Upper Three Runs mouth @ RM 157.4	BDC
SV-2015	Fourmile Branch creek mouth @ RM 150.6	FMB
SV-2017	Steel Creek mouth @ RM 141.5	SC
SV-2020	Lower Three Runs mouth @ RM 129.1	LTR
	Non-Publicly Accessible Streams	
SV-324	Tims Branch at Road C.	TB
SV-325	Upper Three Runs @ SC 125 (SRS Road A)	UTR
SV-2048	Pen Branch @ Road 125	PB
SV-2049	Fourmile Branch @ Road 125	FMB
SV-2027	Upper Three Runs @ SRS Road 2-1	UTR
SV-2069	McQueen Branch off Monroe Owens Road.	McQ
SV-175	Lower Three Runs at Highway 125.	LTR
SV-2073	Upper Three Runs off Road C.	UTR
	SRS Stormwater Basins	
SME-001	E-001E Area stormwater basin	
SME-002	E-002 E Area stormwater basin	
SME-005	E-005 E Area stormwater basin	

Table 1b. Locations of Publicly Accessible Boat Landings

2013 Publicly Accessable Boat Landing Sediment Sampling Locations		
Sample Name	**Abbr.**	**Location Description**
Upstream of SRS		
SMFF13	FF	Fury's Ferry Boat Landing
SMSC13	SC	Steven's Creek Landing
SMRVP13	RVP	North Augusta Riverview Park Boat Landing
SMJBL13	JBL	Jackson Boat Landing
Downstream of SRS		
SMSCL13	SCL	Steel Creek Landing, Barnwell County
SMLHL13	LHL	Little Hell Landing
SMJL13	JL	Johnson's Landing
SMBFL13	BFL	Burtons' Ferry Landing
SMCB13	CB	Cohen's Bluff Landing
SMSBL13	SBL	Stoke's Bluff Landing

Tables and Figures
Radiological and Nonradiological Monitoring of Sediments

Table 2. Background Sediment Samples

2013 ESOP Background Samples	
Sample ID	**County**
SM NWB 13	Newberry
SM UNI 13	Union
SM ABB 13	Abbeville
SM COL 13	Colleton
SM HMP	Hampton
SM BEU 13	Beufort

Table 3. Gamma Analytes

Radioisotope	Abbreviation
Actinium-228	Ac-228
Americium-241	Am-241
Antimony-125	Sb-125
Berylium-7	Be-7
Cobalt-58	Co-58
Cobalt-60	Co-60
Cerium-144	Ce-144
Cesium-134	Cs-134
Cesium-137	Cs-137
Europium-152	Eu-152
Europium-154	Eu-154
Europium-155	Eu-155
Iodine-131	I-131
Lead-212	Pb-212
Lead-214	Pb-214
Manganese-54	Mn-54
Potassium-40	K-40
Radium-226	Ra-226
Ruthenium-103	Ru-103
Sodium-22	Na-22
Thorium-234	Th-234
Yttrium-88	Y-88
Zinc-65	Zn-65
Zirconium-95	Zr-95

Note: Units are reported in pCi/g.

Table 4. Inorganic Metal Analytes

Analyte	Abbreviation	ESV
Barium	Ba	20
Beryllium	Be	0.5
Cadmium	Cd	0.6
Chromium	Cr	36
Copper	Cu	18.7
Lead	Pb	30.2
Manganese	Mn	630
Mercury	Hg	0.13
Nickel	Ni	15.9
Zinc	Zn	98

Note: Units are reported in mg/kg.

Tables and Figures
Radiological and Nonradiological Monitoring of Sediments

Figure 1. Comparisons of Cs-137 Activity Among Sample Groups

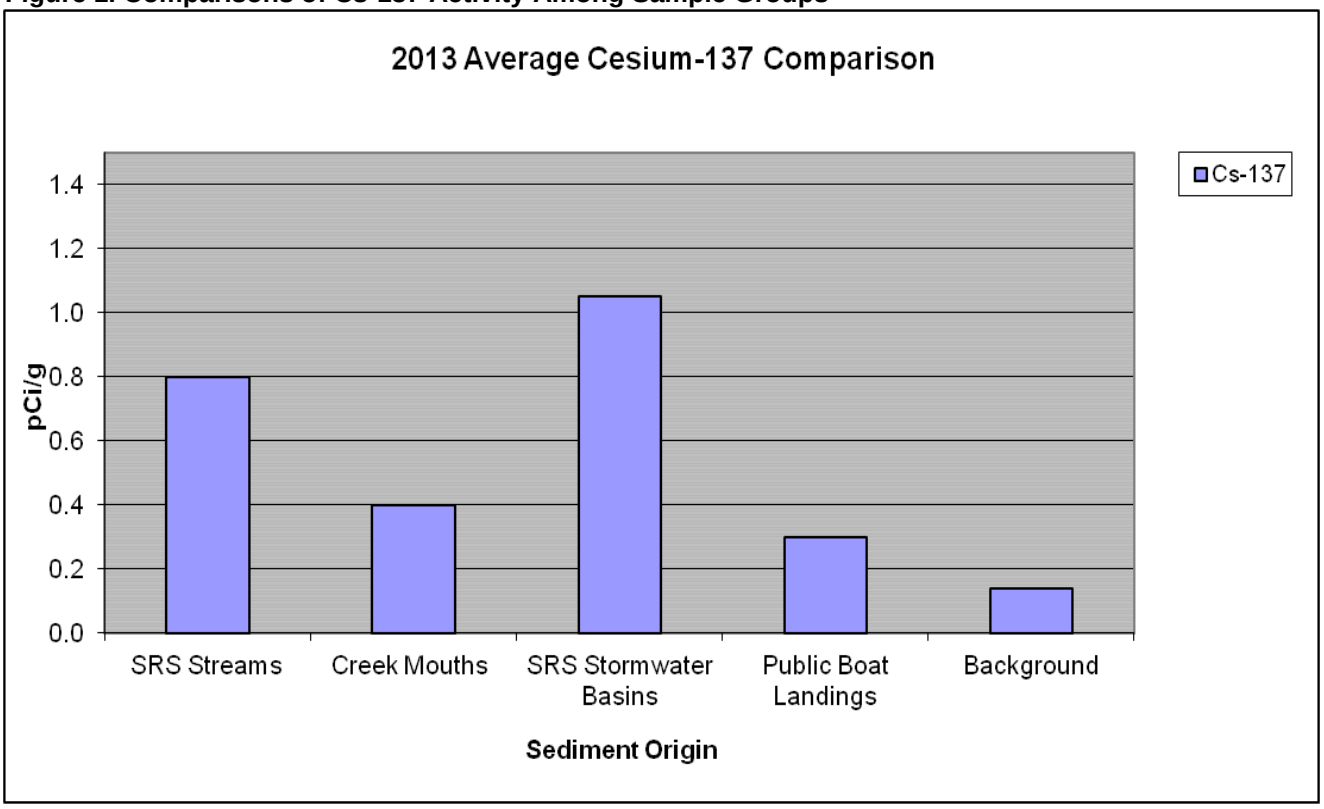
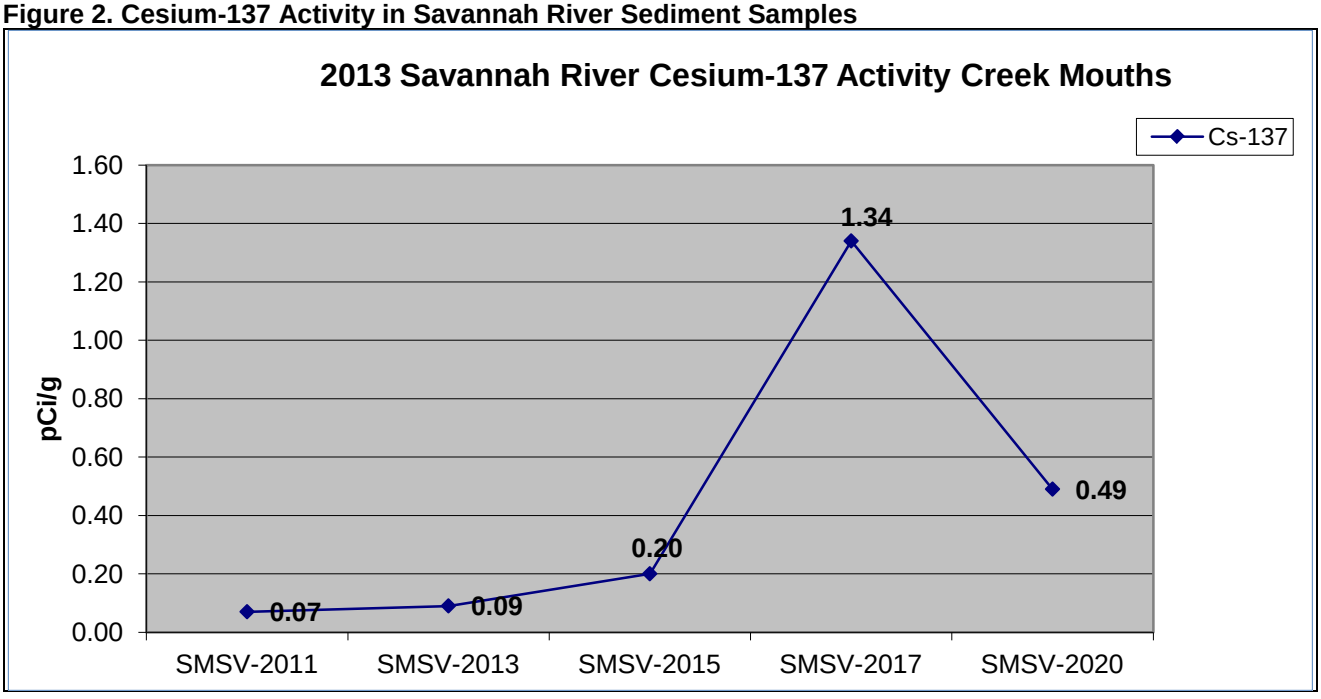


Figure 2. Cesium-137 Activity in Savannah River Sediment Samples



Tables and Figures
Radiological and Nonradiological Monitoring of Sediments

Figure 3. Comparisons of Gross-Alpha and Non-volatile Beta Activity Among Sample Groups

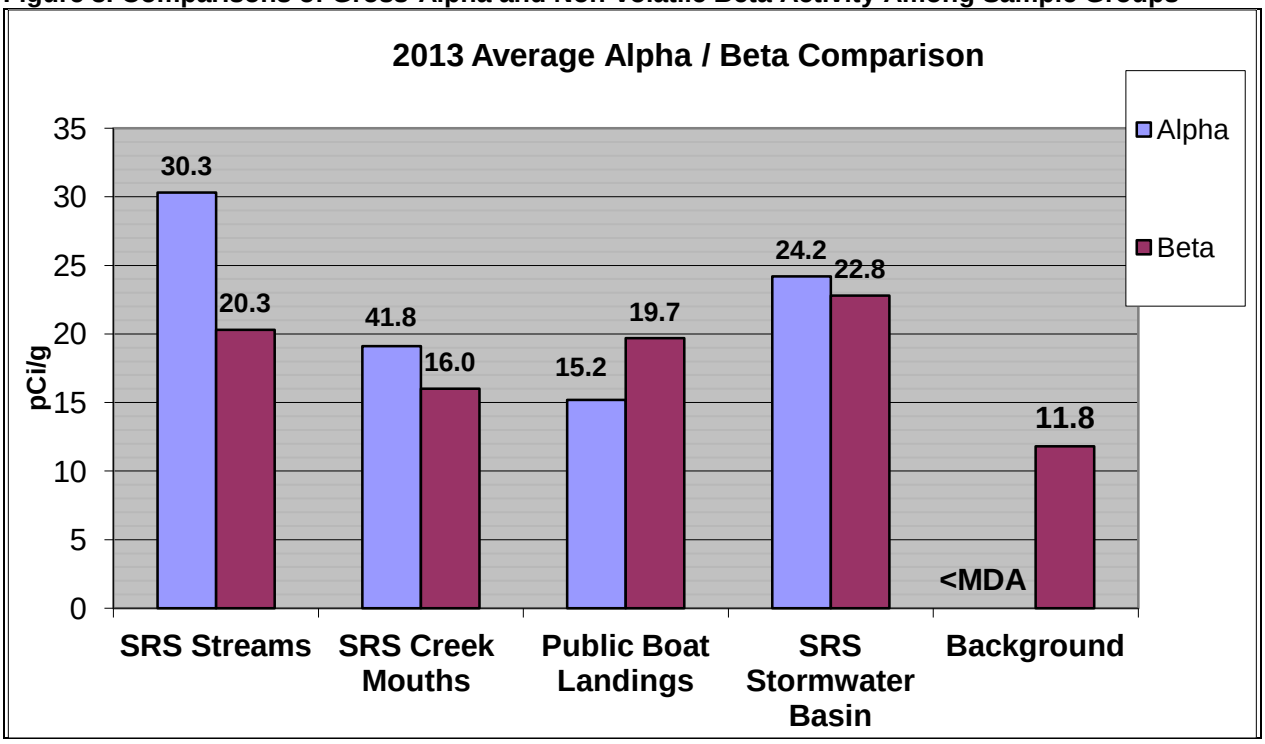
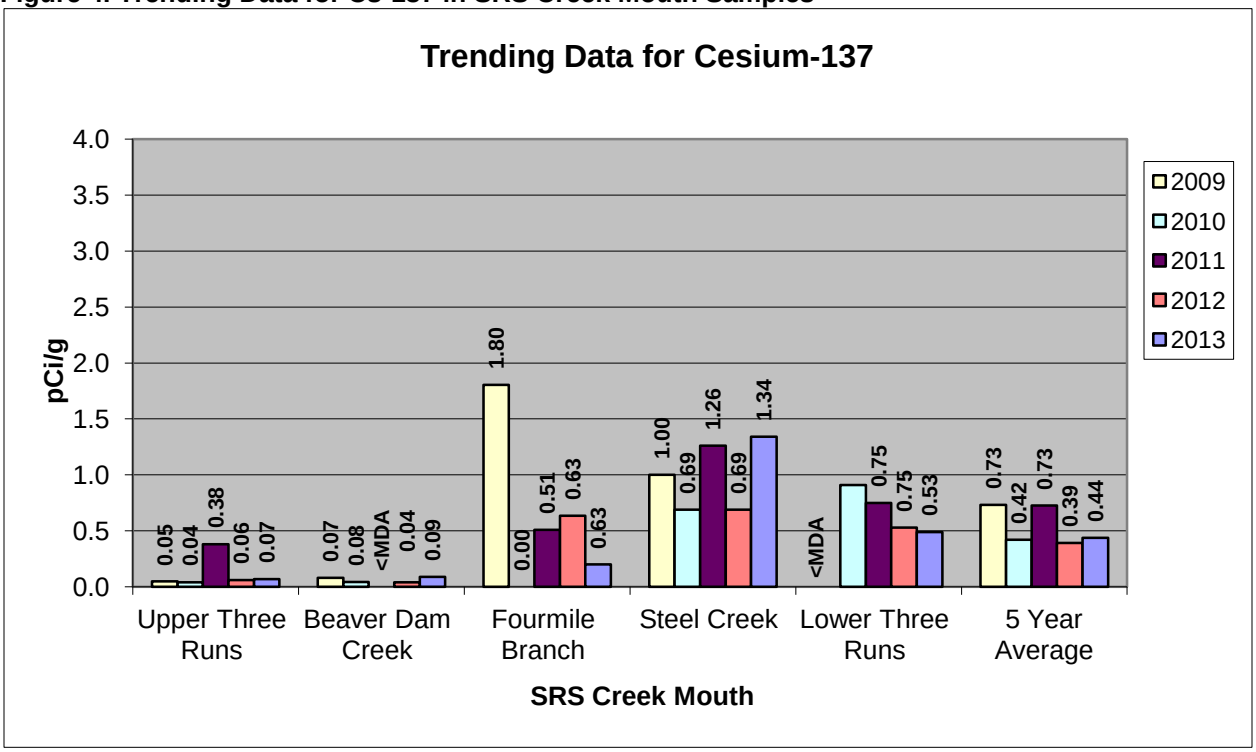


Figure 4. Trending Data for Cs-137 in SRS Creek Mouth Samples



Tables and Figures
Radiological and Nonradiological Monitoring of Sediments

Figure 5. SRS Creek mouth Metals Average

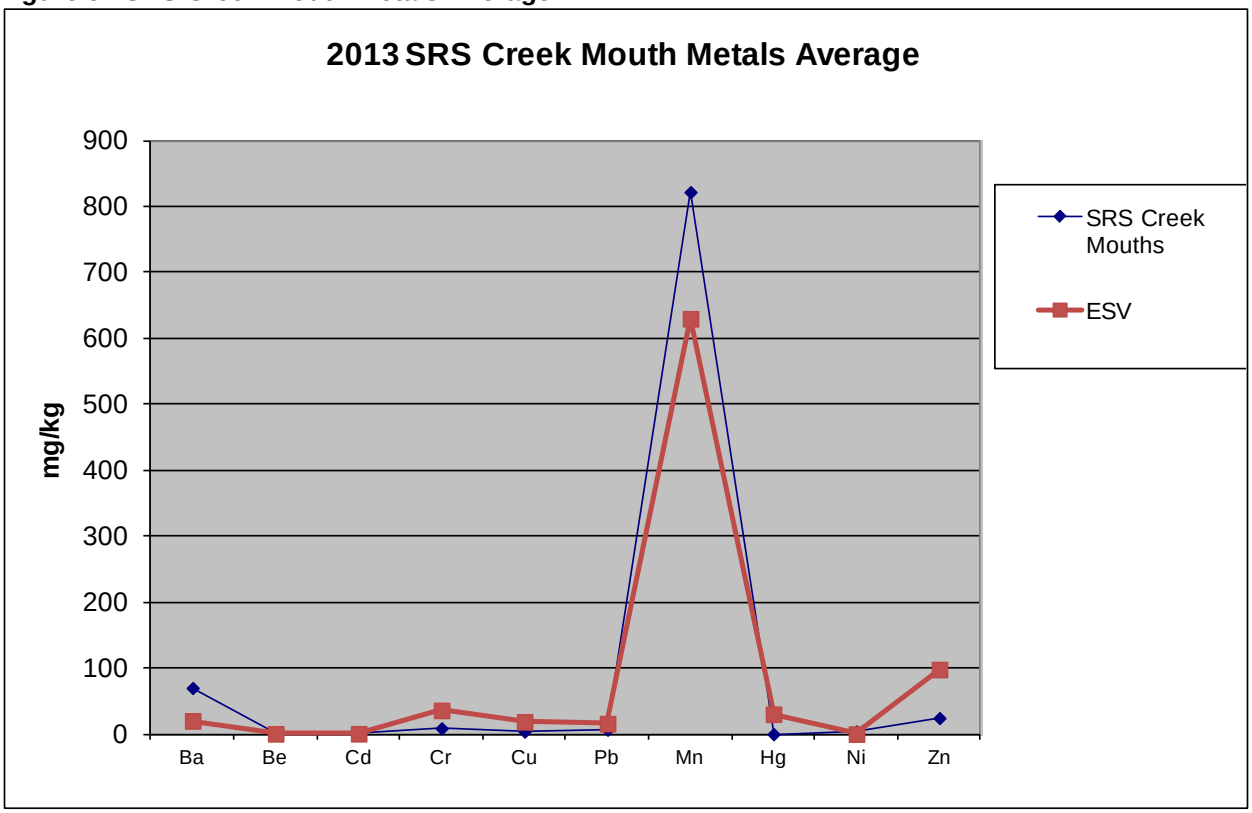
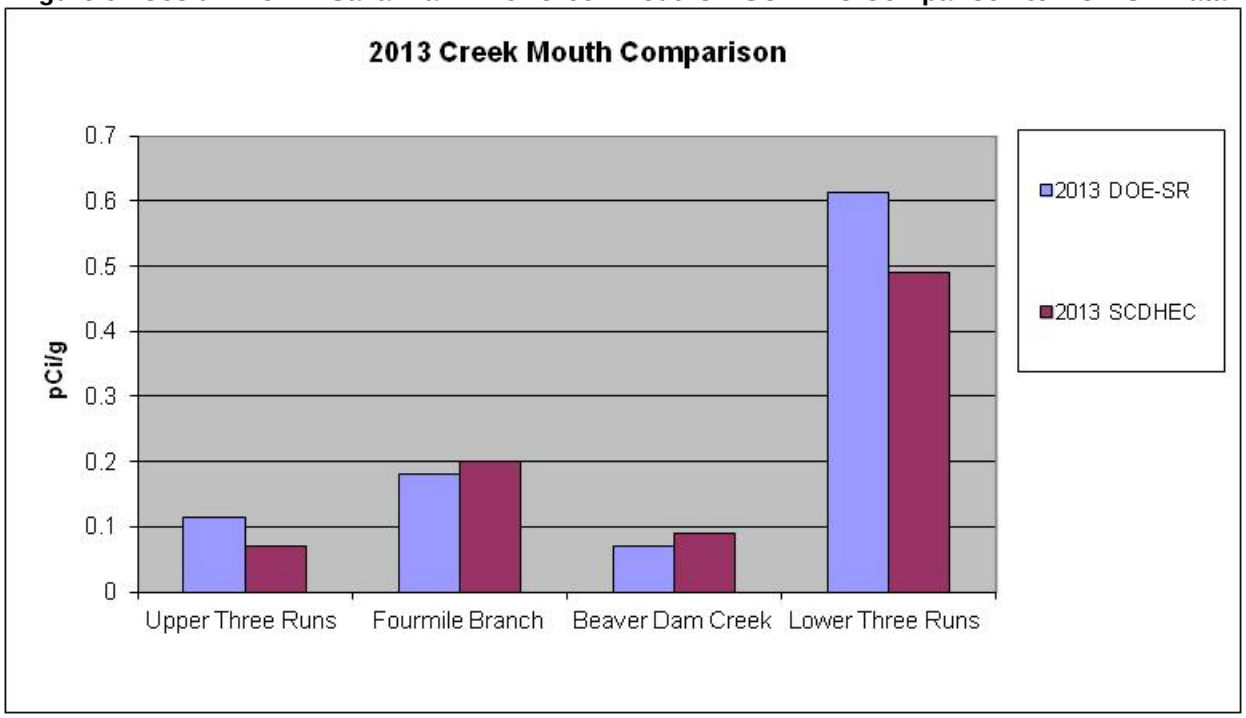


Figure 6. Cesium-137 in Savannah River Creek Mouths – SCDHEC Comparison to DOE-SR Data



6.0 Summary Statistics

Radiological and Nonradiological Monitoring of Sediments

Notes:

1. N/A = Not Applicable
2. MIN. = Minimum
3. MAX. = Maximum
4. AVG = Average
5. SD = Standard Deviation
6. MED = Median

2013 Statistics – SCDHEC Radiological Data
SRS Creek Mouths

	AVG:	SD:	MED:	MIN:	MAX:	Total Number of Samples	Number of Detections
Alpha	19.10	5.30	19.10	15.30	22.80	5	2
Beta	16.00	5.00	14.30	12.30	22.90	5	4
K-40	12.20	4.40	12.80	5.00	15.70	5	5
Cs-137	0.44	0.53	0.20	0.07	1.34	5	5
Pb-212	1.30	0.60	1.10	0.90	2.40	5	5
Pb-214	1.70	0.80	1.60	0.90	3.00	5	5
Ra-226	3.30	1.20	3.10	1.90	5.20	5	5
Ac-228	1.40	0.50	1.30	0.90	2.20	5	5

2013 Statistics – SCDHEC Radiological Data
Non Publicly Accessible SRS Streams

	AVG:	SD:	MED:	MIN:	MAX:	Total Number of Samples	Number of Detections
Alpha	30.30	15.00	26.90	17.40	50.00	8	4
Beta	20.20	0.90	20.40	19.30	21.00	8	3
K-40	2.93	3.83	1.52	0.61	11.26	8	7
Cs-137	0.80	1.26	0.14	0.06	3.40	8	7
Pb-212	1.46	0.69	1.31	0.70	2.47	8	8
Pb-214	3.33	2.46	2.46	1.16	7.95	8	8
Ra-226	6.45	4.77	5.23	2.29	16.44	8	8
Ac-228	1.54	0.76	1.33	0.71	2.95	8	8

2013 Statistics – SCDHEC Radiological Data
Publicly Accessible Boat Landings

	AVG:	SD:	MED:	MIN:	MAX:	Total Number of Samples	Number of Detections
Alpha	15.20	1.50	15.90	13.50	16.30	10	3
Beta	19.70	6.40	18.90	10.80	27.80	10	6
K-40	8.80	5.70	10.80	1.30	17.00	10	10
Cs-137	0.30	0.40	0.17	0.07	1.18	10	7
Pb-212	0.74	0.27	0.68	0.28	1.27	10	10
Pb-214	0.82	0.34	0.88	0.34	1.33	10	10
Ra-226	1.91	0.61	1.73	1.10	3.02	10	8
Ac-228	1.00	0.40	0.99	0.42	1.69	10	10

2013 Statistics – SCDHEC Radiological Data
Non-Publicly Accessible SRS Stormwater Basins

	AVG:	SD:	MED:	MIN:	MAX:	Total Number of Samples	Number of Detections
Alpha	24.20	N/A	24.20	24.20	24.20	3	1
Beta	22.90	18.30	22.90	9.90	35.80	3	2
K-40	9.40	12.60	2.50	1.80	23.90	3	3
Cs-137	1.05	1.62	0.16	0.06	2.92	3	3
Pb-212	1.52	0.22	1.59	1.28	1.70	3	3
Pb-214	1.08	0.15	1.15	0.91	1.20	3	3
Ra-226	2.40	0.13	2.42	2.26	2.51	3	3
Ac-228	1.50	0.09	1.49	1.42	1.60	3	3

2013 Statistics – SCDHEC Radiological Data
Nonrandom Background Samples

	AVG:	SD:	MED:	MIN:	MAX:	Total Number of Samples	Number of Detections
Alpha	N/A	N/A	N/A	N/A	N/A	6	0
Beta	11.80	N/A	11.80	11.80	11.80	6	1
K-40	4.30	3.40	3.10	0.60	9.50	6	6
Cs-137	0.14	0.07	0.12	0.07	0.25	6	5
Pb-212	0.85	0.15	0.86	0.69	1.06	6	6
Pb-214	0.71	0.15	0.64	0.58	0.96	6	6
Ra-226	1.32	0.37	1.21	0.87	1.78	6	6
Ac-228	0.87	0.16	0.88	0.67	1.05	6	6

Note: Units are in pCi/g.

2013 Statistics – SCDHEC Sediment Metals Data
SRS Streams Creek Mouths

	AVG:	SD:	MED:	MIN:	MAX:	Total Number of Samples	Number Detects
Barium	70.00	46.00	58.00	24.00	140.00	5	5
Beryllium	0.39	0.12	0.34	0.30	0.52	5	3
Cadmium	1.50	0.36	1.40	1.20	1.90	5	3
Chromium	8.82	4.83	9.10	2.90	14.00	5	5
Copper	3.88	2.13	3.95	1.20	6.40	5	4
Lead	6.70	1.61	6.50	5.20	8.40	5	3
Manganese	822	800	410	140	2100	5	5
Mercury	N/A	N/A	N/A	N/A	N/A	5	0
Nickel	4.12	1.46	3.90	2.70	6.20	5	5
Zinc	24.40	13.58	21.00	12.00	44.00	5	5

Note: Units are in mg/kg.

2013 Statistics – SCDHEC Sediment Metals Data
Publicly Accessible Boat Landings

	AVG:	SD:	MED:	MIN:	MAX:	Total Number of Samples	Number Detects
Barium	53.30	18.48	55.50	19.00	75.00	10	10
Beryllium	0.51	0.21	0.45	0.30	0.83	10	7
Cadmium	1.16	0.21	1.10	1.00	1.60	10	7
Chromium	11.47	4.68	12.50	4.70	18.00	10	10
Copper	7.09	5.65	5.10	2.00	20.00	10	10
Lead	8.06	1.63	8.40	5.40	10.00	10	9
Manganese	596	605	300	49	1800	10	10
Mercury	N/A	N/A	N/A	N/A	N/A	10	0
Nickel	4.62	2.07	4.55	2.00	8.60	10	10
Zinc	26.00	9.71	30.00	11.00	37.00	10	10

Note: Units are in mg/kg

List Of Acronyms

CDC	Centers for Disease Control
DOE-SR	Department of Energy – Savannah River
ESOP	Environmental Surveillance and Oversight Program
ESV	Ecological Screening Value
LLD	Lower Limit of Detection
LTR	Lower Three Runs
MDA	Minimum Detectable Activity
MDC	Minimum Detectable Concentration
MDL	Minimum Detection Limit
NORM	Naturally Occurring Radioactive Material
SCDHEC	South Carolina Department of Health and Environmental Control
SMSV	Sediment from Savannah River Study area
SRNS	Savannah River Nuclear Solutions
SRS	Savannah River Site
USDOE	United States Department of Energy
USEPA	United States Environmental Protection Agency
WSRC	Washington Savannah River Company, formerly Westinghouse Savannah River Company

Units Of Measure

mg/kg	milligrams per kilogram
pCi/g	picocuries per gram
±	plus or minus. Refers to one standard deviation unless otherwise stated

References

Alloway, B.J. 1995. *Heavy Metals in Soils*. Great Britain, St Edmundsbury Press, Suffolk.

Canova, J.L. 1999. Elements in South Carolina Inferred Background Soil and Stream Sediment Samples. South Carolina Geology, 1999, v.41, p.11-25.

Centers for Disease Control (CDC). 2006. Phase III of the SRS dose reconstruction project. Available from URL http://www.cdc.gov/nceh/radiation/Savannah/docs/TOCs.pdf.

Savannah River Nuclear Solutions, LLC (SRNS). 2014. Savannah River Site Environmental Report for 2013. Savannah River Site Aiken, SC. SRNS-STI-2014-00006.

Till, J.E., et al. 2001. Savannah River Site Environmental Dose Reconstruction Project, Phase II: Source Term Calculation and Ingestion Pathway Data Retrieval, Evaluation of Materials Released from the Savannah River Site. RAC Report No. 1-CDC-SRS-1999-Final. Risk Assessment Corporation (RAC).

United States Department of Energy (USDOE). 1995. SRS Waste Management Final Environmental Impact Statement. Doc. No. DOE/EIS-0217 http://www.eh.doe.gov/nepa/eis/eis0217/eis0217_toc.html.

United States Environmental Protection Agency (USEPA). 1987. An Overview of Sediment Quality in the United States, EPA-905/9-88-002, Office of Water Regulations and Standards, Washington, DC and Region 5, Chicago, IL.

USEPA. 2009a. *EPA Facts about Cesium*. http://www.epa.gov/rpdweb00/radionuclides/cesium.html.

USEPA. 2009b. *EPA Facts about Technetium-99*. http://www.epa.gov/rpdweb00/radionuclides/technetium.html.

Westinghouse Savannah River Company (WSRC). 1993a. Assessment of Technetium In the Savannah River Site Environment. Carlton, W.H., Denham, M., Evans, A.G., Aiken, South Carolina. WSRC-TR-93-217.

WSRC. 1993b. Final Record of Decision Remedial Alternative Selection for H-Area Hazardous Waste Management Facility. Westinghouse Savannah River Company, Savannah River Site, Aiken, South Carolina. WSRC-RP-93-1043.

WSRC. 1998. Assessment of Radionuclides in The Savannah River Site Environment-Summary (U), Environmental Protection Department, Environmental Monitoring Section, Aiken, South Carolina. WSRC-TR-98-00162.

WSRC. 2002. Viability of Sodium Iodide Detector Field Measurements and X-Ray Florescence Measurements for Recognition of Benchmark Exceedances in the Steel Creek Integrator Operable Unit. Westinghouse Savannah River Company, Aiken, South Carolina.

WSRC. 2005. Ecological Screening Values for Surface Water, Sediment, and Soil: 2005 Update, Friday, G.P., Westinghouse Savannah River Company, Savannah River Site, Aiken, South Carolina.WSRC-TR-2004-00227.

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Section 3 2013 Terrestrial Monitoring

2013 Surface Soil Monitoring Adjacent to SRS

Environmental Surveillance and Oversight Program

97SS006
John Simpkins, Project Manager
January 01, 2013 - December 31, 2013

Midlands EQC Region-Aiken
206 Beaufort Street N.E.
Aiken, SC 29801

D H E C
PROMOTE PROTECT PROSPER
South Carolina Department of Health
and Environmental Control

Table of Contents

1.0 PROJECT SUMMARY

The South Carolina Department of Health and Environmental Control (SCDHEC) Environmental Surveillance and Oversight Program (ESOP) provides independent evaluation of the Department of Energy – Savannah River (DOE-SR) environmental monitoring programs. ESOP personnel independently evaluated surface soils from ground surface to a 12 inch depth for gross alpha and gross non-volatile beta and select gamma-emitting radionuclides, as well as specific metals of concern at the Savannah River Site (SRS). These soil samples were collected to determine if SRS activities might have impacted areas outside of the site boundary. Radionuclide detections in soil are the result of accumulation over many years and do not represent yearly depositions.

Surface soil is an important medium that can be contaminated by radionuclides and metals, and transported to other ecological systems. Plants absorb contaminants from soil that in turn introduce contaminants to the food chain. Radionuclides and metals in soil can leach into groundwater and possibly emerge into surface water, potentially contaminating aquatic systems (Corey 1980). Air and water are subject to a much greater mixing than soil; therefore, dilution of metals does not occur as much in soil as in air or water. As a result, the accumulation of metals in surface soils is often more intense on both local and global scales than in the other components of the biosphere (Alloway 1995). The re-suspension and subsequent airborne contamination of materials due to cleanup processes that include soil excavation and disturbance during remediation and prescribed burns facilitates the movement of contaminants to areas outside of the SRS boundary.

The ESOP surface soil monitoring project changed in 2004 to include more random background soils (those greater than 50 miles from an SRS center point) within the boundaries of the state of South Carolina (SC). A 50 mile SRS center point area was chosen for comparison to the DOE-SR study area. Sampling outside of the 50 mile study area was implemented to allow data comparisons between the SRS perimeter and SC background contaminant levels in soils. ESOP initiated the random sampling system to determine if elevated levels of contaminants are attributable to SRS activities. SRS Perimeter and SC background averages were used to determine if SCDHEC data were comparable to radiological data from DOE-SR. Since DOE-SR environmental monitoring division does not report metals data for surface soil, no direct data comparisons can be made. Assessment of radiological and nonradiological contaminants in surface soil is necessary to detect any impact from DOE-SR operations beyond the historically impacted areas within the SRS boundaries.

ESOP collected samples in 2013 from six random background sites outside of the 50 mile SRS center point radius. Nineteen nonrandom samples were collected from SRS perimeter locations (Section 5.0, Table 1). Nonrandom SRS perimeter sampling locations are depicted on Map 1 of Section 4.0. A list of all nonrandom sampling locations is located in Section 5.0, Table 1. The majority of samples had detectable amounts of cesium-137 (Cs-137), an anthropogenic radionuclide, that may be a legacy of releases by SRS and atmospheric fallout from past nuclear weapons testing (USEPA 2013a). Cesium-137 activity in 2013 is comparable to levels detected by ESOP in the past. There were no surface soil samples collected in 2013 that were above the United States Environmental Protection Agency (USEPA) Preliminary Remediation Goals (PRGs) or the USEPA Regional Screening Levels (RSLs) (USEPA 2013b). There were no soil

samples in 2013 that exceeded the radiological USEPA Soil Screening Levels (SSLs) (USEPA 2013c). SSLs are more conservative screening values that are utilized when soil is in close proximity to groundwater (e.g. near rivers and other surface water bodies). USEPA PRGs are generic/default screening values for radioactive contamination in soil. USEPA RSLs are generic/default values for the toxicity of chemical contaminants in soil. The PRGs, RSLs and SSLs of select radionuclides and metals sampled by SCDHEC are listed in Section 5.0, Tables 2, 3 and 4.

There were two gross alpha-emitting radionuclides detected in the samples collected in 2013. Gross non-volatile beta was detected in three of the samples.

Results for all metal analytes were below the USEPA RSLs. Metals data has been trended over time and the samples collected near the SRS perimeter are similar to those collected randomly throughout South Carolina.

A data comparison of 2013 surface soil data from SCDHEC and DOE-SR resulted in similar findings. Both data sets report average Cs-137 levels lower outside the 50 mile radius of SRS than within the SRS perimeter. SCDHEC data from 2013 perimeter samples show a slight decrease in the average level of Cs-137 from the 2012 data. DOE-SR reports in 2013 that Cs-137 concentrations are consistent with historical results. Metals data could not be compared to SCDHEC results since the DOE-SR environmental monitoring division does not analyze nonradiological contaminants.

2.0 RESULTS AND DISCUSSION

Radiological Parameter Results

All radiological data can be found in Appendix A-ESOP Data, and summary statistics found in Section 6.0.

Surface soils were evaluated for gross alpha and gross non-volatile beta as well as a suite of 24 gamma-emitting radionuclides. The suite of 24 gamma-emitting radionclides is part of a gamma spectroscopy analysis performed by the Radiological Environmental Monitoring Division Laboratory in Columbia, SC (Section 5.0, Table 5). Radioisotopes were detected not only in samples collected around the perimeter of SRS, but in background samples as well. The USEPA PRGs are used as a screening tool that corresponds to certain levels of human health risk in regards to radioactivity in soil (USEPA 2013d). The conservative PRGs correspond to a risk for chronic soil ingestion for a residential scenario and a one in one million (1E-06) increased cancer risk. Uranium has both a PRG and an RSL because it is both carcinogenic and toxic (USEPA 2013d). In 2013, ESOP analyzed for all of the radioisotopes listed in Section 5.0, Table 5.

Cesium-137 is a man-made fission product. Atmospheric Cs-137 was released from the Separation Areas and was a key radionuclide released to water and air, mainly from F- and H-Areas (CDC 2006). Cesium-137 was detected in 17 of 19 SRS nonrandom perimeter samples at an average of 0.10 (±0.05) picocuries per gram (pCi/g) and ranged from less than Minimum

Detectable Activity (MDA) to 0.22 pCi/g . The highest detection was located at SSAIK0213 in Aiken County.

All six background samples had Cs-137 detections (Section 5.0 Table 8). The random background sample detection average was 0.07 (±0.03) pCi/g. The random background samples had detections ranging from 0.04 to 0.13 pCi/g. Cesium-137, on average, was highest in the SRS perimeter sample soils. The results are depicted in Section 5.0, Figure 1.

In addition, potassium-40, lead-212, lead-214, radium-226, and actinium-228 were the only other gamma-emitting radionuclides detected among surface soil samples. These are Naturally Occurring Radioactive Material (NORM) decay products that may account for these detections. All other gamma-emitting radionuclides had no detections above their respective MDA.

Gross alpha-emitting radionuclides were released to the air primarily from M-Area, the reactor areas, and the separations Areas (CDC 2006). Analyses were conducted on gross alpha-emitting radionuclides in surface soil samples collected during 2013. There were only two detection of gross alpha-emitting radionuclides in any soil samples collected in 2013.

Gross beta-emitting radionuclides were released from the Separations Areas (CDC 2006). Gross beta was detected in two SRS nonrandom perimeter samples averaging 13.7 pCi/g. There was only one detection of gross beta-emitting radionuclides in any background soil samples collected in 2013. Results are depicted in Figure 2 of Section 5.0.

Nonradiological Parameter Results

Data for all metals detected can be found in Appendix A-ESOP Data. The summary statistics are found in Section 6.0. SRS perimeter averages of select metal results are depicted in Figure 3 of Section 5.0.

Ten metals were analyzed in 19 nonrandom SRS perimeter surface soil samples collected in 2013. A complete list of all nonradiological analytes can be found in Section 5.0, Table 6. Findings were compared to the USEPA RSLs that are used as a screening tool, corresponding to certain levels of human health risk in soils (USEPA 2013). All sample results were below the conservative generic/default USEPA RSLs, corresponding to a risk for chronic soil ingestion for a residential scenario. ESOP 2013 samples had detections of barium, chromium, copper, lead, manganese, cadmium, beryllium, nickel, and zinc. There were no detections above the Minimum Detection Limit (MDL) for mercury in the SRS perimeter samples. The following discussion of individual analytes will be limited to those of potential concern due to SRS operations.

Barium has been a constituent of the H-Area Hazardous Waste Management Facility (WSRC 1993). Barium was detected in 18 of the 19 SRS nonrandom perimeter samples at an average of 17.0 (±12.0) milligrams per kilogram (mg/kg) and ranged from less than MDL to 49 mg/kg. The highest detection was located at SSWIL13 in Barnwell County. All samples were well below the RSL of 15,000 mg/kg and also below the SC average of 38 mg/kg (Canova 1999).

Beryllium is a strong, lightweight metal used in nuclear weapons work as a shield for radiation and as a neutron source (Till et al. 2001). Beryllium was detected in four of the SRS nonrandom perimeter samples at an average of 0.39 (±0.09) mg/kg. The RSL for beryllium in soil is 160 mg/kg.

Chromium solutions were used at the SRS as corrosive inhibitors. Chromium was a part of wastewater solutions resulting from dissolving stainless steel. It was also used in cleaning solutions in the separation areas (Till et al. 2001). The legal disposal of fly ash on land as a result of burning coal is a contributor of both chromium and nickel to soils. Fly ash particles can travel considerable distance in the air and contain trace elements of chromium (Alloway 1995). Chromium was detected in all 19 SRS nonrandom perimeter samples at an average of 3.5 (±3.0) mg/kg and ranged from 1.2 to 13 mg/kg. The highest detection was located in SSAIK0413 in Aiken County. For comparison, the most conservative RSL screening level (ChromiumVI) is 230 mg/kg. The SC average for total chromium in soil is 16 mg/kg (Canova 1999).

Copper, while naturally occurring, can also be released to the environment through the combustion of wood, coal and oil (Alloway 1995). D-Area and the other coal combustion powerhouses emitted copper and other heavy metals (Till et al. 2001). These mechanisms are possible sources of elevated copper in surface soils. Copper was detected in nine SRS nonrandom perimeter samples at an average of 2.6 (±0.86) mg/kg and ranged from less than MDL to 3.7 mg/kg. The highest detection was located in SSAIK0413 in Aiken County. All samples were below the RSL of 3,100 mg/kg. The SC average for copper in soil is 9 mg/kg (Canova 1999).

Atmospheric emissions of lead from SRS occurred through coal and fuel combustion (Till et al. 2001). Lead can deposit in soil, (due to its immobility) and have a long residence time when compared to other pollutants. Lead tends to accumulate in soil where its bioavailability can exist far into the future (Alloway 1995). Lead was detected in nine SRS nonrandom perimeter samples at an average of 9.0 (±4.5) mg/kg and ranged from less than MDL to 16 mg/kg. The highest detection was located at SSAIK0413 in Aiken County. For comparison, the RSL is 400 mg/kg and the SC average for lead in soil is 16 mg/kg (Canova 1999).

Manganese has been released in the separations area processes and discharged to liquid waste tanks (Till et al. 2001). It is also a byproduct of coal burning. Manganese was detected in all 19 SRS nonrandom perimeter samples at an average of 45.5 (±48.6) mg/kg and ranged from 5.6 to 160 mg/kg. The highest detection was located at SSGP13 in Aiken County. Three samples exceeded the SC average of 100 mg/kg (Canova 1999), and all were below the RSL of 1,800 mg/kg.

The largest anthropogenic source of nickel globally is the burning of fuels and coal combustion (Alloway 1995). At SRS, nickel was directly released through M-Area effluent from the plating rinse tanks and through site use of diesel generators (Till et al. 2001). Nickel was detected in two of the 19 SRS nonrandom perimeter samples at an average of 3.1 (±.71) mg/kg. The highest detection was located at SSDKH13 in Barnwell County. The SC average for nickel is 6 mg/kg (Canova 1999), and the RSL of nickel is 1,500 mg/kg.

Zinc was released in relatively small amounts to the separations area seepage basins as well as the M-Area seepage basin (Till et al. 2001). Zinc was detected in all 19 SRS nonrandom perimeter samples at an average of 5.91 (±3.51) mg/kg and ranged from 2.10 to 13.0 mg/kg. The highest detection was located at SSGP13. The RSL is 23,000 mg/kg. All samples were below the SC average of 23 mg/kg (Canova 1999).

SRS facilities, such as F- and H- Area, tritium facilities, waste tanks, and the coal-fired power plants have emitted mercury to the atmosphere (Till et al. 2001). Atmospheric fallout contributes to mercury findings in surface soil. None of the surface soil samples collected in 2013 yielded detections above the MDL of 0.1 mg/kg for mercury. The SC average for mercury is 0.18 mg/kg (Canova 1999) and the RSL for mercury is 5.6 mg/kg.

Cadmium enters the atmosphere through fuel and coal combustion (Till et al. 2001). Only SSGP13 (1.1 mg/kg) yielded detections above the MDL of 1.0 mg/kg for cadmium. The SC average for cadmium is 1.0 mg/kg (Canova 1999) and RSL for cadmium in soil is 70 mg/kg.

SCDHEC and DOE-SR Data Comparison

Cesium-137 (Cs-137), cobalt-60 (Co-60), and americium-241 (Am-241) were the only gamma-emitting radionuclides that SCDHEC and DOE-SR shared in analytical results. DOE-SR did not have any detections of Co-60 above the Minimum Detectable Concentration (MDC). DOE-SR did detect Am-241 in ten perimeter locations at an average of 0.004 (± .001) pCi/g as well as in all three 25 mile perimeter location at an average of 0.003 (± .001) pCi/g. Since SCDHEC did not have any detections of Co-60 or Am-241 above the MDA, only the Cs-137 detections are compared. DOE-SR did not analyze for alpha or beta-emitting radionuclides, nor did they analyze for metals; therefore, no comparisons could be made. Soil samples from both programs varied by location and in number. DOE-SR collected 12 samples near the SRS perimeter and three samples within 25 miles. ESOP collected 19 nonrandom SRS perimeter samples. ESOP also sampled six background locations outside of the 50 mile SRS center point study area. DOE-SR sampled one background location 100 miles from SRS at Savannah, Georgia. When interpreting data, it should be taken into consideration that samples were collected from a variety of soil types and locations.

Cesium-137 was detected by both DOE-SR and SCDHEC. Cesium-137 was detected above the MDC in all 12 DOE-SR perimeter samples. SCDHEC detected Cs-137 in 17 of 19 nonrandom perimeter SCDHEC samples. Cesium-137 was also detected in the SCDHEC background locations. For the 2013 samples, the SCDHEC nonrandom perimeter average for Cs-137 was 0.10 (± 0.05) pCi/g. The average for all the SCDHEC background samples was 0.07 (± 0.03) pCi/g. The DOE-SR Cs-137 average for all SRS perimeter samples was 0.23 (± 0.13) pCi/g, and 0.23 (± 0.11) pCi/g for those locations within 25 miles of SRS. The DOE-SR 100 mile background Cs-137 activity was less the MDC (SRNS 2013). The DOE-SR data average for Cs-137 activity falls within one standard deviation of the SCDHEC data. Comparative data can be found in Section 5.0, Tables 7 and 8.

Cesium-137 was the only consistently detected parameter over past years. Trending data for Cs-137 in SRS perimeter samples is in Section 5.0, Figure 4. SCDHEC has trended Cs-137 since

2008 (SCDHEC 2008-2013). Data shows that SCDHEC levels of Cs-137 in perimeter surface soils from 2008 to 2013 averaged 0.51 pCi/g. DOE-SR data of Cs-137 in perimeter surface soils from 2008 through 2013 averaged 0.15 pCi/g (WSRC 2008, SRNS 2009-2013). DOE-SR data shows steady Cs-137 levels from 2008-2013 although 2012 Cs-137 (0.22 pCi/g) results were higher than the average of 0.15 pCi/g from 2007-2012. SCDHEC Cs-137 data during 2008-2013 shows a steady decline from Cs-137 levels of 1.01 pCi/g in 2008. The results found by both SCDHEC and DOE-SR are influenced by the number of samples used to determine the average and by collecting samples from different locations. The average level of Cs-137 in surface soil can vary due to the highly variable nature of soils. Radiocesium bioavailability in soil is influenced by soil properties such as clay content, pH, organic matter, and soil microflora (Absalom et al. 2001). The increase of Cs-137 activity in the perimeter SCDHEC samples in 2008 and 2009 could be due to the addition of samples in closer proximity to the boundary of SRS, specifically in the Steel Creek floodplain. In the previous years only random samples within 50 miles of the SRS center point were sampled to determine the yearly average. In 2008, the addition of sampling at public boat landings was initiated. Excursions outside normally expected levels, contributed through unplanned Cs-137 releases, occurred at boat landings downstream of SRS, specifically in the Steel Creek floodplain area. These areas have historically been impacted by SRS operations and higher than background results are to be expected. These yielded higher averages in 2008 and 2009. DOE-SR does not collect samples at these locations.

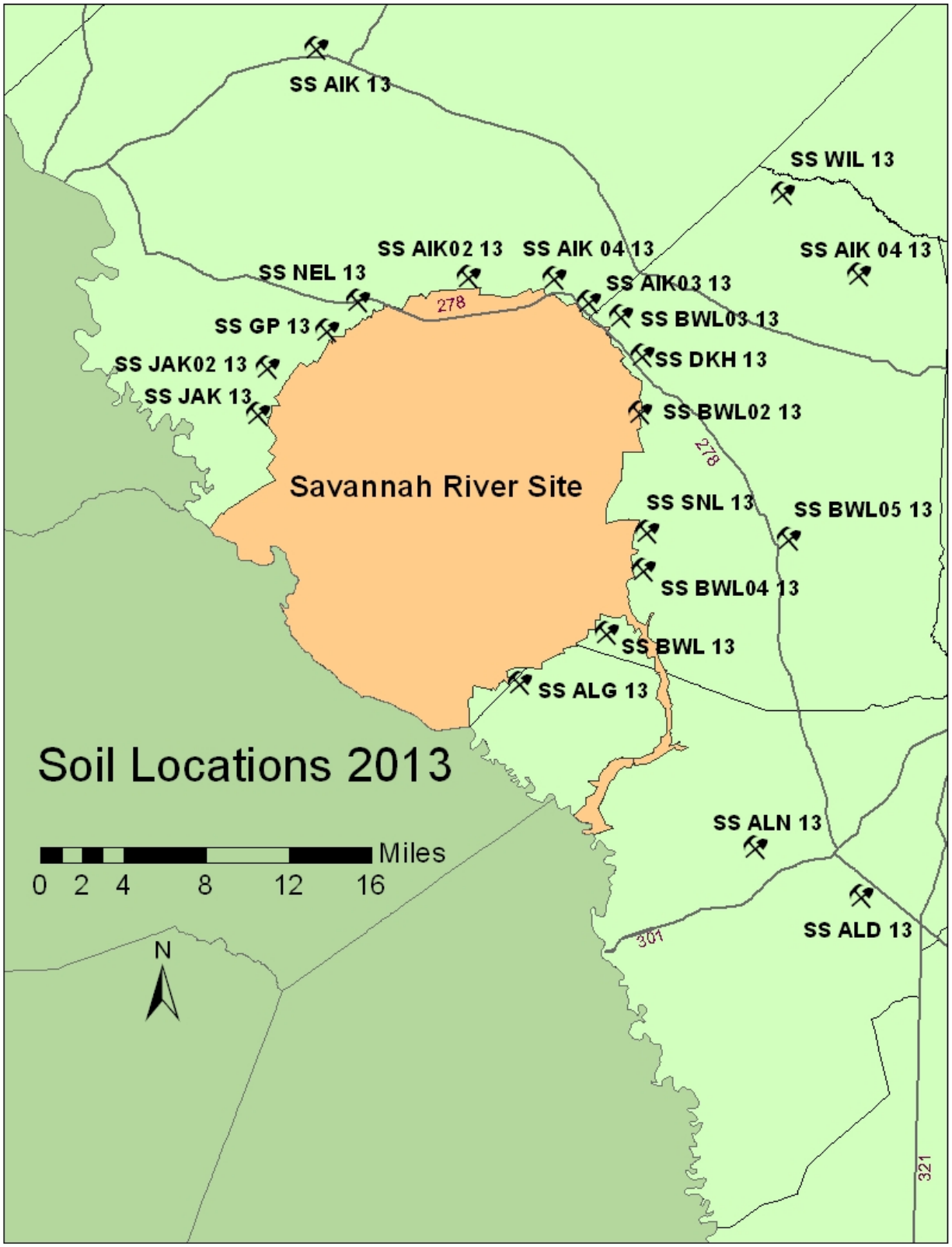
3.0 CONCLUSIONS AND RECOMMENDATIONS

ESOP will continue independent monitoring of SRS perimeter surface soil and will periodically evaluate modification of the monitoring activities to better accomplish project goals and objectives. Monitoring will continue as long as there are activities at the SRS that create the potential for contamination entering the environment. Continued monitoring will provide an improved understanding of radionuclide and non-radionuclide activity in SRS perimeter surface soils and the surrounding areas. Additional monitoring will impart valuable information to human health exposure pathways. Trending of data over multiple years will give a more definitive answer as to whether radionuclide concentrations in the SRS area are declining due to radioactive decay or possibly increasing due to flooding, soil disturbances and prescribed burns on SRS. The comparison of data results allows for independent data verification of DOE-SR monitoring activities. Cooperation between DOE-SR and SCDHEC provides credibility and confidence in the information being provided to the public.

In 2014, SCDHEC will continue to monitor the surface soil along the perimeter of SRS for radionuclides. Riverbank soil samples will be collected from the publicly accessible Savannah River watershed boat landings where human exposure is likely. The SCDHEC data at this time does not show there is an impact of elevated metal concentrations to areas outside of SRS. However, continued monitoring along the perimeter of SRS is still necessary due to the potential impact of SRS site operations to the surrounding environments. Possible atmospheric releases due to prescribed forest burning and soil disturbance at SRS could elevate metals in the surrounding area. Only through continued monitoring will this be determined. If perimeter samples show elevated metals concentration, additional samples will be evaluated.

4.0

Map 1. SRS Perimeter Surface Soil Monitoring and River Bank Locations



5.0 Tables and Figures
Surface Soil Monitoring Adjacent to SRS

Table 1. Nonrandom Soil Samples Collected in 2013

SAMPLE ID	LOCATION	COUNTY
SS ALG 13	Allendale Gate	Allendale
SS SNL 13	Snelling Gate	Barnwell
SS DKH 13	Darkhorse	Barnwell
SS ALN 13	Allendale	Allendale
SS GP 13	Green Pond	Aiken
SS JAK 13	Jackson	Aiken
SS AIK 13	Aiken	Aiken
SS JAK02 13	Jackson	Aiken
SS NEL 13	New Ellenton	Aiken
SS BWL 13	Co-located at VEG site BWL-004	Barnwell
SS AIK02 13	Boggy Gut Road	Aiken
SS BWL02 13	Co-located at VEG site BWL-002	Barnwell
SS BWL03 13	Co-located at VEG site BWL-001	Barnwell
SS AIK03 13	Co-located at EV site AIK 0903	Barnwell
SS ALD 13	Co-located at Allendale VEG Site ALD-251	Allendale
SS BWL04 13	Co-located at VEG site BWL-003	Barnwell
SS AIK04 13	Upper Three Runs @ Old Barnwell Rd.	Aiken
SS BWL05 13	Barnwell Lake Edgar Brown	Barnwell
SS WIL 13	Williston Plum Location EVBWL-02	Barnwell

Tables and Figures
Surface Soil Monitoring Adjacent to SRS

Table 2. Preliminary Remediation Goals of Anthropogenic Radionuclides Samples by SCDHEC

Radionuclide	Abbreviation	PRG
Americium-241	Am-241	**3.75 pCi/g**
Cesium-137	Cs-137	**25.4 pCi/g**
Cobalt-60	Co-60	**79.2 pCi/g**
Iodine-131	I-131	**5940 pCi/g**

Table 3. Regional Screening Levels of Metals sampled by SCDHEC

Analyte	Abbreviation	RSL
Barium	Ba	**15,000 mg/kg**
Cadmium	Cd	**70 mg/kg**
Chromium	Cr	**230 mg/kg**
Copper	Cu	**3,100 mg/kg**
Mercury	Hg	**400 mg/kg**
Manganese	Mn	**1,800 mg/kg**
Nickel	Ni	**1,500 mg/kg**
Lead	Pb	**400 mg/kg**
Zinc	Zn	**23,000 mg/kg**

Table 4. Soil Screening Levels of Anthropogenic Radionuclides Samples by SCDHEC

Radionuclide	Abbreviation	SSL
Americium-241	Am-241	**0.088 pCi/g**
Cesium-137	Cs-137	**0.492 pCi/g**
Cobalt-60	Co-60	**0.081 pCi/g**
Iodine-131	I-131	**5.05 pCi/g**

Tables and Figures
Surface Soil Monitoring Adjacent to SRS

Table 5. Radiological Analytes

Radioisotope	Abbreviation
Actinium-228	Ac-228
Americium-241	Am-241
Antimony-125	Sb-125
Berylium-7	Be-7
Cobalt-58	Co-58
Cobalt-60	Co-60
Cerium-144	Ce-144
Cesium-134	Cs-134
Cesium-137	Cs-137
Europium-152	Eu-152
Europium-154	Eu-154
Europium-155	Eu-155
Iodine-131	I-131
Lead-212	Pb-212
Lead-214	Pb-214
Manganese-54	Mn-54
Potassium-40	K-40
Radium-226	Ra-226
Ruthenium-103	Ru-103
Sodium-22	Na-22
Thorium-234	Th-234
Yttrium-88	Y-88
Zinc-65	Zn-65
Zirconium-95	Zr-95

Note: Units are reported in pCi/g.

Table 6. Nonradiological Analytes

Analyte	Abbreviation	ESV
Barium	Ba	20
Beryllium	Be	0.5
Cadmium	Cd	0.6
Chromium	Cr	36
Copper	Cu	18.7
Lead	Pb	30.2
Manganese	Mn	630
Mercury	Hg	0.13
Nickel	Ni	15.9
Zinc	Zn	98

Note: Units are reported in mg/kg.

Tables and Figures
Surface Soil Monitoring Adjacent to SRS

Table 7. Cs-137 Surface Soil Data Comparison: Nonrandom Perimeter SCDHEC and DOE-SR Perimeter Surface Soil Samples

SCDHEC

Sample ID	County	Cs-137
SS ALG 13	Allendale	0.13
SS SNL 13	Barnwell	0.06
SS DKH 13	Barnwell	0.06
SS ALN 13	Allendale	0.06
SS GP 13	Aiken	0.04
SS JAK 13	Aiken	0.17
SS AIK 13	Aiken	0.1
SS JAK02 13	Aiken	0.18
SS NEL 13	Aiken	0.11
SS BWL 13	Barnwell	0.09
SS BWL02 13	Barnwell	0.12
SS BWL03 13	Barnwell	<MDA
SS AIK03 13	Barnwell	0.04
SS ALD 13	Allendale	0.08
SS BWL04 13	Barnwell	0.07
SS AIK04 13	Aiken	0.06
SS BWL05 13	Barnwell	0.06
SS WIL 13	Barnwell	<MDA
SS AIK02 12	Aiken	0.22
AVG		**0.1**
MEDIAN		**0.08**
STD		**0.05**

DOE-SR

SRS Perimeter	Cs-137
Allendale Gate	0.15
Barnwell Gate	0.23
D-Area	0.5
Darkhorse @ Williston Gate	0.22
East Talatha	0.32
Green Pond	0.44
Highway 21/167	0.13
Jackson	0.1
Patterson Mill Road	0.13
Talatha Gate	0.1
West Jackson	0.25
Windsor Road	0.18
AVG	**0.23**
MEDIAN	**0.2**
STD	**0.13**

DOE-SR 25 Mile Radius	Cs-137
Aiken Airport	0.25
Augusta Lock and Dam 614	0.11
Highway 301 @ State Line	0.32
AVG	**0.23**
MEDIAN	**0.25**
STD	**0.11**

Tables and Figures
Surface Soil Monitoring Adjacent to SRS

Table 8. Cs-137 Surface Soil Data Comparison: SCDHEC and DOE-SR Surface Soil Samples Collected > 50 miles from the SRS Center Point.

SCDHEC		
Sample ID	**County**	**Cs-137**
SS NWB 13	Newberry	0.13
SS UNI 13	Union	0.04
SS ABB 13	Abbeville	0.09
SS COL 13	Colleton	0.05
SS HMP 13	Hampton	0.05
SS BEU 13	Beaufort	0.08
AVG		**0.07**
MEDIAN		**0.06**
STD		**0.03**
DOE-SR		
Sample ID	**Sample Location**	**Cs-137**
100-Mile Radius	Savannah, GA	**<MDC**

Tables and Figures
Surface Soil Monitoring Adjacent to SRS

Figure 1. Trending Data for Cesium-137 by Yearly Averages of 2008-2013 and Individual Years

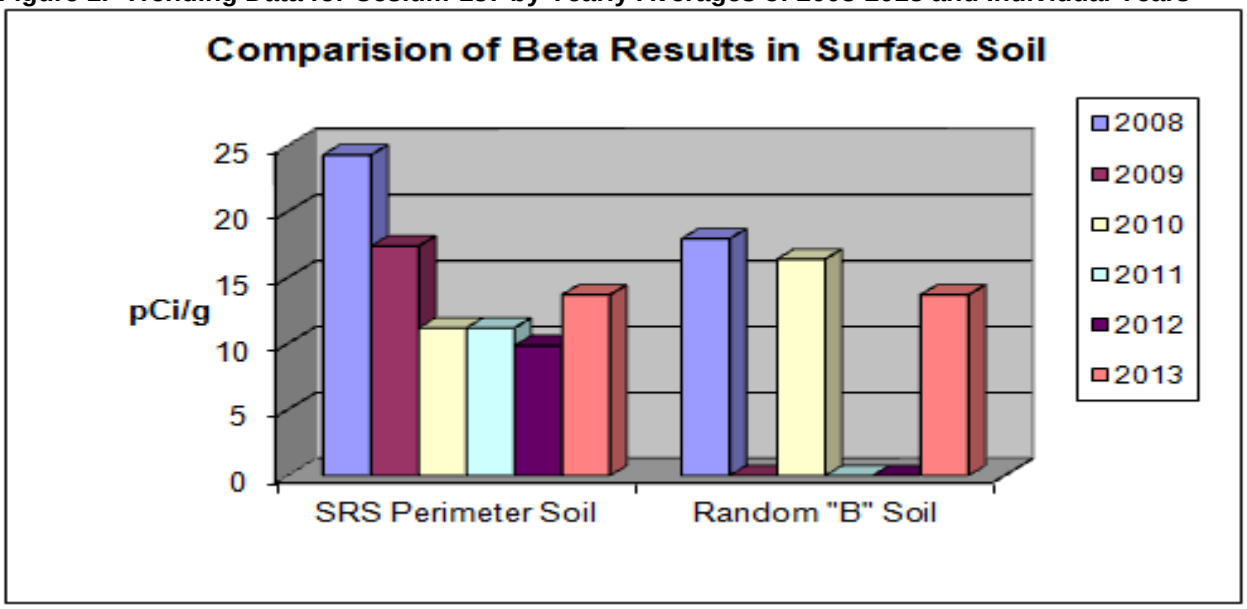
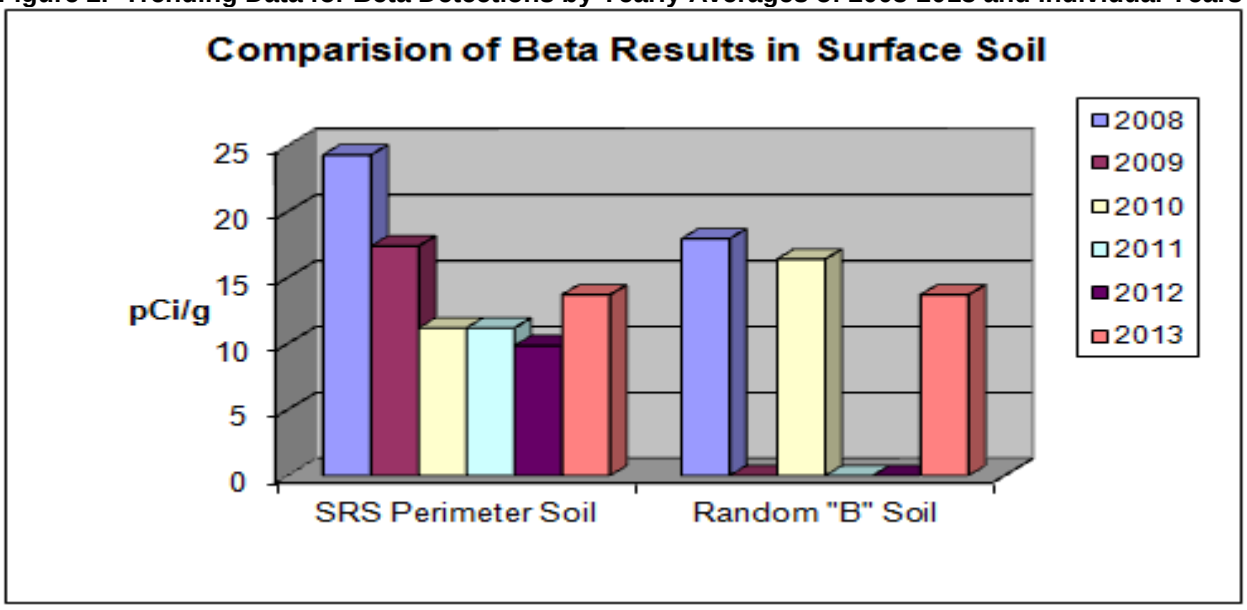
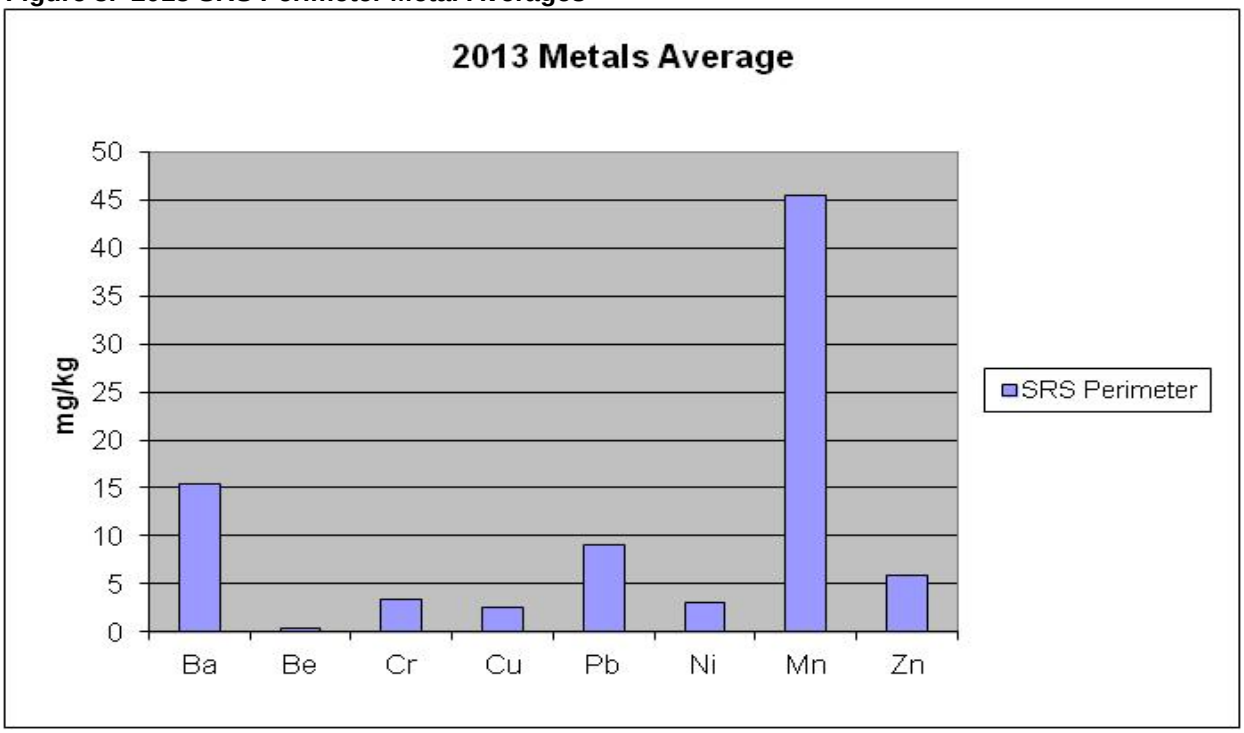


Figure 2. Trending Data for Beta Detections by Yearly Averages of 2008-2013 and Individual Years



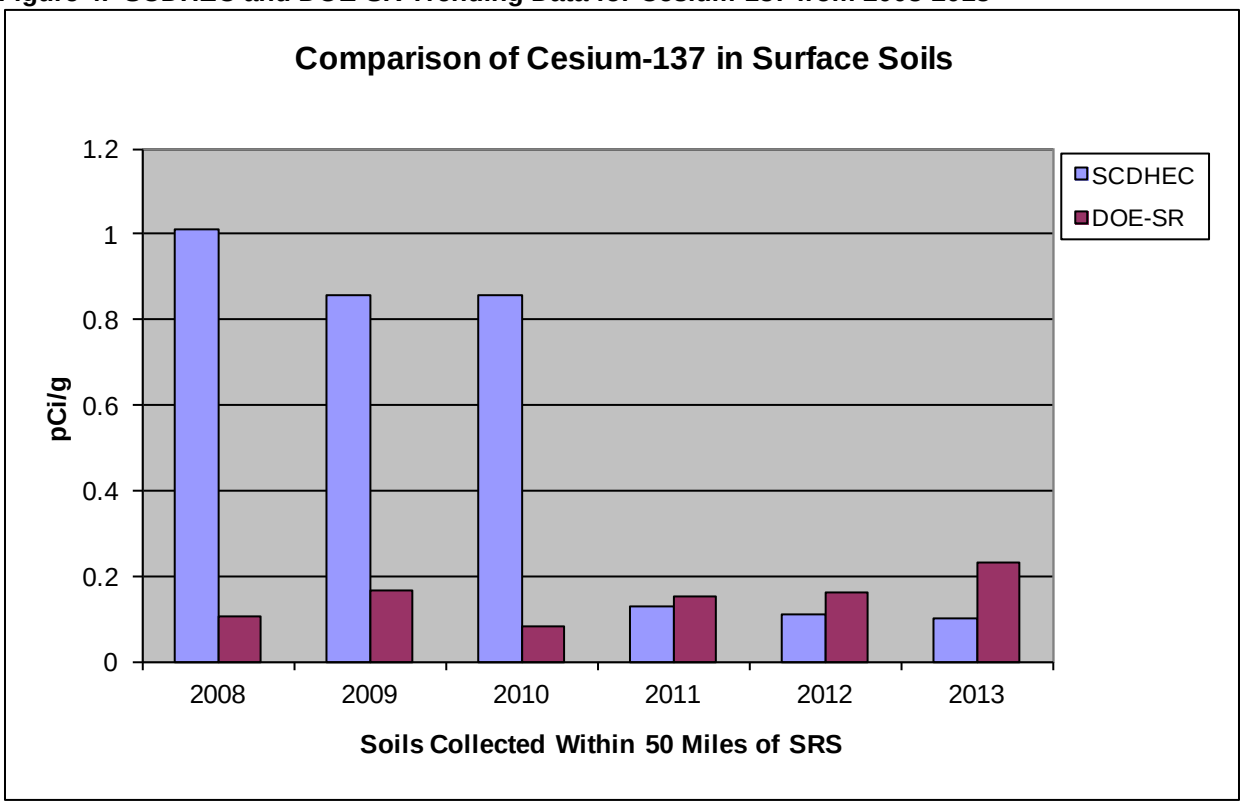
Note: There were no beta detections in any of the “B” soil samples collected in 2010 and 2012

Figure 3. 2013 SRS Perimeter Metal Averages



Note: There were no Hg detections in the SRS perimeter samples.

Figure 4. SCDHEC and DOE-SR Trending Data for Cesium-137 from 2008-2013



6.0 Summary Statistics

Surface Soil Monitoring Adjacent to SRS

1. Notes: N/A = Not Applicable

Surface Soil Monitoring Adjacent to SRS

2013 Summary Statistics – SCDHEC Surface Soil Metals Data
Nonrandom Perimeter Samples

	AVG:	SD:	MED:	MIN:	MAX:	Total Number of Samples	Number Detects
Barium	17.08	12.44	12	6.2	49	19	18
Beryllium	0.39	0.09	0.39	0.31	0.46	19	4
Cadmium	1.00	N/A	N/A	N/A	N/A	19	1
Chromium	3.45	3.00	2.00	1.00	13.00	19	19
Copper	2.59	0.86	2.7	1.1	3.7	19	9
Mercury	N/A	N/A	N/A	N/A	N/A	19	0
Manganese	45.5	48.6	20	5.6	160	19	19
Nickel	3.10	0.71	3.10	2.60	3.60	19	2
Lead	9.08	4.57	7.00	5.00	16.00	19	9
Zinc	5.91	3.51	3.90	2.10	13.00	19	19

Note: Units are in mg/kg.

2013 Summary Statistics – SCDHEC Surface Soil Radiological Data
Nonrandom Perimeter Samples

	AVG:	SD:	MED:	MIN:	MAX:	Total Number of Samples	Number of Detections
Alpha	13.9	N/A	N/A	N/A	N/A	19	1
Beta	13.7	1.7	13.7	12.5	14.9	19	2
K-40	2.78	3.01	1.48	0.39	8.73	19	19
Cs-137	0.1	0.05	0.08	0.04	0.22	19	17
Pb-212	0.79	0.26	0.78	0.31	1.22	19	19
Pb-214	0.66	0.35	0.57	0.3	1.91	19	19
Ra-226	1.42	1.02	1.12	0.75	5.05	19	16
Ac-228	0.78	0.24	0.82	0.29	1.16	19	19

Note: Units are in pCi/g.

2013 Summary Statistics – SCDHEC Surface Soil Radiological Data
Background "B" Samples

	AVG:	SD:	MED:	MIN:	MAX:	Total Number of Samples	Number of Detections
Alpha	17.4	N/A	N/A	N/A	N/A	6	1
Beta	13.7	N/A	N/A	N/A	N/A	6	1
K-40	2.35	2.92	1.29	0.61	8.24	6	6
Cs-137	0.07	0.03	0.06	0.04	0.13	6	6
Pb-212	0.71	0.21	0.64	0.52	1.09	6	6
Pb-214	0.56	0.14	0.53	0.41	0.79	6	6
Ra-226	1.31	0.32	1.22	0.94	1.67	6	5
Ac-228	0.67	0.19	0.62	0.47	1.00	6	6

Note: Units are in pCi/g

LIST OF ACRONYMS

DOE-SR	Department of Energy – Savannah River
ESOP	Environmental Surveillance and Oversight Program
LLD	Lower Limit of Detection
MDA	Minimum Detectable Activity
MDC	Minimum Detectable Concentration
MDL	Minimum Detection Level
NORM	Naturally Occurring Radioactive Material
PRG	Preliminary Remediation Goals
RSL	Regional Screening Level
SC	South Carolina
SCDHEC	South Carolina Department of Health and Environmental Control
SRS	Savannah River Site
SS	Surface Soil
SSL	Soil Screening Level
USEPA	United States Environmental Protection Agency

UNITS OF MEASURE

mg/kg	milligrams per kilogram
pCi/g	picocuries per gram
±	Plus or minus. Refers to one standard deviation unless otherwise stated

REFERENCES

Absalom, J.P.; Young, S.D.; Crout N.M.J.; Sanchez A.; Wright, S.M.; Smolders, E.; Nisbet, A.F. and Gillett A.G. 2001. Predicting the Transfer of Radiocaesium from Organic Soils to Plants Using Soil Characteristics. Journal of Environment Radioactivity, vol. 52, no. 1, p. 31-43.

Alloway, B.J., 1995. Heavy Metals in Soils. Great Britain, St Edmundsbury Press, Suffolk.

Canova, J.L., 1999. Elements in South Carolina Inferred Background Soil and Stream Sediment Samples. South Carolina Geology, 1999, v.41, p.11-25.

Centers for Disease Control (CDC). 2006. Phase III of the SRS dose reconstruction project. Available from URL http://www.cdc.gov/nceh/radiation/Savannah/docs/TOCs.pdf

Corey, J.C. 1980. Transport of Radionuclides Through Soil and Groundwater. E. I. DuPont de Nemours and Company, Savannah River Plant, Aiken, SCDP-MS-80-95.

Savannah River Nuclear Solutions, LLC (SRNS). 2010. Savannah River Site Environmental Report for 2009. Savannah River Site Aiken, SC. SRNS-STI-2009-00190

Savannah River Nuclear Solutions, LLC (SRNS). 2011. Savannah River Site Environmental Report for 2010. Savannah River Site Aiken, SC. SRNS–STI–2011–00059

Savannah River Nuclear Solutions, LLC (SRNS). 2012. Savannah River Site Environmental Report for 2011. Savannah River Site Aiken, SC SRNS-STI-2012-00021

Savannah River Nuclear Solutions, LLC (SRNS). 2013. Savannah River Site Environmental Report for 2012. Savannah River Site Aiken, SC. SRNS-STI-2013-00024

Savannah River Nuclear Solutions, LLC (SRNS). 2014. Savannah River Site Environmental Report for 2014. Savannah River Site Aiken, SC. SRNS -STI-2014-00006

SCDHEC. 2008. South Carolina Department of Health and Environmental Control 2007 Environmental Data Report, Bureau of Environmental Services, Environmental Surveillance and Oversight Program, Aiken, South Carolina.

SCDHEC. 2009. South Carolina Department of Health and Environmental Control 2008 Environmental Data Report, Bureau of Environmental Services, Environmental Surveillance and Oversight Program, Aiken, South Carolina.

SCDHEC. 2010. South Carolina Department of Health and Environmental Control 2009 Environmental Data Report, Bureau of Environmental Services, Environmental Surveillance and Oversight Program, Aiken, South Carolina.

SCDHEC. 2011. South Carolina Department of Health and Environmental Control 2010 Environmental Data Report, Bureau of Environmental Services, Environmental Surveillance and Oversight Program, Aiken, South Carolina.

SCDHEC. 2012. South Carolina Department of Health and Environmental Control 2011 Environmental Data Report, Bureau of Environmental Services, Environmental Surveillance and Oversight Program, Aiken, South Carolina.

SCDHEC. 2013. South Carolina Department of Health and Environmental Control 2012 Environmental Data Report, Bureau of Environmental Services, Environmental Surveillance and Oversight Program, Aiken, South Carolina.

Till, J.E., et al. 2001. Savannah River Site Environmental Dose Reconstruction Project, Phase II: Source Term Calculation and Ingestion Pathway Data Retrieval, Evaluation of Materials Released From the Savannah River Site. RAC Report No. 1-CDC-SRS-1999-Final. Risk Assessment Corporation (RAC).

USEPA. 20013a. Preliminary Remediation Goals for Radionuclides. http://www.epa.gov/region9/superfund/prg/

USEPA. 2013a. Regional Screening Levels for Chemical Contaminants. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm

USEPA. 2013c. RadNet
http://www.epa.gov/radnet/docs/402r08007.pdf

USEPA. 2013d. Soil Screening Levels for radionuclides
http://www.epa.gov/superfund/health/contaminants/radiation/pdfs/tbd-part-2-clean.pdf

Westinghouse Savannah River Company (WSRC). 1993. Final Record of Decision Remedial Alternative Selection for H-Area Hazardous Waste Management Facility. Westinghouse Savannah River Company, Savannah River Site, Aiken, South Carolina. WSRC-RP-93-1043.

WSRC. 2009. Savannah River Site Environmental Report for 2009. Washington Savannah River Company, Savannah River Site, Aiken, SC. WSRC-TR-2009-00010

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2013 Radiological Monitoring of Terrestrial Vegetation Related to the Savannah River Site

Environmental Surveillance and Oversight Program

97VG003
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January 01, 2013 – December 31, 2013

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Table of Contents

1.0 PROJECT SUMMARY

Terrestrial vegetation can be contaminated externally by direct deposition of airborne materials, water runoff, and precipitation that contains radioactivity. Vegetation can also be contaminated internally by uptake of radionuclides through the roots. Contaminated vegetation can be transported by physical means and, if eaten by animals, this radioactivity can enter the food chain.

The Department of Energy-Savannah River (DOE-SR) contracts for the collection and analysis of terrestrial vegetation, primarily Bermuda grass, to determine concentrations of radionuclides (SRNS 2014). The samples are obtained from twelve locations at the Savannah River Site (SRS) perimeter, one onsite location at the burial grounds, three 25-mile locations, and one 100-mile location. The Environmental Surveillance and Oversight Program (ESOP) of the South Carolina Department of Health and Environmental Control (SCDHEC) monitors for the presence of radionuclides in vegetation around SRS, collecting leaves from broad-leafed evergreen trees and shrubs, such as wax myrtle (*Myrica cerifera*), laurel oak (*Quercus laurifolia*), or Carolina laurelcherry (*Prunus caroliniana*).

In 2013, ESOP conducted independent vegetation monitoring at 17 locations along the perimeter of SRS as well as three former SRS monitoring locations 25 miles from the center of SRS. These 25-mile samples allow comparisons to be made between tritium levels at the site perimeter and tritium levels in the general SRS area. Sampling was performed on a quarterly basis with samples obtained in March, June, September, November, and December. ESOP and DOE-SR perimeter stations sampled in 2013 are shown in Section 4.0, Map 1.

Samples from eight of 17 perimeter stations exhibited tritium levels greater than the lower limit of detection (LLD; approximately 240 picocuries per liter (pCi/L) with the highest activity found on the western side of SRS. Vegetation was also collected for gamma analysis at nine perimeter locations. Each gamma sample was analyzed for beryllium-7 (Be-7), sodium-22 (Na-22), potassium-40 (K-40), manganese-54 (Mn-54), cobalt-58 (Co-58), cobalt-60 (Co-60), zinc-65 (Zn-65), yttrium-88 (Y-88), zirconium-95 (Zr-95), ruthenium-103 (Ru-103), antimony-125 (Sb-125), iodine-131 (I-131), cesium-134 (Cs-134), cesium-137 (Cs-137), cerium-144 (Ce-144), europium-152 (Eu-152), europium-154 (Eu-154), europium-155 (Eu-155), lead-212 (Pb-212), lead-214 (Pb-214), radium-226 (Radium-226), actinium-228 (Ac-228), thorium-234 (Th-234), and americium-241 (Am-241).

Particular attention was paid to seven radionuclides: Be-7, K-40, Co-60, Cs-137, Pb-212, Pb-214, and Am-241, each of which has been detected in the past. During calendar year 2013, only Be-7, K-40, Cs-137, Pb-212, and Pb-214 were detected. Cs-137, a nonNORM fission product, was of particular importance.

Cs-137 was detected at three of these locations, with the highest activities from stations on the northern side of SRS. Overall, both Cs-137 and tritium average detection

activities have increased from last year, although it should be noted that the total number of Cs-137 detections decreased.

2.0 RESULTS AND DISCUSSION

All monitoring data are in Appendix A-ESOP Data and summary statistics are in section 6.0. All established sampling locations are found in Appendix A-ESOP Data and Section 4.0, Map 1.

Tritium in Vegetation

Tritium is a naturally occurring radioisotope of hydrogen that is normally found in very low concentrations (USEPA$_b$ 2012). Pre-bomb tritium levels are estimated to have been approximately 24 pCi/L in rainwater (DEQ 2013). Sources of man-made tritium include nuclear reactors and government weapons production plants. Tritium releases on SRS include both atmospheric and liquid contributions (SRNS 2014). Although the United States Environmental Protection Agency (USEPA) has not established a Maximum Contaminant Level (MCL) for tritium in solid media (e.g. vegetation), the MCL for drinking water has been set at 20,000 pCi/L (USEPA$_b$ 2012).

Tritium was detected in vegetation from 8 of the 17 perimeter sites sampled in 2013 (Section 5 Figures 1 and 2). The highest tritium levels detected during 2013 for each quarter were:

- Quarter 1 (March): BWL-002 at 276 (± 111) pCi/L (wax myrtle)
- Quarter 2 (June): AKN-001 at 2906 (± 172) pCi/L (wax myrtle)
- Quarter 3 (September): BWL-009 at 2980 (± 177) pCi/L (wax myrtle)
- Quarter 4 (December): BWL-009 at 1235 (± 138) pCi/L (wax myrtle)

There was one tritium detection at a 25-mile station: a 460 (± 113) pCi/L detection at ALD-251 in March, a level of activity significantly below the perimeter average of 769 (± 123) pCi/L, falling slightly above the 160 pCi/L to 320 pCi/L range typically seen in the atmosphere today (DEQ 2013). The highest yearly average based on more than one detection was 2074 (± 156) pCi/L at AKN-001 (Section 6.0).

The highest single tritium detection in 2013 was from BWL-009, located on the west-southwest side of SRS (Map 1). The three highest averages based on more than one detection were AKN-001 on the west side of SRS, BWL-001 on the northeast side, and BWL-009 on the west southwest side. Samples were also collected at three stations located 25 miles from the SRS centerpoint. The only detection was at ALD-251, which is located just outside of the town of Allendale, SC. Additional samples, collected as background samples, in St. George, SC, Walterboro, SC, and at the Old Sheldon Church ruins in Beaufort County yielded no detections.

The average perimeter tritium detection increased from 742 (± 115) pCi/L in 2012 to 769 (± 123) pCi/L in 2013 (Section 5 Figures 1 and 2). Six locations (AKN-001, BWL-001, BWL-002, BWL-007, BWL-008, and BWL-009) showed increases relative to 2012, although the BWL-007 average is based on one detection only. Nine locations (AKN-

002, AKN-003, AKN-004, AKN-005, AKN-006, AKN-007, AKN-008, BWL-003, and ALD-001) showed decreased activity in 2013. Two locations (BWL-004 and BWL-006) showed no change.

Tritium analysis results from ESOP and DOE-SR sampling are presented in Section 5.0, Table 1. However, differences between the two programs in sampling dates, the vegetation sampled, and analysis methods should be considered during comparison. Data comparison of associated locations from the two programs was conducted by converting from picocuries per gram (pCi/g) to pCi/L, using a dry/wet weight ratio of 0.3 furnished by DOE-SR, using the formula:

pCi/L = [pCi/g x (1/0.3)] / (1 - 0.3) = pCi/mL x 1000.

Two colocations (i.e. sample locations in relatively close proximity in space and time) are relevant to this report: the Patterson Mill Road and Allendale Gate locations. Both locations showed a tritium activity that was less than LLD for DOE-SR and ESOP samples.

DOE-SR and ESOP sampled vegetation at ten comparable locations, including colocations, in 2013. The DOE-SR program detected tritium from one perimeter station that had a comparable ESOP location in 2013 (SRNS 2014); ESOP detected tritium at four comparable locations. The DOE-SR average, 633 (± 70; this is based on one detection only) pCi/L, was within one standard deviation of the ESOP average, 639 (± 546) pCi/L. All measures of central tendency and standard deviation were calculated using detections only. It should also be noted that temporal proximity was also taken into account when ESOP samples were "matched" to DOE-SR samples.

Gamma in Vegetation

The naturally occurring isotopes potassium-40 (K-40) and beryllium-7 (Be-7) were detected from all stations where gamma samples were collected in 2013. The lead (Pb) isotopes Pb-212, a member of the thorium decay series, and Pb-214, a member of the radium decay series, were also detected, but not from all locations. Because these are naturally occurring isotopes the results will not be discussed in this section, but are presented in Appendix A-ESOP Data.

The man-made isotopes Cobalt-60 (Co-60) and Americium-241 (Am-241) were not detected during 2013; Cesium-137 (Cs-137), however, was detected at three locations. Cesium-137 is a man-made fission product and was a constituent of air and water releases on SRS, mainly from F and H-Areas. Liquid releases also occurred from the production reactors as a result of leaking fuel elements in the 1950s and 1960s (WSRC 1999).

Cesium-137, which has an MCL of less than four mrem/year for drinking water (USEPA$_a$ 2013), was detected at three of the nine perimeter stations sampled in 2013, and one station, AKN-005, produced Cs-137 results greater than the Minimum Detectable Activity (MDA) in all four quarters (Appendix A-ESOP Data). AKN-005, located on the

north side of SRS (Map 1), exhibited the highest Cs-137 activity in all four quarters: 0.24 (± 0.02) pCi/g in March, 0.52 (± 0.05) pCi/g in June, 0.57 (± 0.05) pCi/g in September, and 0.31 (± 0.04) pCi/g in December. AKN-005 also showed the highest yearly average Cs-137 activity, at 0.41 pCi/g (± 0.04; Section 5 Figure 3).

Results of analysis for Cs-137 at AKN-002, AKN-005, AKN-006, and BWL-006 showed lower levels than results from the previous calendar year (Section 5 Figure 3). Averages for AKN-001, AKN-003, AKN-008, BWL-004, and ALD-001 showed no change in activity from 2012; none of the sampling locations showed increases in Cs-137 activity. The overall average for Cs-137 detections is higher than in 2012, at 0.22 (± 0.02) pCi/g. However, it should be noted that the total number of detections is lower.

Gamma analysis results for Cs-137 from ESOP and DOE-SR sampling in 2013 are presented in Section 5.0, Table 2. DOE-SR detected Cs-137 at the Patterson Mill Road/BWL-004 colocation, at 0.12 (± 0.04) pCi/g, and the Allendale Gate/BWL-006 colocation, at 0.23 (± 0.05) pCi/g. ESOP results for both colocations were less than MDA. Differences in analysis, sampling methods, and the dates samples were obtained may account for any discrepancies between the data.

For the other DOE-SR stations, the closest ESOP stations were selected for comparison, except for the DOE-SR Highway 21/167 detection of 0.50 (± 0.06) pCi/g (SRNS 2014). This gamma sampling location does not have a corresponding ESOP sampling location and any attempted comparison would be invalid. For this reason, it was not used for calculating the DOE-SR mean, median, and standard deviation and is also not shown in Table 2.

DOE-SR detected Cs-137 at six of nine sampling stations that had a comparable ESOP location or colocation. ESOP had detections at two of nine comparable locations, although some ESOP locations correspond with more than one DOE-SR location. ALD-001, which has no comparable DOE-SR location, had no detections in 2013.

Average Cs-137 levels were also compared, using only detections to calculate the mean, median, and standard deviation (Section 5 Table 2). The DOE-SR average of 0.21 (±0.09) pCi/g (SRNS 2014) was within one standard deviation of the ESOP average of 0.28 (± 0.34) pCi/g.

3.0 CONCLUSIONS AND RECOMMENDATIONS

ESOP conducted independent vegetation monitoring in 2013 at 17 locations around the perimeter of SRS and three locations 25 miles from the center of SRS. Tritium was detected in vegetation from 8 of 17 of the perimeter stations and one of the 25-mile stations. The highest activity sample, at 2980 (± 177) pCi/L, was collected on the west southwest side of SRS at SCDHEC location BWL-009. The average tritium activity detected at the SRS perimeter increased from 742 (± 115) pCi/L in 2012 to 769 (± 123) pCi/L in 2013. The average Cs-137 level was also higher in 2013, increasing to 0.22 (±

0.02) pCi/g from 0.17 (± 0.07) pCi/g in 2012, but the total number of detections was lower.

A comparison of ESOP and DOE-SR tritium data was performed. DOE-SR and ESOP did not detect tritium at either colocation (SRNS 2014). At the SRS perimeter locations, DOE-SR had a detection at one sample location while ESOP had detections at three sample locations. The DOE-SR and ESOP average activities are within one standard deviation of each other, although it should be emphasized that the DOE-SR average is based on one detection only.

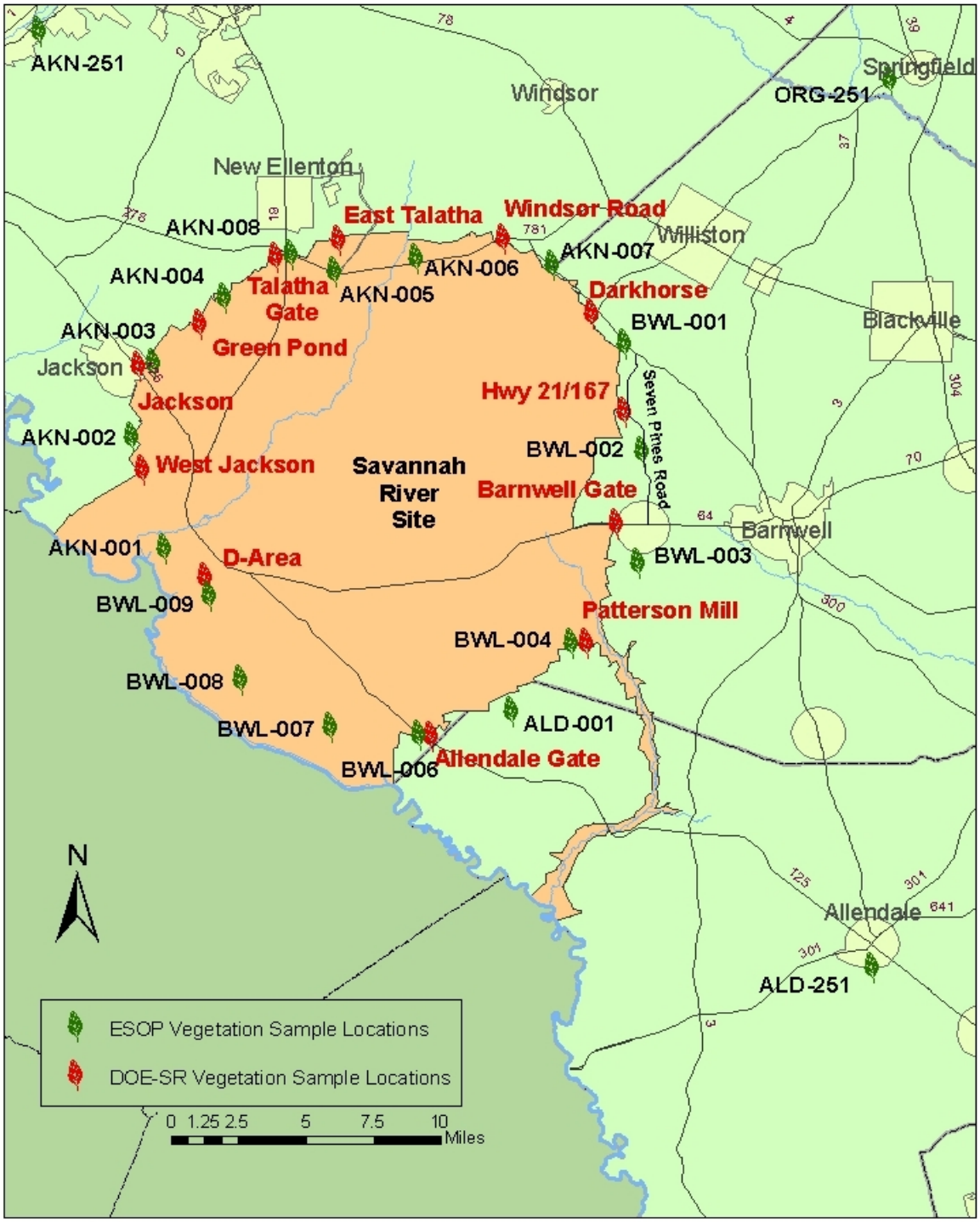
A comparison of DOE-SR data and ESOP Cs-137 data was also performed. DOE-SR and ESOP data were similar, within one standard deviation of each other. All ESOP locations showed either decreasing or static Cs-137 activity in 2013.

ESOP data supports the DOE-SR conclusion that elevated tritium levels at the site perimeter are due to atmospheric releases from SRS, although Plant Vogtle, a commercial nuclear power plant across the Savannah River from SRS, may also have an effect. The average tritium level at the SRS perimeter was higher than the average tritium level at the 25-mile locations, which serves as an indicator of decreasing tritium levels as the distance from SRS increases.

There are differences in analysis and sampling methods between the programs (e.g., ESOP collects leaves from trees, whereas DOE-SR conducts annual grass collections). Reconciling ESOP and DOE-SR methods would provide better comparability of data.

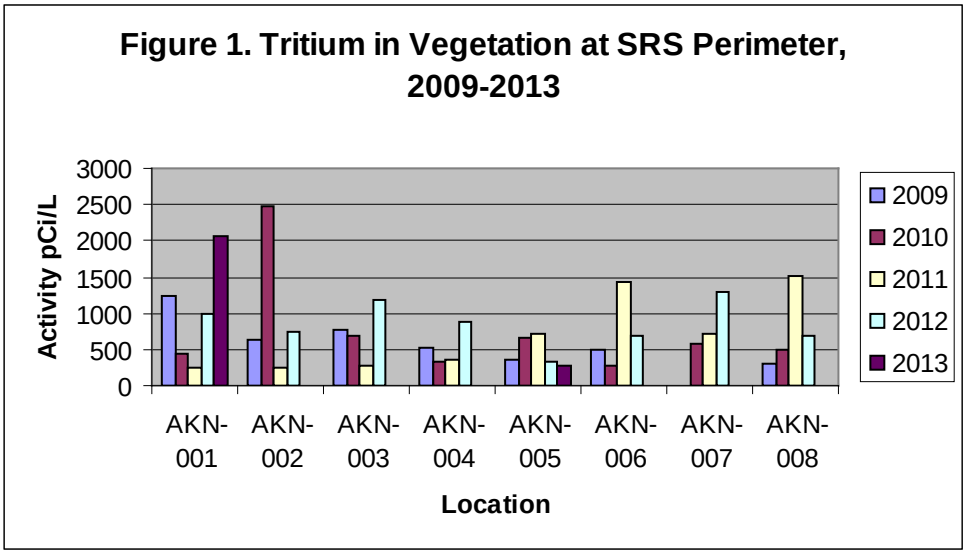
4.0 Radiological Monitoring of Terrestrial Vegetation

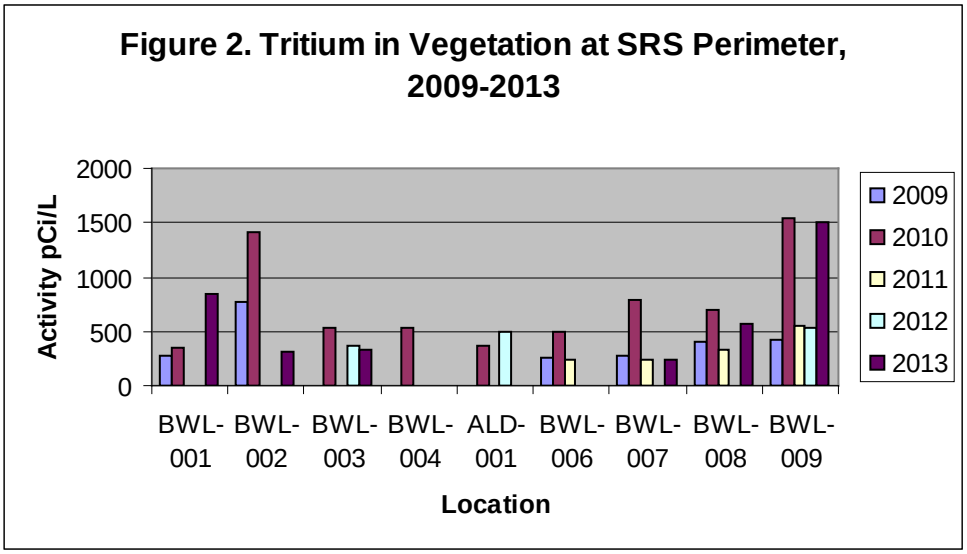
Map 1. ESOP and DOE-SR Radiological Vegetation Sampling Locations, 2013



5.0 Tables and Figures

Radiological Monitoring of Terrestrial Vegetation

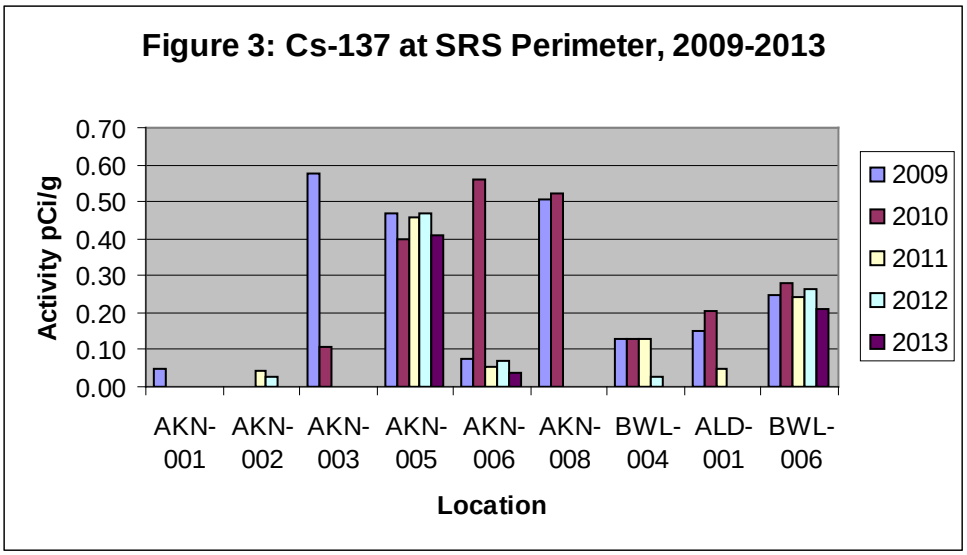




Notes:
(1) These graphs depict the average of all detections for calendar years 2009-2013 by sampling station.
(2) 2009 was the first year AKN-008 was sampled for tritium.
(3) Missing bars indicate an average that was less than the lower limit of detection.
(4) The bar for BWL-007 represents a single detection.
(5) There was one 25-mile location detection in 2013: a 460 pCi/L detection at ALD-251 in June.

5.0 Tables and Figures

Radiological Monitoring of Terrestrial Vegetation



Notes:
(1) This graph depicts the average of all detections for calendar years 2009-2013 by sampling station.
(2) Missing bars indicate an average that was less than the minimum detectable activity.
(3) The bar for BWL-006 represents a single detection.

5.0 Tables and Figures

Radiological Monitoring of Terrestrial Vegetation

Table 1. Comparison of Tritium Analyses, DOE-SR and ESOP Data, 2013

DOE-SR Data					ESOP Data			
Station	**Date**	**pCi/g**	**+/- 1 sig**	**pCi /L[a]**	**Station**	**Date**	**pCi/L**	**+/- 2 sig**
D-Area	5/20/13	<LLD	NA	NA	BWL-009 [b]	6/20/13	306	108
Jackson	5/20/13	<LLD	NA	NA	AKN-003 [b]	6/26/13	<LLD	NA
Green Pond	5/20/13	<LLD	NA	NA	AKN-004 [b]	6/20/13	<LLD	NA
Talatha Gate	5/20/13	0.13	0.01	633	AKN-005 b	6/20/13	<LLD	NA
East Talatha	5/21/13	<LLD	NA	NA	AKN-006 [b]	6/20/13	<LLD	NA
Darkhorse	5/21/13	<LLD	NA	NA	BWL-001 [b]	6/14/13	1269	136
Highway 21/167	5/21/13	<LLD	NA	NA	BWL-002 [b]	6/14/13	341	110
Barnwell Gate	5/21/13	<LLD	NA	NA	BWL-004 [a]	6/14/13	<LLD	NA
Patterson Mill Road [c]	5/20/13	<LLD	NA	NA	BWL-004 [c]	6/14/13	<LLD	NA
Allendale Gate [c]	5/20/13	<LLD	NA	NA	BWL-006 [c]	6/14/13	<LLD	NA

Average	633	**Average**	639
Std Dev	NA	**Std Dev**	546
Median	633	**Median**	341

< LLD Denotes Less Than Reported Lower Limit of Detection
NA Denotes Not Applicable
[a] Converted Using the Following Formula: pCi/L = [pCi/g x (1/0.3)] / (1 - 0.3) = pCi/mL x 1000
The above formula is used for comparison purposes only.
b Comparable ESOP Location
c Colocation
West Jackson and Windsor Road Locations were not collected by DOE-SR in 2013.

5.0 Tables and Figures

Radiological Monitoring of Terrestrial Vegetation

Table 2. Comparison of Cs-137 Analyses, DOE-SR and ESOP Data, 2013

DOE-SR Data				ESOP Data			
Location	**Date**	**pCi/g (dry)**	**+/- 1 sig**	**Station**	**Date**	**pCi/g (fresh)**	**+/- 2 sig**
D-Area	5/20/13	<MDC	NA	AKN-001 [a]	6/20/13	<MDA	NA
Jackson	5/20/13	<MDC	NA	AKN-003 [a]	6/26/13	<MDA	NA
Green Pond	5/20/13	<MDC	NA	AKN-003 [a]	6/26/13	<MDA	NA
Talatha Gate	5/20/13	0.13	0.04	AKN-008 [a]	6/20/13	<MDA	NA
East Talatha	5/21/13	0.37	0.07	AKN-005 [a]	6/20/13	0.52	0.05
Darkhorse	5/21/13	0.19	0.04	AKN-006 [a]	6/20/13	0.04	0.01
Barnwell Gate	5/21/13	0.26	0.04	BWL-004 [a]	6/14/13	<MDA	NA
Patterson Mill Road [b]	5/20/13	0.12	0.04	BWL-004 [b]	6/14/13	<MDA	NA
Allendale Gate [b]	5/20/13	0.23	0.05	BWL-006 [b]	6/20/13	<MDA	NA
Average		0.21		**Average**		0.28	
Std Dev		0.09		**Std Dev**		0.34	
Median		0.21		**Median**		0.28	

<MDC denotes less than the WSRC Minimum Detectable Concentration

<MDA denotes less than the SCDHEC/ESOP Minimum Detectable Concentration

[a] Comparable ESOP location

b Colocation

West Jackson and Windsor Road Locations were not collected by DOE-SR in 2013.

6.0 Summary Statistics

Radiological Monitoring of Terrestrial Vegetation Data

Notes:

1. pCi/L-picocuries per liter
2. pCi/g -picocuries per gram
3. N-Number of Samples With Detections
4. Std Dev-Standard Deviation
5. LLD-Lower Limit of Detection
6. MDA-Minimum Detectable Activity
7. ND-Non Detects
8. NA-Not Applicable

6.0 Summary Statistics

Radiological Monitoring of Terrestrial Vegetation Summary Statistics
2013 Vegetation Tritium Summary

Table 1. Tritium Levels in Vegetation from SRS Perimeter Stations

Tritium Levels (pCi/L) in Vegetation from SRS Perimeter Stations, 2013						
Station	**N (ND)**	**Average**	**Uncertainty**	**Median**	**Maximum**	**Minimum**
AKN-001	3 (1)	2074	156	2797	2906	<LLD
AKN-002	0 (4)	NA	NA	NA	NA	<LLD
AKN-003	0 (4)	NA	NA	NA	NA	<LLD
AKN-004	0 (4)	NA	NA	NA	NA	<LLD
AKN-005	2 (2)	277	110	277	303	<LLD
AKN-006	0 (4)	NA	NA	NA	NA	<LLD
AKN-007	0 (4)	NA	NA	NA	NA	<LLD
AKN-008	0 (4)	NA	NA	NA	NA	<LLD
BWL-001	2 (2)	845	127	845	1269	<LLD
BWL-002	2 (2)	308	110	308	341	<LLD
BWL-003	3 (1)	326	111	271	447	<LLD
BWL-004	0 (4)	NA	NA	NA	NA	<LLD
ALD-001	0 (4)	NA	NA	NA	NA	<LLD
BWL-006	0 (4)	NA	NA	NA	NA	<LLD
BWL-007	1 (3)	244	111	244	244	<LLD
BWL-008	3 (0)	567	118	711	728	<LLD
BWL-009	3 (1)	1507	141	460	2980	<LLD

Table 2. Average Tritium Levels in Vegetation from SRS Perimeter Stations

Tritium Levels (pCi/L) in SRS Perimeter Vegetation Samples, 2013					
N (ND)	**Average**	**Uncertainty**	**Median**	**Maximum**	**Minimum**
19 (48)	769	123	447	2980	<LLD

Table 3. Tritium Levels in 25-mile Radius Vegetation Samples

Tritium Levels (pCi/L) in 25-mile Radius Vegetation Samples, 2013						
Station	**N (ND)**	**Average**	**Uncertainty**	**Median**	**Maximum**	**Minimum**
AKN-251	0 (4)	NA	NA	NA	<LLD	<LLD
ALD-251	1 (3)	460	113	460	460	<LLD
ORG-251	0 (4)	NA	NA	NA	<LLD	<LLD

Table 4. Average Tritium Levels in 25-mile Radius Vegetation Samples

Tritium Levels (pCi/L) in 25-mile Radius Vegetation Samples, 2013					
N (ND)	**Average**	**Uncertainty**	**Median**	**Maximum**	**Minimum**
1 (11)	460	113	460	460	<LLD

Note: All measures of central tendency exclude non-detections.

6.0 Summary Statistics

Radiological Monitoring of Terrestrial Vegetation Summary Statistics
2013 Vegetation Cesium-137 Summary

Table 5. Cesium-137 Levels in SRS Perimeter Vegetation Samples

Cesium-137 Levels (pCi/g-fresh) in SRS Perimeter Vegetation Samples, 2013						
Station	**N (ND)**	**Average**	**Confidence Interval**	**Median**	**Maximum**	**Minimum**
AKN-001	0 (4)	<MDA	NA	NA	<MDA	<MDA
AKN-002	0 (4)	<MDA	NA	NA	<MDA	<MDA
AKN-003	0 (4)	<MDA	NA	NA	<MDA	<MDA
AKN-005	4 (0)	0.41	0.04	0.42	0.57	0.24
AKN-006	2 (2)	0.04	0.01	0.04	0.04	0.04
AKN-008	0 (4)	<MDA	NA	NA	<MDA	<MDA
BWL-004	0 (4)	<MDA	NA	NA	<MDA	<MDA
ALD-001	0 (4)	<MDA	NA	0.05	<MDA	<MDA
BWL-006	1 (3)	0.21	0.02	0.21	0.21	0.21

Table 6. Average Cesium-137 Levels in SRS Perimeter Vegetation Samples

Cesium-137 Levels (pCi/g-fresh) in SRS Perimeter Vegetation Samples, 2013						
Station	**N (ND)**	**Average**	**Confidence Interval**	**Median**	**Maximum**	**Minimum**
All Locations	7 (29)	0.22	0.02	0.21	0.57	<MDA

Note: All measures of central tendency exclude non-detections.

List of Acronyms

ALD	Sample locations in Allendale County
AKN	Sample locations in Aiken County
BWL	Sample locations in Barnwell County
DOE-SR	Department of Energy-Savannah River
ESOP	Environmental Surveillance and Oversight Program
LLD	Lower Limit of Detection: The lowest concentration of a radioactive isotope that can be detected by a given instrument.
MCL	Maximum Contaminant Level: The threshold concentration of a contaminant above which water is not suitable for drinking.
MDA	Minimum Detectable Activity: The smallest concentration of radioactivity in a sample that can be reliably detected.
NORM	Naturally Occurring Radioactive Material
ORG	Orangeburg
SCDHEC	South Carolina Department of Health and Environmental Control
SD	Standard Deviation: A measure of the variation from the mean within a body of data.
SRS	Savannah River Site
USEPA	United States Environmental Protection Agency

Units of Measure

±	plus or minus one standard deviation
pCi/g	picocuries per gram
pCi/L	picocuries per liter
pCi/mL	picocuries per milliliter

List of Isotopes and Abbreviations

Be-7	Beryllium-7
Na-22	Sodium-22
K-40	Potassium-40
Mn-54	Manganese-54
Co-58	Cobalt-58
Co-60	Cobalt-60
Zn-65	Zinc-65
Y-88	Yttrium-88
Zr-95	Zirconium-95
Ru-103	Ruthenium-103
Sb-125	Antimony-125
I-131	Iodine-131
Cs-134	Cesium-134
Cs-137	Cesium-137
Ce-144	Cerium-144
Eu-152	Europium-152
Eu-154	Europium-154
Eu-155	Europium-155
Pb-212	Lead-212
Pb-214	Lead-214
Ra-226	Radium-226
Ac-228	Actinium-228
Th-234	Thorium-234
Am-241	Americium-241

REFERENCES

Michigan Department of Environmental Quality (DEQ). 2013. Tritium: Use of Tritium in Assessing Aquifer Vulnerability. http://www.michigan.gov/documents/deq/deq-wb-dwehs-swpu-tritiumanalysisguidance_212715_7.pdf.

Savannah River Nuclear Solutions, LLC (SRNS). 2014. Savannah River Site Environmental Report for 2013. Savannah River Site Aiken, SC. SRNS-STI-2014-00006.

United States Environmental Protection Agency ($USEPA_a$). 2013. Drinking Water Contaminants. http://water.epa.gov/drink/contaminants/index.cfm.

United States Environmental Protection Agency ($USEPA_b$). 2012. USEPA Information. www.epa.gov/radiation/radionuclides

Westinghouse Savannah River Company (WSRC). 1999. Radionuclides in the Savannah River Site Environment. Westinghouse Savannah River Company, Aiken, South Carolina. WSRC-MS-99-00667.

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2013 Radiological Monitoring of Edible Vegetation Adjacent to Savannah River Site

Environmental Surveillance and Oversight Program

01EV002
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Table of Contents

1.0 Project Summary

Radionuclide uptake by vegetation may occur by direct absorption into the plant through the foliage or roots, and grazing animal dose exposure occurs primarily by ingestion of the contaminated plant (Kathren 1984). Plant uptake of radionuclides depends upon many factors including species, tissue type, soil-water-plant relationships, soil type, and the chemical nature of the radionuclide in the soil (Hanlon 2004). "Sampling and analyzing native vegetation can provide information about the presence and movement of radionuclides in the environment" (Lawrence Livermore National Laboratory, LLNL 1997). Any acronyms not defined in the text are defined in the acronyms, units, reference, and appendix lists at the end of this report.

Since 1988, when the last heavy water reactor at SRS was shut down, the tritium supply was re-established using the new Tritium Extraction Facility (TEF). This facility's mission is to transfer new tritium gas to the nation's tritium inventory (WSRC 2006). The Southern Nuclear Operating Company operates the Vogtle Electric Generating Plant (VEGP) located in Burke County, Georgia (GA) adjacent to the SRS. Permitted tritium releases coming from the VEGP are a result of spent fuel pools during power operation, reactor operation by the fission process, and from fuel assemblies mainly during reactor operation and shortly after shutdown (Federal Register 1968).

The Radiological Monitoring of Edible Vegetation (EV) Project is a component of the South Carolina Department of Health and Environmental Control's (SCDHEC) Environmental Surveillance and Oversight Program (ESOP) that monitors edible food in perimeter and background locations around the Savannah River Site (SRS). SCDHEC ESOP monitoring addresses public concerns pertaining to SRS operations through independent monitoring of radionuclide activities in edible vegetation and fungi found around the perimeter of SRS. ESOP compares data with DOE-SR annually to address these concerns.

ESOP defined a study area comprised of perimeter counties, <50-miles from the SRS center point, and background locations, > 50-miles from the SRS centerpoint. Section 4.0, Map 1 depicts the counties around the perimeter of SRS and the United States Geological Survey (USGS) 7.5-minute quadrants that overlay those counties (USDOI 1992).

Edible vegetation was collected based solely on availability, and was directly dependent upon the growing season. Farmers, gardeners, and/or businesses surrounding the perimeter of SRS contribute some domestically grown crops. Wild edible vegetation, including fungi, are collected to monitor potential consumer exposures. Typical domestic crops collected in 2013 include mustard, squash, tomatoes, and grapes. Wild food sources include pokeberry leaves, plums, and wild mustard. Edible fungi were added in 2010 to address exposure for the wild mushroom consumer due to the evidence for bioconcentration of cesium-137 (Cs-137) in some fungi and historical detections in SRS fungi (Botsch 1999, Du Pont 1984).

The SCDHEC detections in the study area are used to establish depositional pattern trends from the SRS boundary and SC background. The subtraction of background helps to separate atomic test fallout contamination levels from other source potential contamination. However, fallout dispersion patterns and concentrations are weather related and not uniform, and no assignment of specific source may be made.

All detections reported are above the lower limit of detection (LLD) for tritium in water from distilled vegetation or the minimum detectable activity (MDA) for gamma radionuclides. SCDHEC detected activities, above the method limits (LLD or MDA), occurred in all three edible vegetation categories (fungi; leafy greens/vegetables; fruits/nuts) as indicated in 2013 (Section 5.0, Table 2).

Tritium was detected above the MDA in perimeter samples of leafy greens, vegetables, fruits and nuts. Fungi samples, from both perimeter and background locations, had detections of tritium and cesium (Section 6.0, Tables 2-3). Of the samples submitted for total strontium, there was only one detection from a perimeter location.

All of the detected radionuclides except tritium, Cs-137, and Sr-89/90 originated from naturally occurring radioactive material (NORM). NORM radionuclides were the source of most public exposure. NORM was not discussed herein as radionuclides of concern unless greater than a South Carolina background.

2.0 RESULTS AND DISCUSSION

Section 5.0, Tables 1-3 show the radionuclides of concern, the guideline levels, the intervention levels and their conversion to picocuries per gram (pCi/g) for data comparison. The International Atomic Energy Agency (IAEA 2009) has established guideline levels for radionuclides in foods (alpha-, beta-, and gamma-emitters) for general consumption, emphasizing the cumulative radioactivity guideline limits (Section 5.0, Table 2).

The US Food and Drug Administration (USFDA 2005) also has guidance levels for specific radionuclides called derived intervention levels (DILs). The USFDA adopted DILs to help determine whether domestic food in interstate commerce or food offered for import into the United States presents a safety concern (Section 5.0, Table 3).

References to vegetation in this report refer to the edible parts of plants and fungi. The general county and area statistics comparing radionuclide concentrations are in Section 6.0. All of the detections described herein are well below the IAEA and USFDA guidelines for the specific radionuclide in food (Section 5.0, Tables 2 and 3). The actual data for this project can be found in Appendix A – ESOP Data.

2013 Tritium

Tritium is naturally present as a very small percentage of hydrogen in water, both liquid and vapor (ANL 2007). Historically, the main sources of tritium releases from the SRS operations were the reactor areas, the chemical separation facilities, and the tritium packaging areas. Tritiated water reacts chemically in living cells the same as nonradioactive water; however, it is more hazardous biologically than tritium gas (CDC SRSHES 1997). There were only seven (7) tritium detections out of 73 sample scans of edible vegetation and fungi collected by SCDHEC in 2013. Tritium was detected in six (6) perimeter samples bordering SRS, and there was one detection in fungi at the background location in Laurens County, SC.

Leafy green plants and other vegetables from perimeter locations had three detections of tritium from 12 samples, fungi from perimeter locations had two detection out of 39 samples, and fruits/ nuts samples had two detections out of 10 samples collected.

For 2013, Barnwell County had the highest frequency of detections (3 out of 14) across all categories. The highest Barnwell detection was from a greens/vegetable sample at 4.90 pCi/g (4900 pCi/L). The highest perimeter detection came from an Aiken greens/vegetable sample sample (12.4 pCi/g or 12,400 pCi/L). Areas not sampled to the southwest were in Georgia. The observed levels of tritium in edible vegetation were well below the IAEA Radionuclides Guidelines for Food based on a direct unit conversion (Section 5.0, Table 2; 270 pCi/g). This limit would equal {270 pCi/g x (1g/1ml) x (1000ml/L)} = 270,000 pCi/L, and all tritium detections were ≤12,400 pCi/L (Section 6.0, Table 1). Note that 1g/1ml is one gram per one milliliter, and ml/L is milliliter per liter, but the actual content of tritium in food would be relative to the percent moisture and the food wet weight.

2013 Gamma

The gamma-scan (27 radionuclides; Section 5.0, Table 1) detections found in naturally occurring radioisotopes (Be-7, K-40, Pb-214, Pb-212) are part of the South Carolina normal background exposure. Cesium-137 was the only non-NORM detected radionuclide. Only samples with radionuclide detection results are included in the data tables (Appendix A – ESOP Data). All other gamma scan results were less than the MDA.

Cesium-137

The only non-natural decay series gamma and beta radionuclide detections found in edible vegetation including fungi were Cs-137 (gamma) and total strontium. The natural decay series radionuclide concentrations may be related primarily to fertilizers and natural soils and regional geology. Some of the Cs-137 and radioactive strontium concentrations found in edible vegetation were probably related to nuclear test radioactive fallout due to the wide dispersion pattern and occurrence in both perimeter and background locations. Several nuclear test fallout depositions from past nuclear tests tracked across South Carolina and were deposited world-wide (Aracnet 1957). Only two half-lifes of Cs-137 and Sr-90 decay have passed since the earliest nuclear tests and these depositions may be detectable up to eight half-lifes (approximately 240 years) dependent on the technology and method used. Study area concentrations greater than background are not assignable to SRS releases alone due to the wide dispersion of nuclear test fallout.

Cesium-137 is an alkali metal that is chemically and metabolically similar to potassium. If ingested, it is distributed relatively uniformly throughout the whole body including bone marrow (Federal Radiation Council 1965). The largest source of Cs-137 in the environment was fallout from atmospheric nuclear weapons tests in the 1950's and 1960's that dispersed and deposited Cs-137 worldwide. The highest Cs-137 detection (16 pCi/L) in South Carolina rainfall since January 1979 (most nuclear testing ceased after 1980) occurred in Barnwell, May 15, 1985 (USEPA 2013). The many Cs-137 potential contributions to the environment may be passed down through linked critical exposure pathways. However, cesium is poorly absorbed by

vegetation from the soil. Cesium is relatively uniformly distributed throughout all portions of the plant and does not tend to bioconcentrate except in some grains and mushrooms. Grains tend to have relatively high concentrations, but fruits and root vegetables, having a higher water content, tend to have low concentrations of cesium (Kathren 1984). Some fungi appear to bioconcentrate cesium and contribute the highest Cs-137 radioactive exposure through wild mushrooms compared to other food types (Botsch 1999). The concentration of Cs-137 in surface soil from fallout ranges between 0.1 to 1 pCi/g and averages less than 0.4 pCi/g. Cesium is generally one of the less mobile radioactive metals in the environment. Cesium preferentially adheres quite well to the soil organic layer, and the concentration associated with sandy soil particles is estimated to be 280 times higher than in interstitial water. Concentration ratios are much higher in clay and loam soils (ANL 2007).

Total Strontium

Total strontium (Sr) contains many isotopes and the two most important are primarily beta emitters that contribute to dose exposure, i.e., Sr-89/90. Strontium-89 is short-lived (50.5 days) compared to Sr-90 (28.8 years half-life). Historical atomic test fallout depositions contained Sr-90 that is still detected. Strontium has four stable naturally occurring isotopes, but Sr-90 is a by-product of nuclear fission used primarily in nuclear auxiliary power devices (cheaper than Pu-238, but not as long-lived), and presents a health problem since strontium substitutes for calcium in bone. Alternately, Sr-89 and Sr-90 are used in the treatment of bone cancer and to increase bone density in women. Strontium is an abundant element and safe at low concentrations since it is used in toothpastes, treatments for osteoporosis, and fireworks. The IAEA guideline for total exposure to five radionuclides in food including Sr-90 is 2.7 pCi/g, and the USFDA DIL guideline is 4.32 pCi/g for Sr-90 alone in imported foods. One total strontium detection occurred in one wild leafy green (not normally consumed by the general public) (0.0819 pCi/g) in Allendale County. The total strontium detected levels in the assayed samples were all well below those guidelines (Section 5.0, Tables 2-3).

ESOP and DOE-SR Data Comparison

Comparisons are based on tables and data sections of this report, and the SRNS Environmental Report 2013 (SRNS 2014). Direct comparisons between SRNS and SCDHEC could not be made due to variation in sampling and analysis methodologies.

DOE-SR, as compared to SCDHEC, has five defined quadrants where samples are collected annually: four quadrants are within 10 miles of SRS in each direction (NE, NW, SE, SW) along with one quadrant located within 25 miles SE. In 2013, DOE-SR edible vegetation exhibited radiological detections of H-3, Cs-137, Sr-89/90, Uranium-234 (U-234), Uranium-235 (U-235), Uranium-238(U-238), Plutonium-238 (Pu-238), Plutonium-239 (Pu-239), Technicium (Tc-99), and Gross Beta. Tritium detections occurred in collards, wheat, and cabbage (SRNS 2014). DOE-SR detections (two of five samples) in collards averaged 0.034 (±0.003 pCi/g), with a median of 0.034 pCi/g, and a maximum of 0.036 pCi/g. The SCDHEC leafy green and vegetables averaged 7300 pCi/L (7.3 pCi/g (±4.42 pCi/g), with a median of 4.9 pCi/g and a maximum of 12.40 pCi/g. DOE-SR did not sample edible mushrooms. There were two SCDHEC fruit and nuts(all wild types) detections from 10 samples that averaged 330 pCi/L (0.330 pCi/g). Note: that leafy green plants and domestic crops generally have a small canopy

for absorption compared to larger tree canopy fruits, especially wild types. Also, wild type plants have a longer residence time (life cycle) for potential exposure than domestic crops.

The DOE-SR gamma and other beta-emitting radionuclide detections in edible vegetation were:

- Cs-137 was detected in three of five collards samples (0.075 pCi/g ±0.026 pCi/g) with the maximum being 0.093 pCi/g from the 25 mile SE location; three of five cabbage samples (0.075 pCi/g ±0.018 pCi/g) with a maxium of 0.091 pCi/g from the 25 mile SE location; and one wheat sample (0.008 pCi/g) from the 10 mile NE location;
- Sr-89/90 was detected in all five collards samples (0.356 pCi/g ±0.095 pCi/g) with a maximum of 0.508 pCi/g from the 25 mile SE location, one fruit sample (0.007 pCi/g), and one cabbage sample (0.357 pCi/g);
- U-234 was found in three collards samples (0.005 pCi/g ±0.005 pCi/g) with a maximum of .011 pCi/g within 10 miles(NE,NW,SE; four cabbage samples (0.017 pCi/g ±0.015 pCi/g) (three within 10 miles and one within 25 miles SE of SRS) with a maximum of 0.039 pCi/g within 10 miles (SW) of SRS; and one wheat sample within 25 miles SE (.002 pCi/g);
- U-235 was found in one cabbage sample (.002 pCi/g) within 10 miles (SW) of SRS;
- U-238 was found in collards samples (0.005 pCi/g ±0.003 pCi/g) from all locations with a maximum of 0.010 pCi/g from with 10 miles (NE) of SRS; three cabbage samples (0.016 pCi/g ±0.014 pCi/g) with a maximum of 0.037 pCi/g within 10 miles (NW,SE,SW), and one within 25 miles (SE) of SRS;
- Pu-238 was detected in a collards sample within 10 miles (SW) of SRS (.007pCi/g).
- Pu-239 was detected in a cabbage sample within 25 miles (SE) of SRS (.002pCi/g).
- Tc-99 was detected in all five collards samples (0.411 pCi/g ±0.163 pCi/g) with a maximum of 0.689 pCi/g from the 25 mile SE location; one fruit (melon) sample within 25 miles (SE) of SRS (0.037 pCi/g), and four cabbage samples (all locations except within 10 miles (NE) of SRS) (0.206 pCi/g ±0.035 pCi/g) with a maximum of 0.233 pCi/g from the 25 mile SE location.
- Gross Beta was detected in all five samples of collards, fruit (melons), and wheat. There were detections in all cabbage samples except for one taken 10 miles (NE) of SRS.

Note: In the preceding information, if there was more than one detect for the given radionuclide , an average was reported for all sample detections along with the standard deviation. If there was just one detection, only the detection was given for that sample.

The IAEA Radionuclides Guidelines for Food are 27 pCi/g total for Cs-137, Cs-134, S-35, Co-60, Sr-89, Ru-103, Ce-144, and Ir-192; 2.7 pCi/g total for Sr-90, Ru-106, I-129, I-131, and U-235; and 270 pCi/g for tritium (Section 5.0, Table 2). The USFDA Derived Intervention Levels (DILs) for food are 32.4 pCi/g total for Cs-134 plus Cs-137, and 4.32 pCi/g for Sr-90 (Section 5.0, Table 2). All DOE-SR and SCDHEC food sample radionuclide detections respective totals were less than these limits.

3.0 CONCLUSIONS AND RECOMMENDATIONS

Detected radionuclide concentrations found in edible vegetation sampled around SRS are well below the IAEA and USFDA standards for these emitters. Tritium continues to be the prevailing

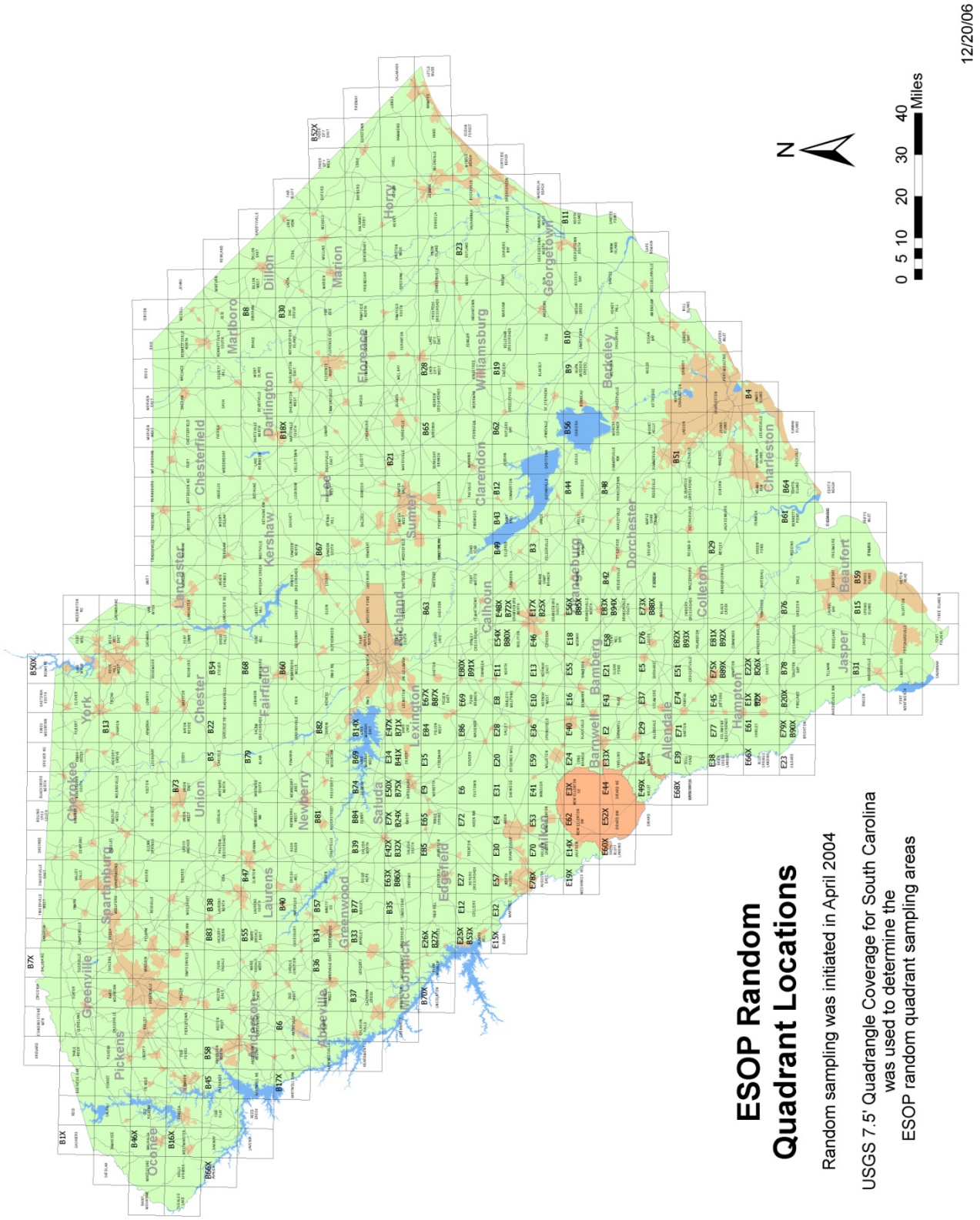
detectable analyte across all edible vegetation. However, Cs-137 dominates non-NORM gamma radionuclide exposure for the mushroom consumer.

The highest tritium sample (12400 pCi/L or 12.4 pCi/g) occurred in a greens sample which is below the IAEA Radionuclide food guideline of 270 pCi/g (Section 6.0, Summary Statistics). The highest Cs-137 occurred in a fungi sample (1.97 pCi/g) . The highest total strontium detection occurred in a wild leafy green (not usually consumed by the general public) sample (0.0819 pCi/g). The only domestic edible vegetation radionuclide detection was tritium in blueberries (446 pCi/L or .446 pCi/g).

SCDHEC and the DOE-SR have different edible vegetation sampling schemes. The DOE-SR samples primarily domestic plants and has annual participants in quadrants at 0-10 miles from the perimeter of the SRS and one quadrant at 25 miles. SCDHEC annual participants supply domestic plants, and the 2013 vegetation collections included perennial wild edible vegetation and fungi found usually within 10 miles of the SRS border. Backgrounds were generally along a 50-mile perimeter with one annual background participant in Laurens County.

In the future, SCDHEC will explore opportunities to split some samples with SRNS and establish colocated sampling locations for better comparisons between the two. SRNS might consider sampling some wild vegetation for better comparisons with SCDHEC.

4.0 Map


ESOP Random
Quadrant Locations
Random sampling was initiated in April 2004
USGS 7.5' Quadrangle Coverage for South Carolina
was used to determine the
ESOP random quadrant sampling areas
N
0 5 10 20 30 40 Miles
12/20/06

5.0 TABLES AND FIGURES

Table 1. Radiological Laboratory Suite

Radioisotope	Abbreviation
Actinium-228	Ac-228
Americium-241	Am-241
Antimony-125	Sb-125
Beryllium-7	Be-7
Carbon-14	C-14
Cerium-144	Ce-144
Cobalt-58	Co-58
Cobalt-60	Co-60
Cesium-134	Cs-134
Cesium-137	Cs-137
Europium-152	Eu-152
Europium-154	Eu-154
Europium-155	Eu-155
Iodine-129	I-129
Iodine-131	I-131
Lead-212	Pb-212
Lead-214	Pb-214
Manganese-54	Mn-54
Potassim-40	K-40
Radium-226	Ra-226
Ruthenium-103	Ru-103
Sodium-22	Na-22
Sulfur-35	S-35
Thorium-234	Th-234
Ytrium-88	Y-88
Zinc-65	Zn-65
Zirconium-95	Zr-95

Table 2. IAEA Radionuclide Guidelines for Food

Radionuclides in Foods		Guideline Levels	
Radionuclides	Units	kBq/kg	pCi/g
Pu-238, Pu-239, Pu-240, Am-241		1	0.27
Sr-90, Ru-106, I-129, I-131, U-235		100	2.7
S-35, Co-60, Sr-89, Ru-103, Cs-134, Cs-137, Ce-144, Ir-192		1000	27
H-3, C-14, Tc-99		10000	270

Table 3. USFDA Derived Intervention Levels for Radionuclides in Food.

USFDA Derived Intervention Levels (DILS) for Each Radionuclide Group for Food in Domestic Commerce and Food Offered for Import		Guideline Levels	
Radionuclide Group	Units	Bq/kg	pCi/g
Strontium-90		160	4.32
Iodine-131		170	4.59
Cesium-134 + Cesium-137		1200	32.4
Plutonium-238 + Plutonium-239 + Am-241		2	0.054
Ruthenium-103 + Ruthenium-106		$((C_3/6800) + (C_6/450)) < 1$	

Notes:
1 - For spices use a dilution factor of 10.
2 - C3 and C6 refer to concentrations of Ru-103 and Ru-106.

6.0 SUMMARY STATISTICS

Table 1. Tritium (pCi/L) Detections in Edible Vegetation (EV) by Counties/Areas, 2013

County Statistics						
	Avg	**SD**	**Median**	**Max**	**D#**	**N#**
All Perimeter Locations	3840	4710	600	12400	6	61
Aiken	6423	8453	6423	12400	2	26
Allendale				<MDA	0	17
Barnwell	1864	2633	487	4900	3	14
Hampton	NA	NA	NA	4600	1	2
Orangeburg	<MDA	<MDA	<MDA	<MDA	0	2
All Background Locations	<MDA	<MDA	<MDA	704	1	13
Laurens	<MDA	<MDA	<MDA	704	1	5
Lexington	NA	NA	NA	NA	0	2
Newberry	NA	NA	NA	NA	0	3
Saluda	NA	NA	NA	NA	0	1
McCormick	NA	NA	NA	NA	0	1
Greenwood	NA	NA	NA	NA	0	1

Table 2. Tritium (pCi/L) Detections in Edible Vegetation (EV) by Type, 2013

Vegetation Type						
	Avg	**SD**	**Median**	**Max**	**D#**	**N#**
All Perimeter Locations						
Fungi	<MDA	<MDA	<MDA	490	1	39
Greens/Vegetable	7300	4420	4900	12400	3	12
Fruits/Nuts	330	170	330	450	2	10
All Background Locations						
Fungi	<MDA	<MDA	<MDA	704	1	6
Greens/Vegetable	NA	NA	NA	NA	0	6
Fruits/Nuts	NA	NA	NA	NA	0	1

Notes:
1. The greatest amount of tritium across the Perimeter locations was found in a Pokeweed sample (Greens) in Aiken County.
2. Tritium was found in one background fungi sample located in Laurens County.
3. D# designates the number of detections.
4. N# designates the number of samples.

Table 3. Cesium 137 (pCi/g) in SRS Counties/Areas, 2013

County Statistics							
		Avg	**SD**	**Median**	**Max**	**D#**	**N#**
All Perimeter Locations		0.38	0.56	0.15	1.97	17	61
Aiken		1.11	0.84	1.16	1.97	4	27
Allendale		0.16	0.13	0.11	0.24	6	15
Barnwell		0.15	0.13	0.08	0.38	5	15
Hampton		0.17	NA	NA	NA	1	4
All Background Locations		0.021	0.001	0.021	0.022	2	13
Laurens		NA	NA	NA	NA	0	4
Lexington		0.021	0.001	0.021	0.022	2	2
Newberry		NA	NA	NA	NA	0	3
Saluda		NA	NA	NA	NA	0	1
McCormick		NA	NA	NA	NA	0	1
Greenwood		NA	NA	NA	NA	0	1
Bamberg		NA	NA	NA	NA	0	1

Notes:
1. All detects were in fungi samples. All edible green vegetables, fruits and nuts were <MDA.
2. D# designates the number of detections.
4. N# designates the number of samples.

LIST OF ACRONYMS

AKN	Aiken County
ALD	Allendale County
ANL	Argonne National Laboratory
AOC	Area of Concern or study area. Includes the IPC and OPC.
BMB	Bamberg County
BWL	Barnwell County
CAL	Calhoun County
CDC	Centers for Disease Control
D#	The number of detections for a particular radionuclide.
DIL	Derived Intervention Level
DOE	Department of Energy
DOE-SR	Department of Energy - Savannah River
EDF	Edgefield County
EQC	Environmental Quality Control
ESOP	Environmental Surveillance and Oversight Program
EV	Edible Vegetation
GA	Georgia
HMP	Hampton County
IAEA	International Atomic Energy Agency
IPC	Inner Perimeter of Counties around and adjacent to the DOE-SRS boundary.
LAU	Laurens County
LEX	Lexington County
LLD	Lower Limit of Detection
LLNL	Lawrence Livermore National Laboratory
MCM	McCormick County
MDA	Minimum Detectable Activity
NORM	Naturally Occurring Radioactive Material
OPC	The Outer Perimeter of Counties adjacent to and outside of the IPC and SRS
ORG	Orangeburg County
SAL	Saluda County
SC	South Carolina
SCDHEC	South Carolina Department of Health and Environmental Control
SD	Standard Deviation
SRS	Savannah River Site
SRNS	Savannah River Nuclear Solutions
SRSHES	Savannah River Site Health Effects Subcommittee
TEF	Tritium Extraction Facility
USDOE	United States Department of Energy
USEPA	United States Environmental Protection Agency
USFDA	United States Food and Drug Administration
USGS	United States Geological Survey
VEGP	Vogtle Electric Generating Plant
WSRC	Washington Savannah River Company (formerly Westinghouse Savannah River Company)

UNITS OF MEASURE

Activity or radioactivity is the number of atoms disintegrating per unit time (CDC 2009).

g/ml	grams per milliliter
ml/L	milliliter per liter
pCi/g	pico curies per gram
pCi/L	pico curies per liter
±	Plus or minus. Refers to one standard deviation unless otherwise stated.

REFERENCES

Aracnet. 1957. Off-Site Radioactive Fallout, Operation Plumbbob, Atomic Cloud Track Maps, 1957. Radioactive Fallout: Operation Plumbbob 1957, http://www.historicalgazette.net/atomi/fallout.htm

Argonne National Laboratory (ANL). 2007. Health-Based Radionuclide Concentrations in Drinking Water and Air. Human Health Fact Sheet. http://www.remm.nlm.gov/ANL_ContaminantFactSheets_All_070418.pdf .

Botsch. 1999. Investigation of the Radiation Exposure of Inhabitants of Contaminated Areas in Northern Ukraine. Center for Radiation Protection and Radioecology, University of Hanover, Germany and the State Agroecological Academie of Ukraine, Ukraine.

Centers of Disease Control (CDC) SRS Health Effects Subcommittee (SRSHES). 1997. Dose Reconstruction News. "Estimating the Atmospheric Tritium Source Term at SRS: A Progress Report", Vol II #3.

Du Pont, 1984. *United States Department of Energy, Savannah River Plant Environmental Report For 1984*, E. I. du Pont de Nemours and Company, Savannah River Plant, Aiken, South Carolina.

Federal Register. 1968. www.gpoaccess.gov/fr/.

Federal Radiation Council. 1965. Revised Fallout Estimates for 1964-1965 and Verification of the 1963 Prediction. http://www.epa.gov/radiation/docs/federal/frc_rpt6.

Hanlon, Edward A., 2004. Naturally Occurring Radionuclides in Agricultural Products, December 2004, University of Florida, Institute of Agricultural and Food Sciences (IAFS), Florida Cooperative Extension Service.

International Atomic Energy Agency (IAEA). https://www.iaea.org/publications/factsheets

Kathren, R.L. 1984. Radioactivity in the Environment: Sources, Distribution, and Surveillance. Harwood Academic Publishers, New York, New York.

Lawrence Livermore National Laboratory (LLNL). 1997. Site Annual Environmental Report, UCRL-50027-97, Oakland, California.

Linkov and W. R. Schell (eds.). 1999. Contaminated Forests: Recent Developments in Risk Identification and Future Perspectives, Kluewer, Amsterdam.

Moore-Landecker. 1972. Fundamentals of the Fungi. Prentice-Hall, Inc., Englewood Cliffs, N.J. ISBN:0-13-339267-8.

RADNET. 2006. Information about source points of anthropogenic radioactivity, A

Freedom of Nuclear Information Resource, http://www.davistownmuseum.org/cbm/, Chernobyl Plume: Country-by-Country.

Rommelt, R., Hiersche, L., Schaller, G., and Wirth, E. 1990. Influence of soil fungi (Basidiomycetes) on the migration of Cs134 + 137 and Sr90 in coniferous forest soil. In: Transfer of Radionuclides in Natural and Semi-Natural Environments (eds. G. Desmet, P. Nassimbeni and M. Belli), Elsevier Applied Science, London, New York.

Savannah River Nuclear Solutions, LLC (SRNS 2013). Savannah River Site Environmental Report for 2012. Savannah River Site Aiken, SC. **SRNS-STI-2013-00024.**

Seel, J. F., Whicker, F. W., and Adriano, D. C. 1995 Uptake of Cs-137 in Vegetable Crops Grown on a Contaminated Ladebed, 1995 Health Physics Society manuscript.

USDOI. 1992. United States Department of the Interior. 7.5 minute topographic map printed by the South Carolina Land Resources Commission, Rv 10/92.

US Environmental Protection Agency (USEPA). 2013. US EPA Information. www.epa.gov/radiation/radionuclides

US Food and Drug Administration (USFDA). 2005. http://www.fda.gov/downloads/NewsEvents/PublicHealthFocus/UCM251056.pdf

Westinghouse Savannah River Company 2006. Savannah River Site Environmental Report for 2005. Washington Savannah River Company, Savannah River Site, Aiken, SC. WSRC-TR-2006-00007.

Yoshida, S., and Muramatsu, Y., 1998. Concentrations of alkali and alkaline earth elements in mushrooms and plants collected in a Japanese pine forest, and their relationship with Cs137. J. Environ. Radioactivity 41, 183-205.

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2013 Radiological Monitoring of Dairy Milk

Environmental Surveillance and Oversight Program

97MK007

Kim Brinkley/ Scott Simons, Project Managers

January 01, 2013 - December 31, 2013

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South Carolina Department of Health and Environmental Control

Table of Contents

1.0 PROJECT SUMMARY

Operations at the Savannah River Site (SRS) have resulted in the potential for radiological constituents to be released to the surrounding environment. Milk from dairies around the SRS is routinely analyzed for levels of radioactivity that could impact human health. This project provides radiological monitoring of milk from selected dairies within a 50-mile radius of the SRS in South Carolina (SC). There are five SCDHEC locations, three of them are within a 50-mile perimeter of an SRS center point and two are background locations beyond the 50-mile perimeter. This project provides analytical data for trending and comparison to published Department of Energy-Savannah River (DOE-SR) data. The 50-mile radius also allows the South Carolina Department of Health and Environmental Control (SCDHEC) to use the data in this report to compare the potential dose from milk consumption to the potential dose calculated by DOE-SR.

Consumption of milk products containing radioactive materials can be a major human exposure pathway. When an atmospheric release occurs, radionuclides can be deposited on pastures and ingested by grazing dairy animals. The animals would then release a portion of the radioactivity into the milk that is consumed by humans (CDC 2001). Radionuclides could also enter the milk exposure pathway by irrigation of a pasture with groundwater containing radioactive materials or uptake by plants from soil containing radioactive materials. Radioactive strontium is a calcium analogue and may show a tendency to accumulate in bones and teeth (Kathren 1984).

Plants and animals assimilate different radioisotopes based on the chemistry and not on the radioactive nature of the components. Cesium-137 (Cs-137) is less readily taken up by plant roots than strontium-90 (Sr-90), but the opposite is true for direct absorption from foliar (leaf) deposits. Cesium-137 is transferred rapidly from pasture grass to the muscles of animals. Strontium-90 can bioconcentrate in bones when there is a deficiency of calcium in the diet of the individual. This pathway is of particular importance in the case of infants and children because they are more likely to drink large quantities of milk and they are actively developing bones and teeth (Kathren 1984). Iodine-131 (I-131) is rapidly transferred to milk and accumulates in the thyroid of humans. Cobalt-60 (Co-60) is unlikely to accumulate in the environment, but if consumed, depending on the individual's health, it can be absorbed in the blood and tissues before it is slowly eliminated (USEPA 2002a). Tritium (H-3) is a radioisotope of hydrogen that produces beta particles, and therefore, can impact anything containing water or hydrocarbons. Tritium exists naturally in the environment**,** and its volatility quickly achieves equilibrium in the environment and the body (Larson 1958).

During 2013, DOE-SR collected samples from nine dairy locations in SC and Georgia (GA) (Table 1). DOE-SR milk samples are collected quarterly within a 25-mile radius of SRS. SCDHEC's Environmental Surveillance and Oversight Program (ESOP) collected milk at five dairy locations within South Carolina to provide an independent source of data on radionuclide concentrations of concern in milk.

SCDHEC personnel collected unpasteurized milk samples on a quarterly basis in 2013. All milk samples from each quarter were analyzed for tritium, strontium-89/90 (Sr-89/90) and gamma-emitting radionuclides. While a select group of gamma-emitting radionuclides, specifically I-131, Cs-137, and Co-60 are analytes of concern in dairy milk for this project, all other detections

are considered naturally occurring radioactive material (NORM). NORM radionuclides were the source of most public exposure. NORM is not discussed herein as radionuclides of concern unless greater than a South Carolina background. SCDHEC analyzes samples for total strontium (Sr-89/90), instead of just Sr-90, due to preferred laboratory techniques. In order to provide a conservative result, it is assumed the total strontium detected is in the form of Sr-90.

DOE-SR detected tritium in one milk sample from a Georgia dairy out of 33 milk samples collected in 2013. Like SCDHEC, DOE-SR did not detect any gamma emitting radionuclides in 2013. DOE-SR had 6 detections of Sr-89/90 in 33 milk samples; three from SC dairies (SRNS 2014).

During 2013, concentrations of radionuclides of concern in milk deviated slightly from historically expected levels as measured by DOE-SR and SCDHEC. SCDHEC will continue to monitor milk for radionuclides that have the potential to impact human health.

2.0 RESULTS AND DISCUSSION

Tritium Results

Three SCDHEC milk samples collected during 2013 exhibited tritium activity above the Lower Limit of Detection (LLD) (Appendix A – ESOP Data). The average for all locations, both perimeter and background, was 251 pCi/L(±24) with a median of 237 pCi/L. Two of the 3 detections came from perimeter locations: Denmark, 278 pCi/L; and Govan, 237 pCi/L. The average detection for the perimeter locations was 258 pCi/L (±29) with a median of 237 pCi/L. The background detection came from a sample collected in Darlington with an average and median of 237 pCi/L. Figure 1 of Section 5.0 illustrates the average tritium detections for the last ten years. DOE-SR detected tritium in one of 33 milk samples for 2013. Summary statistics for tritium are not given due to the lack of numerical data. The tritium results for all milk samples collected by SCDHEC are given in Appendix A - ESOP Data. Past radionuclide contributions to milk may come from the SRS, other nuclear facilities, and legacy contamination from the cold war period (CDC 2001).

Gamma-Emitting Radionuclides Results

SCDHEC analyzed for I-131, Cs-137, and Co-60 in all milk samples collected in 2013. All analytical results for these radionuclides were below the sample Minimum Detectable Activity (MDA), and can be found in Appendix A – ESOP Data. These results are consistent with past gamma results. No summary statistics were calculated for these radionuclides due to a lack of numerical data. DOE-SR did not detect gamma emitting radionuclides in any of the 33 milk samples collected in 2013 (SRNS 2014).

Strontium-89/90 Results

Milk samples were collected quarterly in 2013 for Sr-89/90 analysis (Appendix A – ESOP Data). Eight out of 20 SCDHEC milk samples collected in 2013 exhibited strontium activities above the MDA, including detections in 3 background samples. The range for these detections was 0.343 pCi/L to 0.645 pCi/L. The minimum detection came from a background location in Darlington,

SC, and the maximum detection from Leesville, SC. The average for detections at all locations was 0.467 (± 0.107) pCi/L with a median of 0.467 pCi/L for the year (Section 6.0). Figure 2 (Section 5.0) shows the trend for SCDHEC strontium detections for the last ten years. All results below the MDA are left out of the summary statistics. All strontium averages have been below the USEPA established MCL of 8 pCi/L for Sr-90 since testing initiated in 1998 (USEPA 2002b). DOE-SR detected Sr-90 in six of 33 samples collected in 2013. Three of the six detections were in samples from SC dairies. The average activity for all detections was 1.104 (± 0.425) pCi/L. The highest detection (maximum) was 1.66 pCi/L from a Georgia dairy while the highest detection in South Carolina was 1.58 pCi/L (SRNS 2014).

Summary statistics for the perimeter and background locations are in Section 6.0.

3.0 CONCLUSIONS AND RECOMMENDATIONS

The DOE-SR uses all analytical results to compute averages, including results below the Minimum Detectable Concentration (MDC), which is based on the analysis method and comparable to SCDHEC's MDA and LLD. For a more conservative approach, SCDHEC uses only results above the MDA or LLD to compute averages. This does not affect the general data trend; however, numeric statistics may diverge significantly. Consequently, dairy milk analytical data comparisons between SCDHEC and DOE-SR were not conducted.

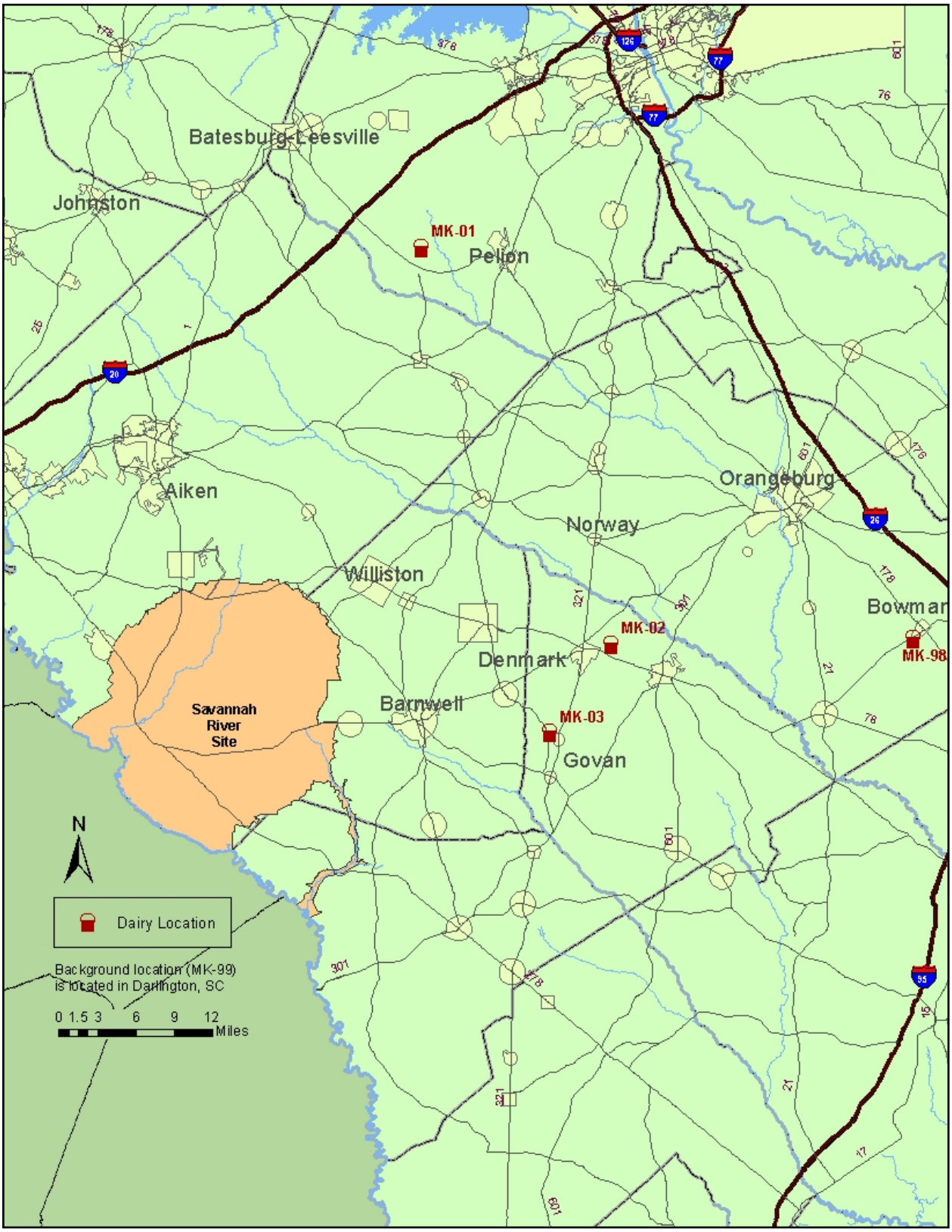
Tritium was detected in samples from 2013. As shown in Section 5.0 Figure 1, tritium has not been detected in any SCDHEC milk sample since 2008 when there was only one detection. Gamma results also continue a trend of non-detections since 2004, with the exception of the I-131 perturbation in 2011. Samples collected after the 2011 occurrence show that I-131 returned to the typically expected results and has not been detected since; however, SCDHEC will continue monitoring for any changes. The statistical analysis shows that Sr-89/90 concentrations in SRS perimeter samples were slightly more than the concentration in background samples.

A large portion of the radiological activity observed in milk samples can be attributed to fallout from past nuclear testing. Also, radionuclides within soil and plants can potentially be redistributed as a result of farming practices and prescribed burns. SCDHEC will continue to monitor tritium, gamma-emitting radionuclides, and strontium in milk to ensure the safety of milk consumption by the public.

The dairies in the ESOP South Carolina study area and background locations appear to be stable with no indication of closing in the foreseeable future. ESOP will continue to seek opportunities for sampling additional dairies for better coverage of the study area.

4.0 Map

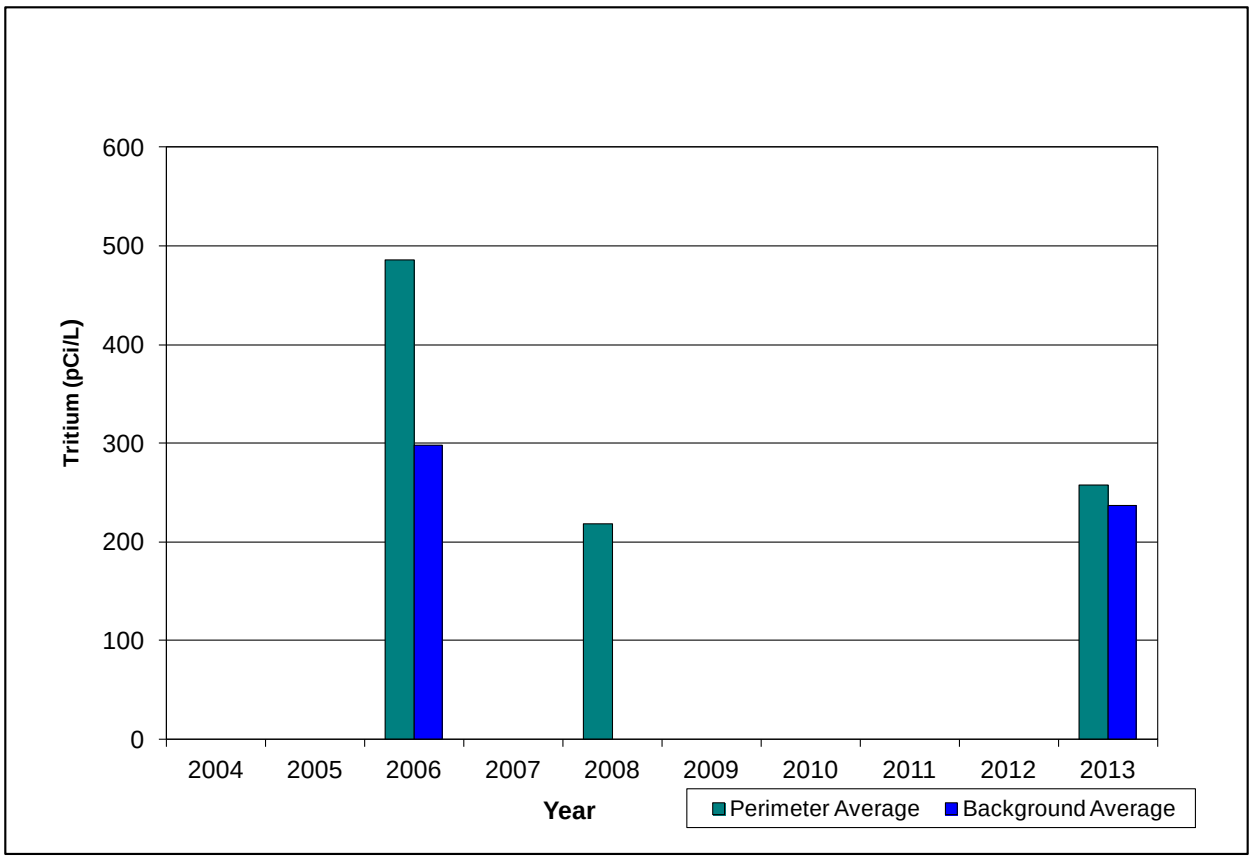
Map 1. 2013 SCDHEC Radiological Monitoring Locations for Dairy Milk



5.0 Tables and Figures

Radiological Monitoring of Dairy Milk

Figure 1. Average Tritium Detections in SCDHEC Milk, 2004-2013

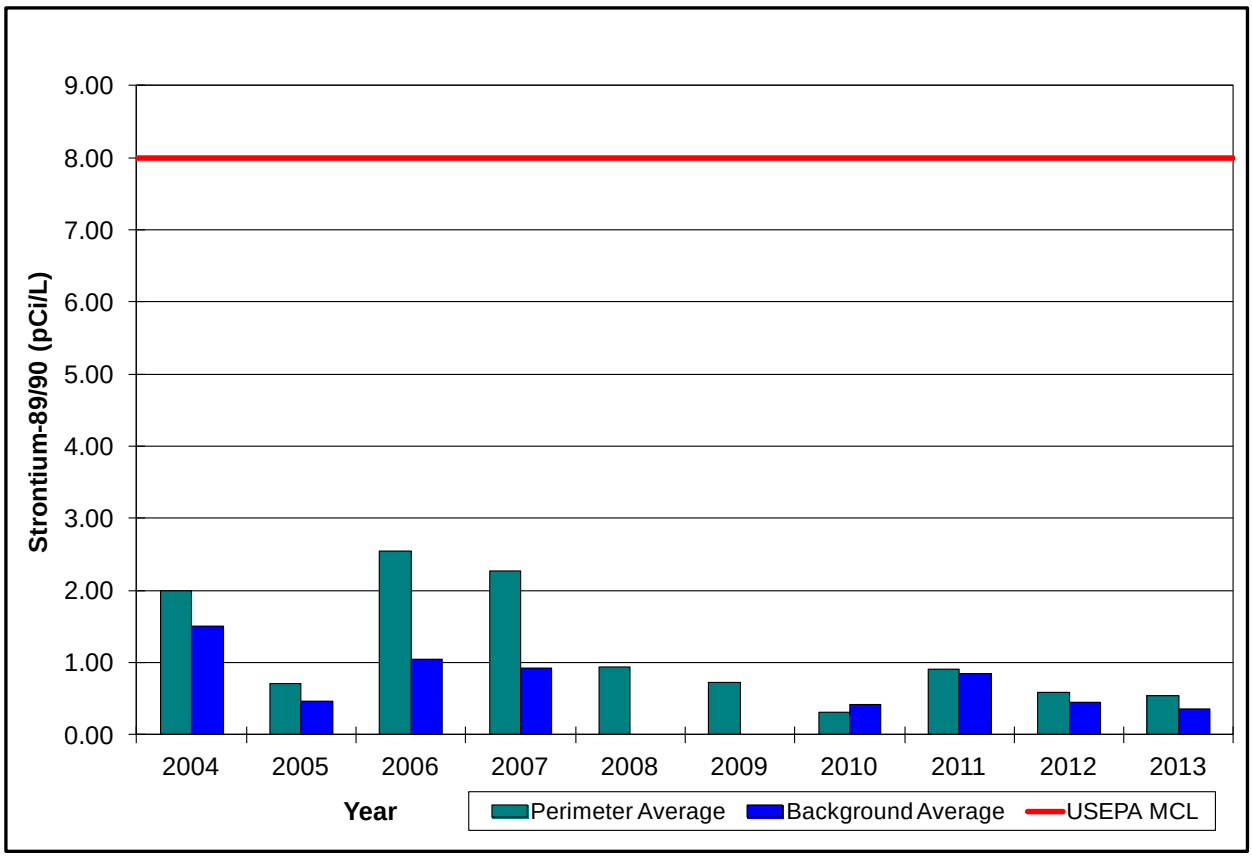


Notes:
1. Average detections are well below the USEPA MCL of 20,000 pCi/L for drinking water.
2. No detections above the LLD were observed in 2004, 2005, 2007, 2009, 2010, 2011 and 2012.
3. Some averages may be based on a single detection.
4. The number of dairies may vary from year to year due to the fluctuating number of dairies.

Tables and Figures

Radiological Monitoring of Dairy Milk

Figure 2. Strontium-89/90 Detection Averages, 2004-2013



Notes:
1. Average detections are below the USEPA MCL of 8.0 pCi/L for drinking water.
2. Background samples for 2008 and 2009 were <MDA.
3. Some averages may be based on a single detection.
4. The number of dairies may vary from year to year due to the fluctuating number of dairies.

6.0 Summary Statistics

Radiological Monitoring of Dairy Milk Data

Notes:
1. N - Number of detections used for statistical analysis
2. TN - Total Number of samples including non-detections
3. Avg - Average
4. St Dev - Standard Deviation
5. Min - Minimum
6. Max - Maximum
7. <MDA - All samples below the Minimum Detectable Activity
8. NA – Not Applicable

Radiological Monitoring of Dairy Milk Data

2013 Tritium Summary Statistics for all Milk Sample Detections

Radionuclide:		Tritium					
Statistical Analysis:		N (TN)	Avg	St Dev	Median	Min	Max
All Sample Locations	**MK-01**	0(4)	<LLD	NA	NA	<LLD	<LLD
	MK-02*	1(4)	278	NA	278	<LLD	278
	MK-03*	1(4)	237	NA	237	<LLD	237
	MK-98	0(4)	<LLD	NA	NA	<LLD	<LLD
	MK-99*	1(4)	237	NA	237	<LLD	237
Yearly Average			251				
Standard Deviation			24				
Median			237				

Radionuclide:		Tritium					
Statistical Analysis:		N (TN)	Avg	St Dev	Median	Min	Max
Perimeter System Number:	**MK-01**	0(4)	<LLD	NA	NA	<LLD	<LLD
	MK-02*	1(4)	278	NA	278	<LLD	278
	MK-03*	1(4)	237	NA	237	<LLD	237
Yearly Average of Tritium			258				
Standard Deviation			29				
Median			258				

Radionuclide:		Tritium					
Statistical Analysis:		N (TN)	Avg	St Dev	Median	Min	Max
Background System Number:	**MK-98**	0(4)	<LLD	NA	NA	<LLD	<LLD
	MK-99*	1(4)	237	NA	237	<LLD	237
Yearly Average of Tritium			237				
Standard Deviation			NA				
Median*			237				

2013 Tritium Summary Statistics Comparison of Perimeter and Background Locations

	Perimeter Locations (<50 Miles)			Background Locations (>50 Miles)			Perimeter minus Background
	Avg	St Dev	Median	Avg	St Dev	Median	Avg
Tritium	258	29	258	237	NA	237	21

Notes:
1. Units are in picocuries per liter (pCi/L)
2. * Based on a single detection

2013 Strontium Summary Statistics for all Milk Sample Detections

Radionuclide:		Total Strontium					
Statistical Analysis:		**N (TN)**	**Avg**	**St Dev**	**Median**	**Min**	**Max**
All Sample Locations	**MK-01***	1 (4)	0.645	NA	0.645	<MDA	0.645
	MK-02*	1(4)	0.440	NA	0.440	<MDA	0.440
	MK-03	3 (4)	0.525	NA	0.538	0.491	0.547
	MK-98*	1 (4)	0.374	NA	0.374	<MDA	0.374
	MK-99	2 (4)	0.350	NA	0.350	0.343	0.357
Yearly Average			0.467				
Standard Deviation			0.121				
Median			0.440				

Radionuclide:		Total Strontium					
Statistical Analysis:		**N (TN)**	**Avg**	**St Dev**	**Median**	**Min**	**Max**
Perimeter System Number:	**MK-01***	1 (4)	0.645	NA	0.645	<MDA	0.645
	MK-02*	1 (4)	0.440	NA	0.440	<MDA	0.440
	MK-03	3 (4)	0.525	NA	0.538	0.491	0.547
Yearly Average of Detectable Sr-89/90			0.537				
Standard Deviation			0.103				
Median			0.525				

Radionuclide:		Total Strontium					
Statistical Analysis:		**N (TN)**	**Avg**	**St Dev**	**Median**	**Min**	**Max**
Background System Number:	**MK-98***	1 (4)	0.374	NA	0.374	<MDA	0.374
	MK-99	2 (4)	0.350	NA	0.350	0.343	0.357
Yearly Average of Detectable Sr-89/90			0.362				
Standard Deviation			0.017				
Median			0.362				

2013 Strontium Summary Statistics Comparison of Perimeter and Background Locations

	Perimeter Locations (<50 Miles)			Background Locations (>50 Miles)			Perimeter minus Background
	Avg	**St Dev**	**Median**	**Avg**	**St Dev**	**Median**	**Average**
Sr-89/90	0.537	0.103	0.525	0.362	0.017	0.362	0.175

Notes:
1. Units are in picocuries per liter (pCi/L)
2. * Based on a single detection

LIST OF ACRONYMS

Cs-137	Cesium-137
Co-60	Cobalt-60
DOE-SR	Department of Energy – Savannah River
ESOP	Environmental Surveillance and Oversight Program
H-3	Tritium
I-131	Iodine-131
LLD	Lower Limit of Detection
MCL	Maximum Contaminant Level
MDA	Minimum Detectable Activity
MDC	Minimum Detectable Concentration
SC	South Carolina
SCDHEC	South Carolina Department of Health and Environmental Control
Sr-89/90	Strontium-89/90
Sr-90	Strontium-90
SRS	Savannah River Site
USEPA	United States Environmental Protection Agency

Units of Measure

pCi/L	picocuries per liter
±	plus or minus 2 standard deviations unless otherwise noted

REFERENCES

Centers for Disease Control and Prevention (CDC), 2001. Savannah River Site Environmental Dose Reconstruction Project. Phase II: Source Term Calculation and Ingestion Pathway Data Retrieval Evaluation of Materials Released from the Savannah River Site. 1-CDC-SRS-1999-Final. Risk Assessment Corporation, No. 200-95-0904.

Kathren, R.L., 1984. Radioactivity in the Environment: Sources, Distribution and Surveillance. Gordon and Breach Publishing Group, Newark, NJ. 271-275.

Larson, B.L. and K. E. Ebner, 1958. Significance of Strontium-90 in Milk. A Review. Journal of Diary Science. 41(12):1647-1662.

Savannah River Nuclear Solutions, LLC (SRNS), 2014. Savannah River Site Environmental Report for 2013. Savannah River Site, Aiken, SC. SRNS-STI-2014-00006.

United States Environmental Protection Agency (USEPA), 2002a. EPA Facts About Cobalt-60. http://www.epa.gov/superfund/health/contaminants/radiation/pdfs/cobalt.pdf.

USEPA, 2002b. EPA Facts About Strontium-90. http://www.epa.gov/superfund/health/contaminants/radiation/pdfs/strontium.pdf.

Westinghouse Savannah River Company (WSRC), 1998. Assessment of Radionuclides in the Savannah River Site Environment-Summary (U). WSRC-TR-98-00162. Westinghouse Savannah River Company, Savannah River Site.

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Section 4 2013 Biological Monitoring

2013 Fish Monitoring Associated with the Savannah River Site

Environmental Surveillance and Oversight Program

96FM001

Jeffrey Joyner, Project Manager

January 1, 2013 – December 31, 2013

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Table of Contents

1.0 PROJECT SUMMARY

The South Carolina Department of Health and Environmental Control (SCDHEC) Environmental Surveillance and Oversight Program (ESOP) conducts non-regulatory, independent monitoring and surveillance of fish to determine the magnitude, extent, and trend levels for radionuclides and selected metals.

Largemouth bass (*Micropterus salmoides)* and channel catfish (*Ictalurus punctatus*) were collected from nine sample stations on the Savannah River and a background station established on the Combahee River between Beaufort and Colleton counties. Studies have shown these species bioaccumulate measurable amounts of radionuclides (Cum *nebulosus*), were collected near Savannah, Georgia. Stations sampled in 2013 are shown in Map 1 Section 4.0, and station descriptions can be found in the Monitoring of Fish in the Savannah River Quality Assurance Project Plan, (SCDHEC 2011).

Fish were collected using boat-mounted electrofishing equipment. Samples were collected at five stations where creeks from the Savannah River Site (SRS) meet the Savannah River: Upper Three Runs Creek (SV-2011), Beaver Dam Creek (SV-2013), Fourmile Branch (SV-2015), Steel Creek (SV-2017), and Lower Three Runs Creek (SV-2020). Samples were also collected from the background station (SV-119), one Savannah River station upstream of SRS, New Savannah Bluff Lock and Dam (NSBLD SV-2028), and four stations downstream of SRS (Highway 301 SV-118, Stokes Bluff SV-355, Highway 17 fresh water SV-2090, and Highway 17 saltwater SV-2091). All of these stations are accessible to the public. Fish collections were conducted from March through November of 2013. Five Largemouth bass and channel catfish were collected from all Savannah River stations and the Combahee River background site. Five red drum and five sea trout were collected from the saltwater station. A portion of the edible fillets from each fish was analyzed for mercury and selected metals. The remainder of the fillets for each species was combined into homogeneous composites and analyzed for gamma-emitting isotopes and tritium. Non-edible composites consisting of spine, ribs, and tails were analyzed for strontium. Detailed procedures can be found in the Quality Assurance Project Plan (SCDHEC 2011).

Four stations did not produce samples with detectable tritium activity in 2013: the background station on the Combahee River, NSBLD, Highway 301, and Stokes Bluff. All other stations adjacent to and downstream of SRS exhibited detectable tritium activity. Six stations did not exhibit Cesium-137 (Cs-137) activity: Upper Three Runs, Beaver Dam Creek, Fourmile Branch, Highway 301, Stokes Bluff, and Highway 17 fresh water. Activities of strontium-89,90 (Sr-89,90) were reported from all stations.

The Department of Energy-Savannah River (DOE-SR) also conducts fish monitoring to assess the environmental effects of current and historical releases of radionuclides. SCDHEC data were compared to DOE-SR reported results. Although there are differences between reported values, the data is consistent with historically reported data. In the past, samples have been collected and split between SCDHEC and DOE-SR for analyses, and no great variations in the data results were found. This would potentially rule out methodology differences and substantiate that differences result from the variability in samples analyzed by the two programs.

2.0 RESULTS AND DISCUSSION

A total of 94 fish were collected. Forty-four composites were processed in 2013. The SCDHEC Midlands EQC Region-Aiken's tritium laboratory analyzed aliquots from all edible samples. Edible samples were sent to the SCDHEC Radiological Environmental Monitoring Division in Columbia, South Carolina for radiological analysis of gamma-emitting radionuclides. The non-edible bone portions samples were sent to Eberline Services for strontium analysis. Graphic presentations of 2013 and 2009-2013 activity levels of tritium, Cs-137, and Sr-89,90 are reported in Section 5.0. Summary statistics are presented in Section 6.0. All data results will be presented in Appendix - A ESOP Data. Tritium results represent the activity level in the water distilled from the fish tissue. Cesium and strontium results represent the activity level in the wet sample itself. A more in-depth understanding on how these radionuclides may impact human health can be found in the 2013 Critical Pathway Dose Report.

Tritium Results

Activity levels of tritium were analyzed in 22 edible composites. Six of the nine freshwater stations exhibited detectable tritium activity in 2013 (Section 5.0, Figure 1a). The saltwater sampling station (SV-2091) produced detections in the red drum sample. The Combahee River background station did not produce tritium activity. The Savannah River stations near the NSBLD (SV-2028), Highway 301 (SV-118), and Stokes Bluff (SV-355) had no detectable tritium activity.

Three of nine bass composites from the Savannah River exhibited detectable tritium activity, with an average of 465 (± 376) picocuries/liter (pCi/L). The composite from the Four Mile Branch station (SV-2015) had the highest reported tritium activity, 899 pCi/L. Five of the nine Savannah River channel catfish samples exhibited tritium activity, with an average of 546 (± 589) pCi/L. The highest tritium level observed in the catfish composites, 1598 pCi/L, was from Four Mile Branch.

The 2013 data are generally similar to SCDHEC historically reported data (Section 5.0, Figures 1b and 1c; SCDHEC 2011). Although results can be quite variable between years, tritium levels tend to be highest at stations adjacent to SRS (creek mouth stations) and decrease with distance downstream. Tritium has been detected upstream of SRS only occasionally, and at low levels.

Gamma Results

Activity levels of Cs-137 were analyzed in 22 edible portions of bass, catfish, red drum, and spotted seatrout composites. The Upper Three Runs, Beaver Dam Creek, Fourmile Branch, Hwy. 301, Stokes Bluff, and the Hwy. 17 fresh/saltwater stations did not exhibit Cs-137 activity in any sample.

Two of nine edible bass composites from the NSBLD and Lower Three Runs Savannah River stations exhibited detectable levels of Cs-137 ranging from 0.045 to 0.050 pCi/g with an average of 0.050 (± 0.004) pCi/g for Cs-137. (Section 5.0, Figure 2a).

Two of nine edible catfish composites from the Steel Creek and the Lower Three Runs Savannah River stations exhibited a detectable level of Cs-137. Ranging from 0.043 to 0.045 pCi/g, with an average of 0.044 (± 0.001) pCi/g (Section 5.0, Figure 2a).

Cs-137 was detected in the bass and catfish composites from the Combahee River background station. The bass composite had a detectable level of 0.062 (± 0.019) pCi/g and the catfish composite had a detectable level of 0.052 (± 0.017) pCi/g.

Strontium Results

The 22 non-edible bone composites were analyzed for Sr-89,90. All stations produced detectable strontium activity, including the background station (Section 5.0, Figure 3a). Sr-89,90 levels reported are for wet results, from analysis of whole fish composites. Averages noted below are for Savannah River freshwater species only, excluding the Combahee River station.

Levels of Sr-89,90 in bass ranged from 0.118 to 0.251 pCi/g with an average of 0.212 (± 0.04) pCi/g. Strontium levels in catfish samples ranged from 0.108 to 0.342 pCi/g with an average of 0.179 (± 0.09) pCi/g.

Section 5.0, Figures 3b and 3c show historically reported SCDHEC data for Sr-89,90 (SCDHEC 2011). The data from 2009-2013 represents calculated wet results using a dry/wet conversion ratio from the actual dry analyses. The 2009 and 2010 data were reported as wet results by the contract laboratory that year.

Mercury and Metals Analyses

In 2013, a total of 22 composites were analyzed. The metals (antimony, arsenic, cadmium, and manganese) were selected for concerns from consumption and analysis for direct comparison to DOE-SR data. Samples were also analyzed for chromium, copper, lead, nickel, and zinc. Although small amounts of mercury were released to the SRS environment from site operations, the majority of mercury contamination is a result of atmospheric fallout from coal-burning power plants. (USEPA 2010). Mercury was detected in fish (primarily bass) from all stations. Composites from the background station on the Combahee River exhibited detectable mercury only in bass. Mercury was detected in bass composite samples from seven of the nine Savannah River stations, ranging from 0.13 to 0.75 milligrams per kilogram (mg/kg), with an average of 0.37 (± 0.23) mg/kg (Section 5.0, Figure 4). Mercury was only detected from one catfish composite (0.13 mg/kg) from the Highway 17 fresh water station (Section 5.0, Figure 4). The following metals were not detected in any samples in 2013: arsenic, antimony, cadmium, chromium, and lead. Manganese was detected in 8 composites. Nickel was detected in 4 composites. Copper and Zinc was detected in all 22 composites analyzed.

SCDHEC and DOE-SR Data Comparison

SCDHEC bass and catfish data collected for this project in 2013 were compared to DOE-SR reported data (SRNS 2014). Data comparison summaries are located in Section 6.0. One difference between the two programs is that ESOP analyzes one composite from each species for each station, whereas the DOE-SR program analyzes three composites per station. Therefore, a single composite for an ESOP station was compared to the average of the three DOE-SR composites reported. Differences in averages of DOE-SR and ESOP data could be attributed to the fact that DOE-SR uses results below the MDC when calculating averages while ESOP only uses detects.

ESOP largemouth bass samples from three stations and DOE-SR bass samples from six stations exhibited tritium activity. ESOP detected tritium in catfish samples from five stations, DOE-SR from six. ESOP largemouth bass samples from two stations and DOE-SR bass samples from six stations exhibited Cs-137 activity. Cesium-137 results for edible bass and catfish from ESOP and DOE-SR were less than 1.00 pCi/g. Strontium-89, 90 was detected at all stations sampled by both programs, although all values were less than 1.50 pCi/g. (SRNS 2014).

Mercury was the only metal detected by both programs. Although sample sizes from each program were different average mercury concentrations for both organizations were essentially the same for catfish and largemouth bass samples.

3.0 CONCLUSIONS AND RECOMMENDATIONS

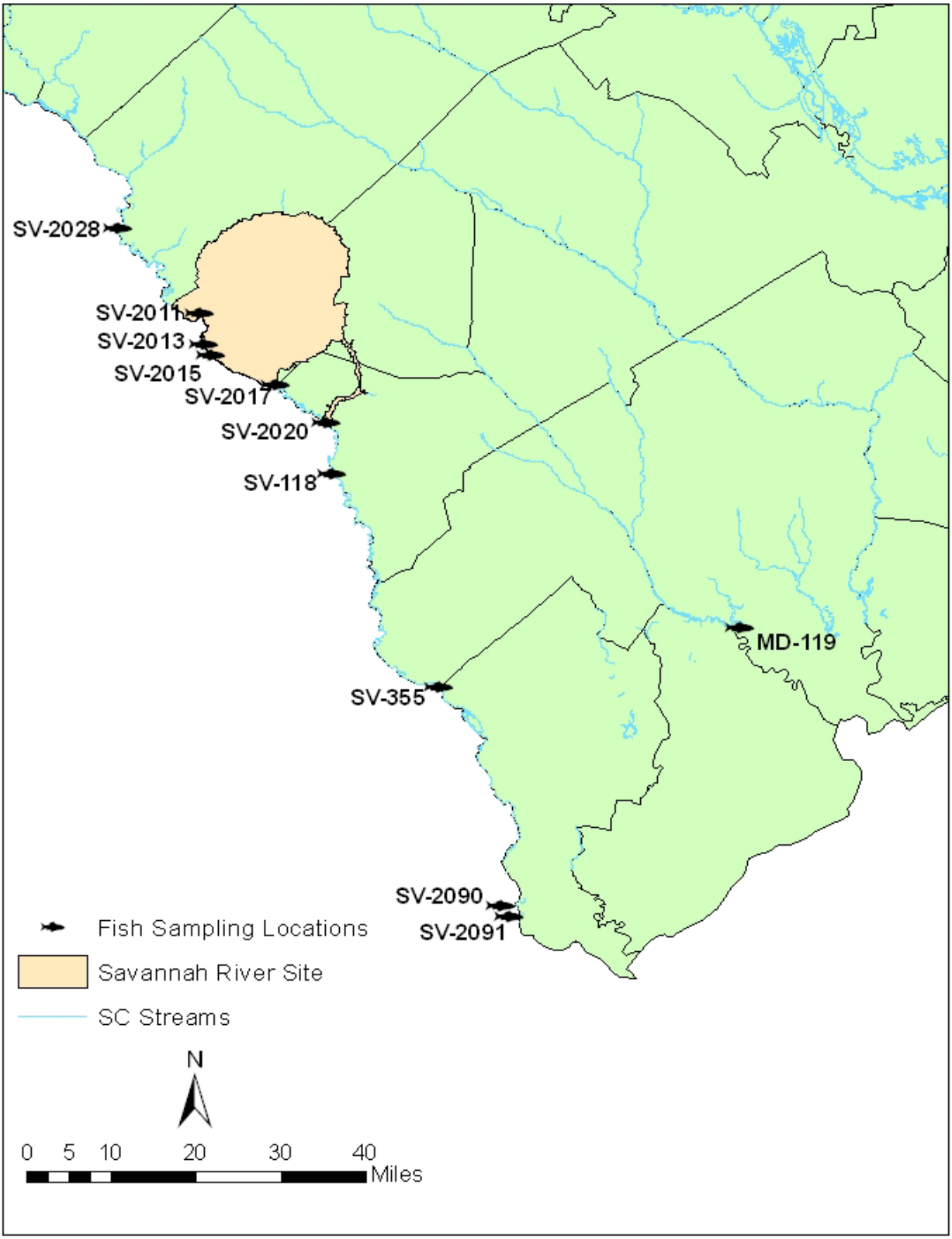
A review of SCDHEC data indicates that DOE-SR operations have impacted fish. Higher levels of radionuclides are found in Savannah River fish collected adjacent to and downstream of SRS compared to upstream.

Independent monitoring of radionuclide levels in Savannah River fish will continue along with evaluating the DOE-SR Radiological Fish Monitoring Program. Continued monitoring will provide a better understanding of actual radionuclide, their extent, and trends. This data will allow SCDHEC to better advise, inform, and protect those people at risk. Although Cs-137 and Sr-89,90 are found in some Savannah River fish, the levels are low and have decreased over time. If the public follows the SCDHEC mercury advisories for consumption of fish from the river, the health risk from these radioactive elements is very low (SCDHEC 2010). Data comparison will also be part of the further evaluation of the DOE-SR program. This independent evaluation will provide credibility and confidence in the DOE-SR data and its uses.

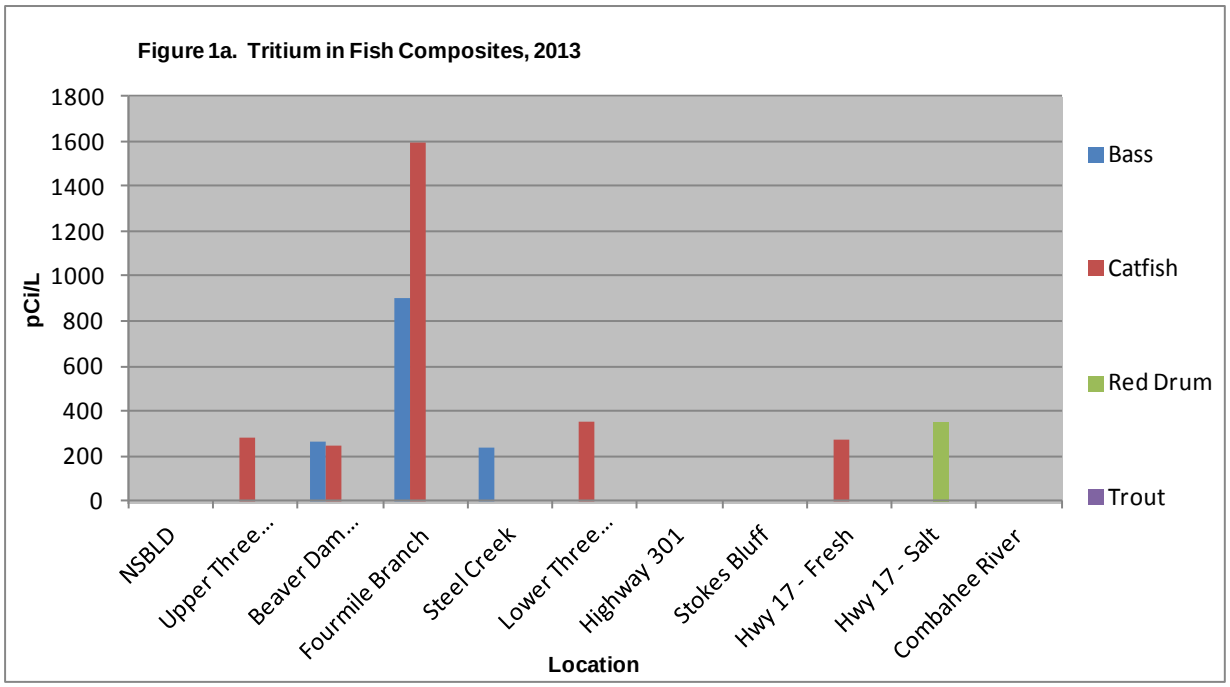
Future analyses of the target species will continue to include mercury and selected metals. This will augment the existing data on Savannah River fish, provide information for human health assessment, and provide another basis for comparison of results with DOE-SR data.

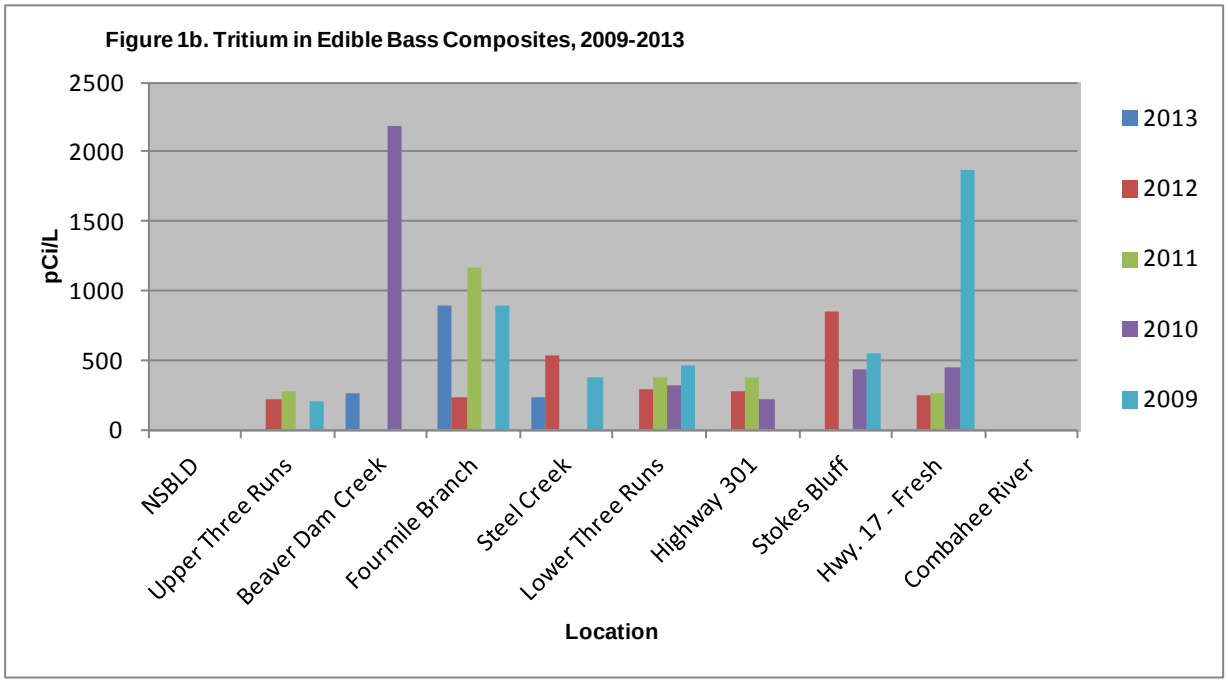
4.0 Fish Monitoring Associated with the Savannah River Site

Map 1. ESOP Fish Sampling Stations, 2013

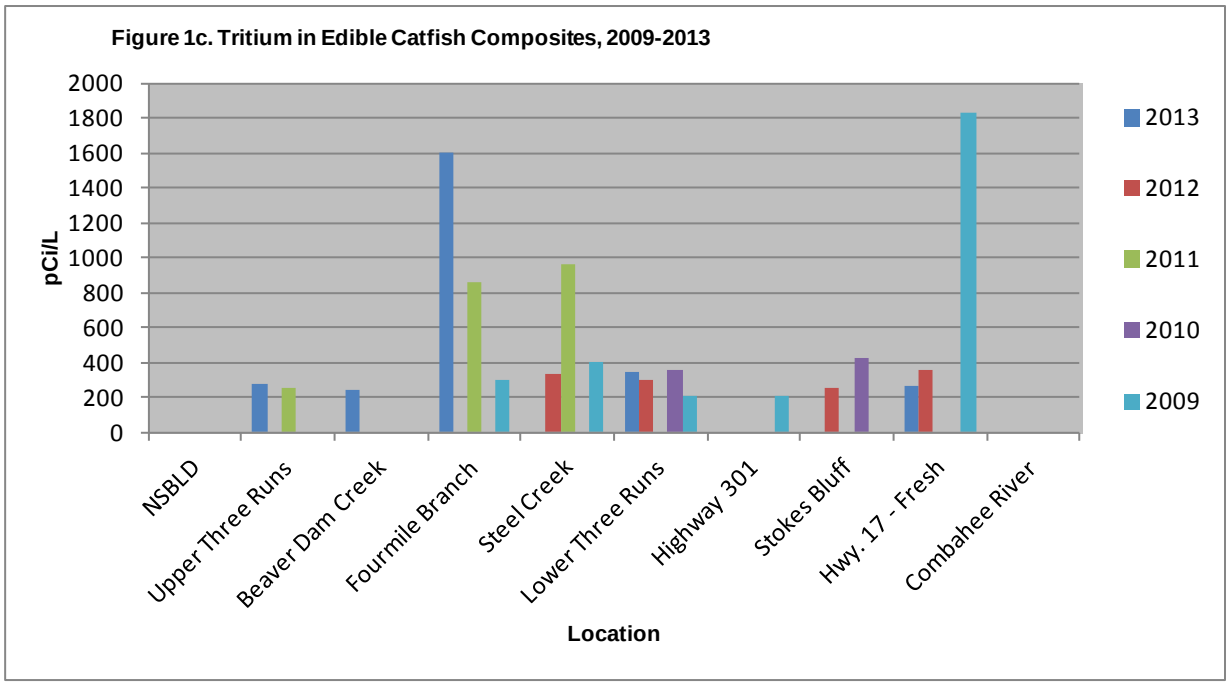


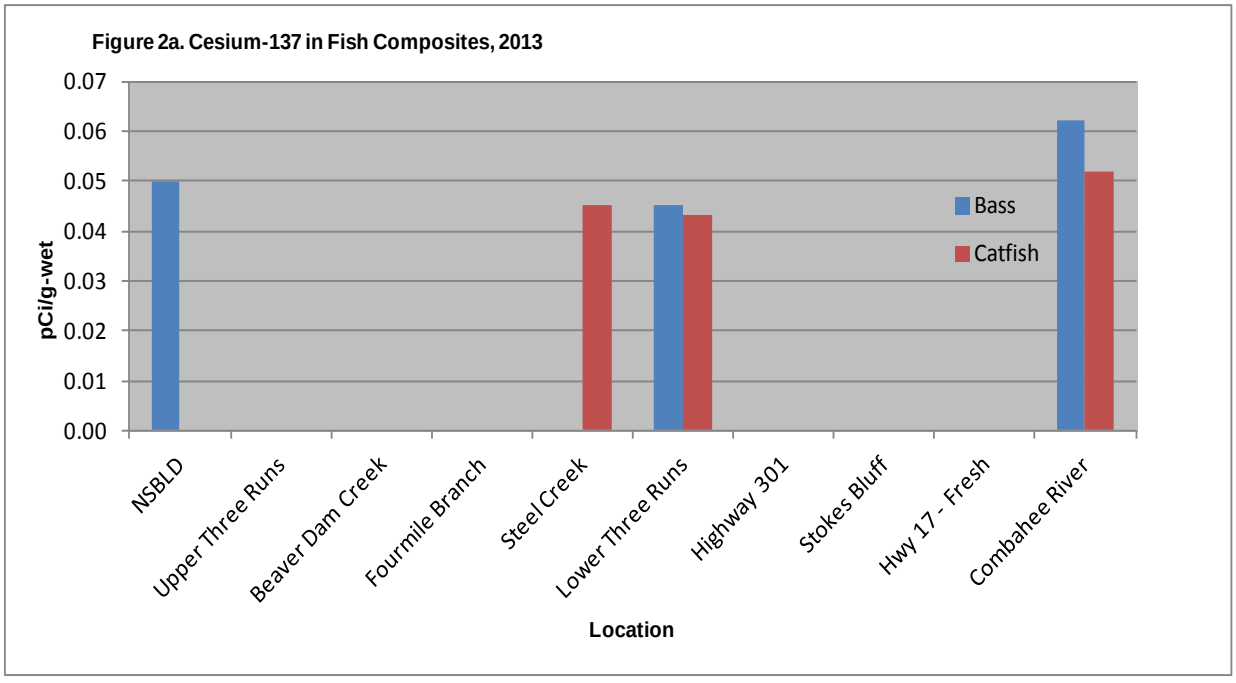
5.0 Tables and Figures
Fish Monitoring Associated with the Savannah River Site



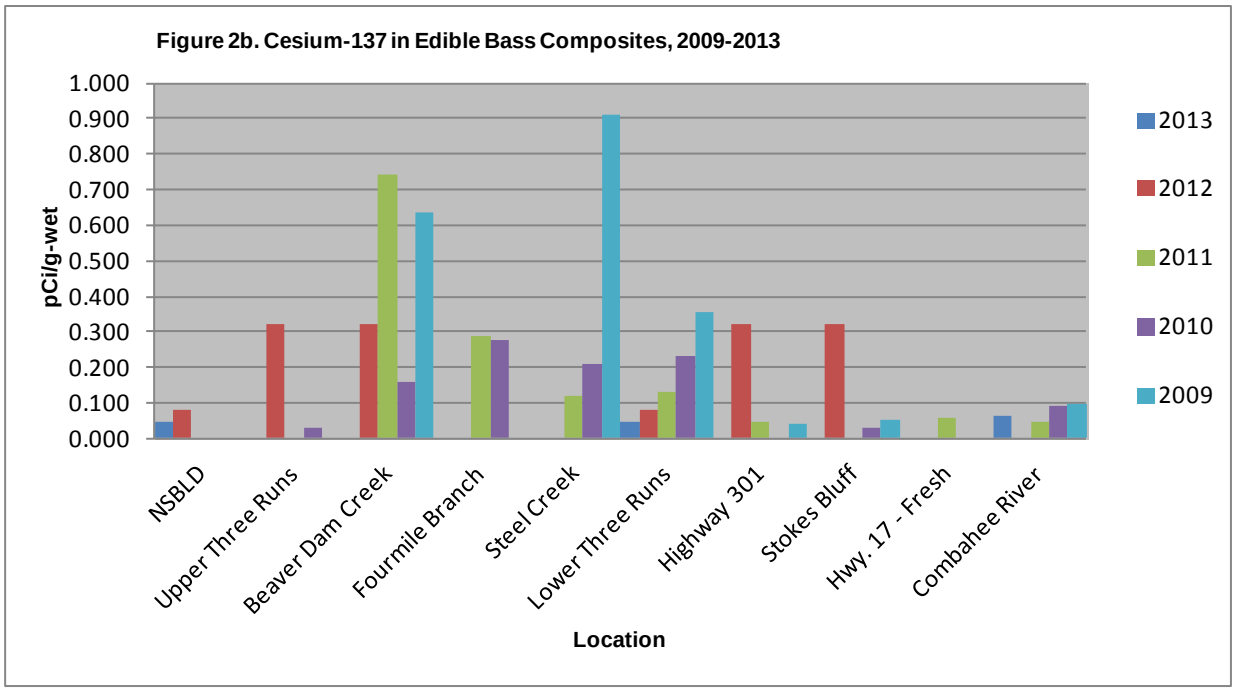


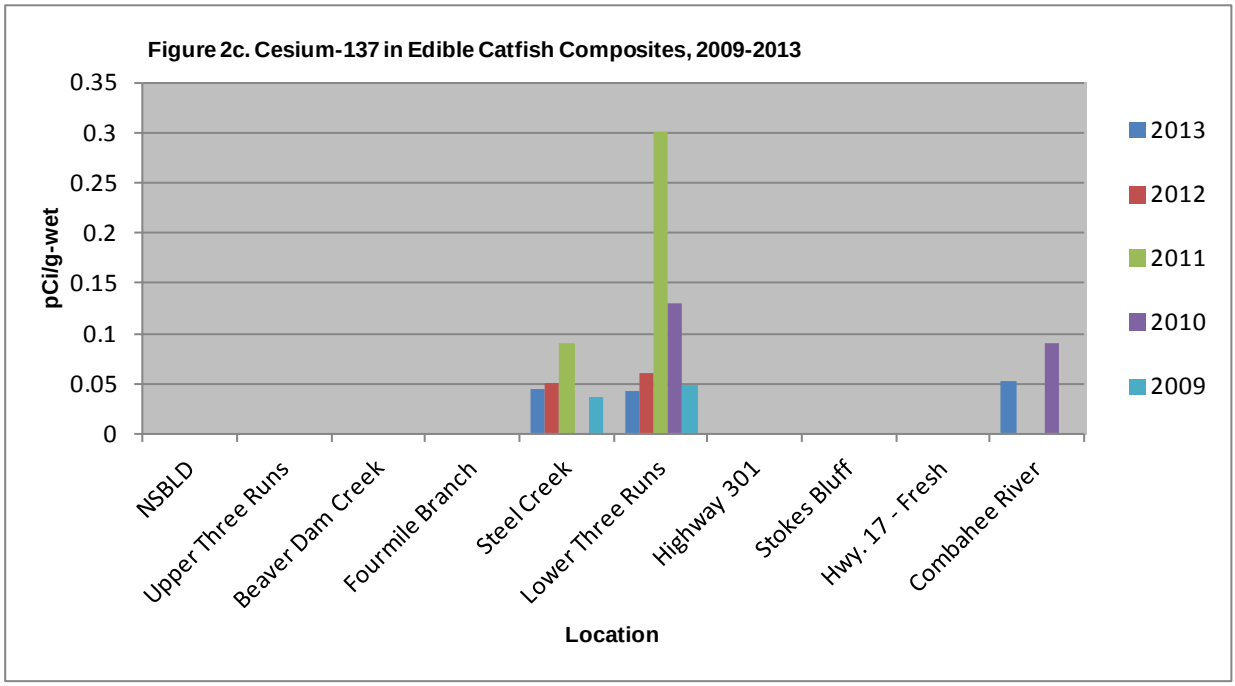
Tables and Figures
Fish Monitoring Associated with the Savannah River Site





Tables and Figures
Fish Monitoring Associated with the Savannah River Site





Tables and Figures
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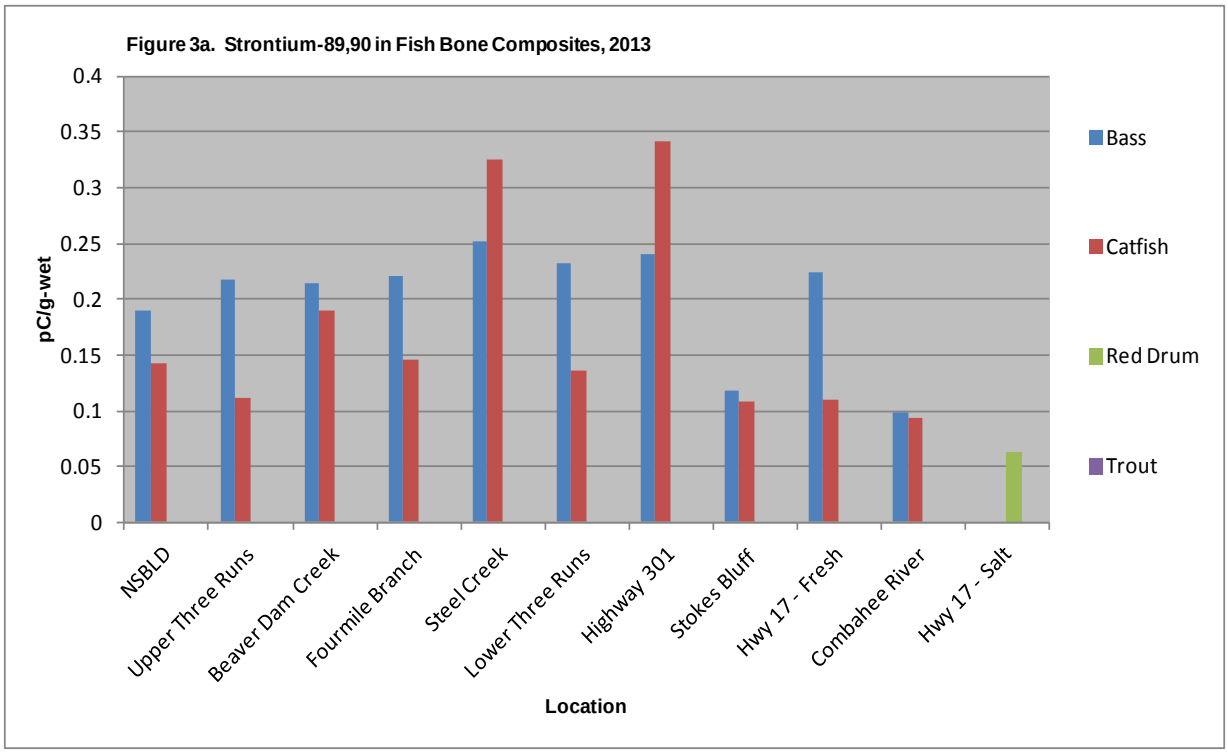
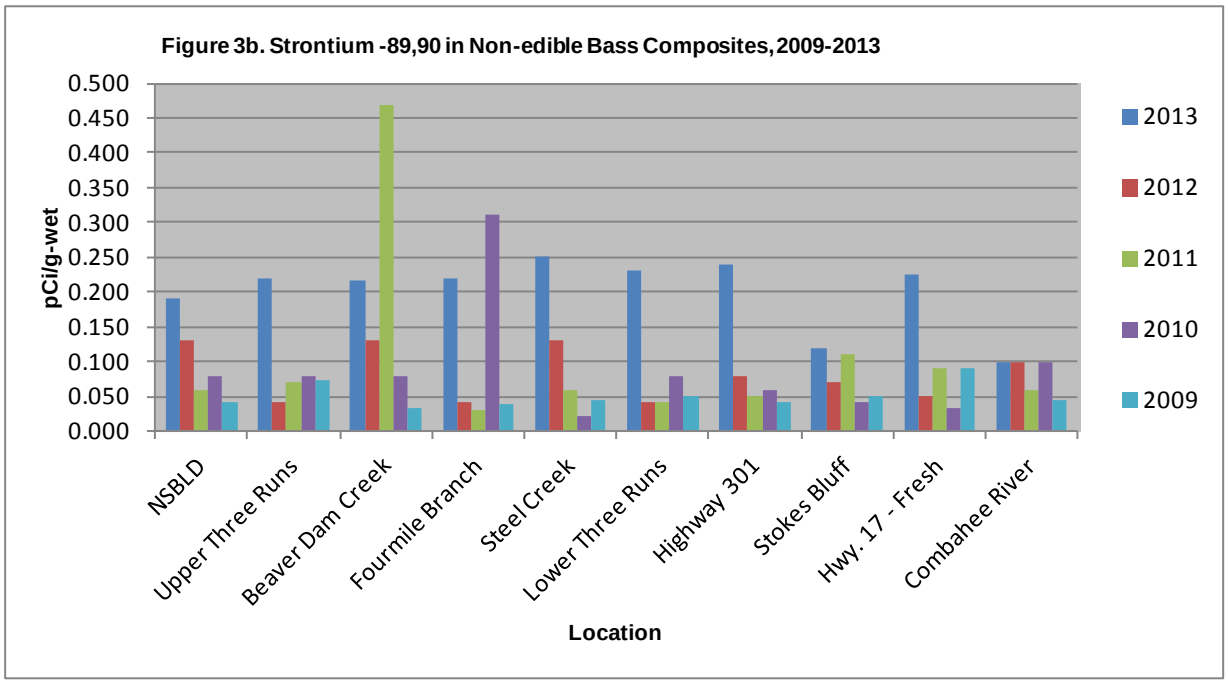
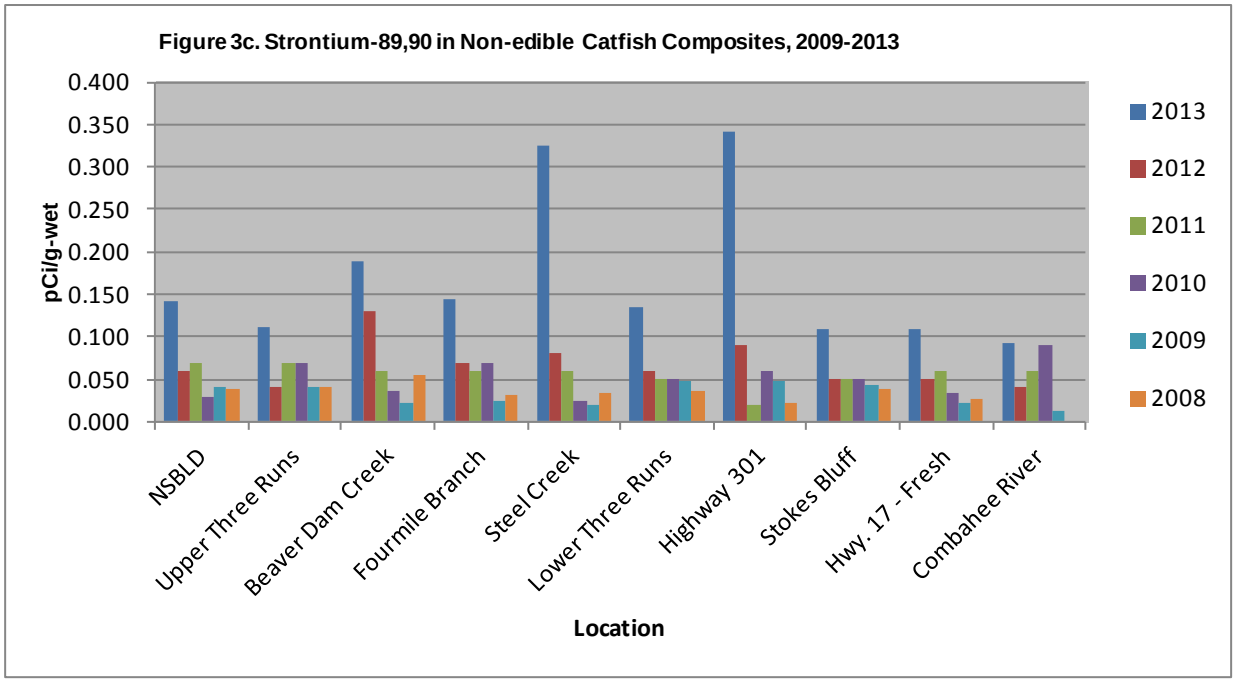
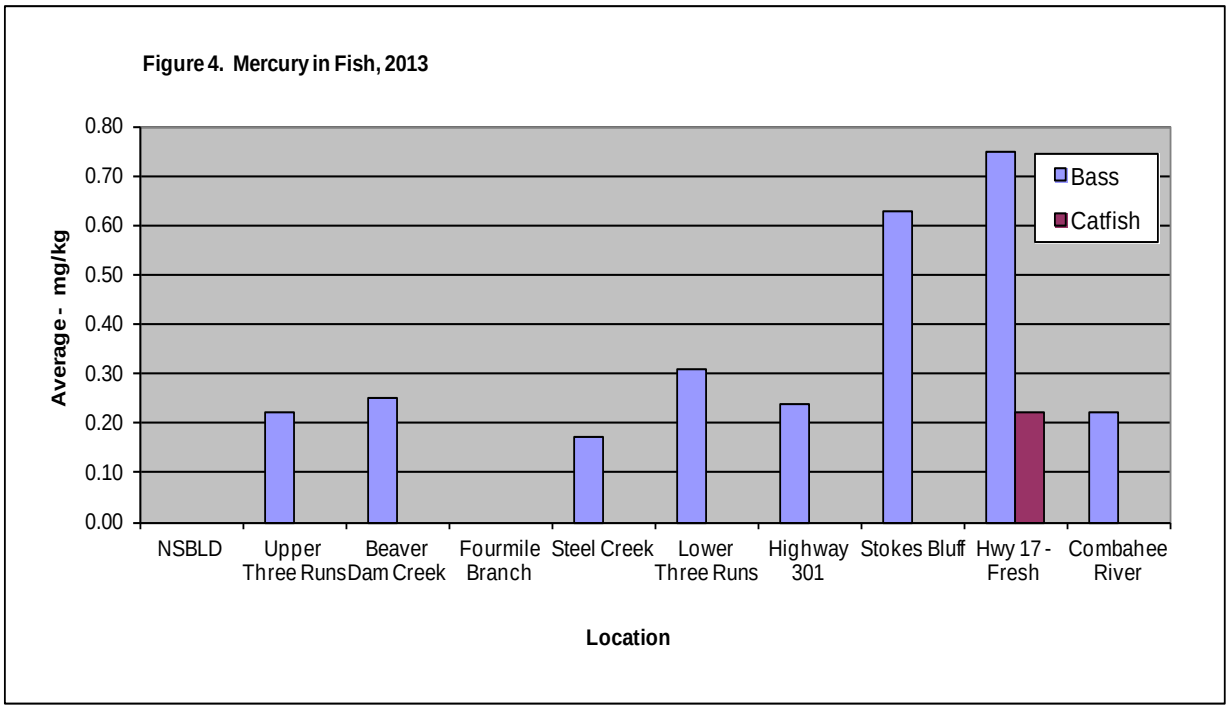




Tables and Figures
Fish Monitoring Associated with the Savannah River Site





6.0 SCDHEC and DOE-SR Data Comparison with Summary Statistics

Notes:

LLD - Lower Limit of Detection
NA – Not Applicable
MDA - Minimum Detectable Activity
Hwy. 301 - Savannah River at U.S. Highway 301
Hwy. 17 - Savannah River at U.S. Highway 17
N - denotes number of samples with detections
ND – denotes non-detections
Tritium results (pCi/L) represent the activity level in water distilled from the fish tissue.
Cs-137 results (pCi/g) represent the activity level in natural fish tissue.
Strontium results (pCi/g) represent the activity level in an aliquot of fish bone.

Fish Monitoring Data
2013 SCDHEC and DOE-SR Data Comparison

Table 1
Tritium Activity Levels in Edible Bass

Location	Agency	# of samples	Result
NSBLD	ESOP	1	<LLD
	DOE-SR	3	0.07
Upper Three Runs	ESOP	1	<LLD
	DOE-SR	3	<MDC
Beaver Dam Creek	ESOP	1	258
	DOE-SR	3	<MDC
Fourmile Branch	ESOP	1	899
	DOE-SR	3	0.63
Steel Creek	ESOP	1	239
	DOE-SR	3	0.12
Lower Three Runs	ESOP	1	AE
	DOE-SR	3	0.12
Hwy. 301	ESOP	1	<LLD
	DOE-SR	3	0.08
Stokes Bluff	ESOP	1	<LLD
	DOE-SR		NS
Hwy. 17	ESOP	1	AE
	DOE-SR	3	0.05
Average[2]	ESOP	3	465
	DOE-SR	5	0.18
Standard Deviation[2]	ESOP	3	376
	DOE-SR	5	0.22

Table 2
Tritium Activity Levels in Edible Catfish

Location	Agency	# of samples	Result
NSBLD	ESOP	1	<LLD
	DOE-SR	3	0.04
Upper Three Runs	ESOP	1	277
	DOE-SR	3	<MDC
Beaver Dam Creek	ESOP	1	242
	DOE-SR	3	0.05
Fourmile Branch	ESOP	1	1598
	DOE-SR	3	0.05
Steel Creek	ESOP	1	AE
	DOE-SR	3	0.17
Lower Three Runs	ESOP	1	347
	DOE-SR	3	0.04
Hwy. 301	ESOP	1	<LLD
	DOE-SR	3	0.14
Stokes Bluff	ESOP	1	<LLD
	DOE-SR		NS
Hwy. 17	ESOP	1	268
	DOE-SR	3	<MDC
Average[2]	ESOP	5	546
	DOE-SR	6	0.09
Standard Deviation[2]	ESOP	4	589
	DOE-SR	5	0.06

Notes:
ESOP Data is reported in pCi/L
DOE-SR Data is reprted in pCi/G
DOE-SR data from SRNS 2014
DOE-SR results are averages
[2]Calculated using detections only
AE - Analitical error
NS - Not sampled

Fish Monitoring Data
2013 SCDHEC and DOE-SR Data Comparison

Table 3
Cesium-137 Activity Levels in Edible Bass
pCi/g

Location	Agency	# of samples	Result
NSBLD	ESOP	1	0.050
	DOE-SR	3	<MDC
Upper Three Runs	ESOP	1	<MDA
	DOE-SR	3	0.04
Beaver Dam Creek	ESOP	1	<MDA
	DOE-SR	3	<MDC
Fourmile Branch	ESOP	1	<MDA
	DOE-SR	3	0.06
Steel Creek	ESOP	1	<MDA
	DOE-SR	3	0.17
Lower Three Runs	ESOP	1	0.045
	DOE-SR	3	0.09
Hwy. 301	ESOP	1	<MDA
	DOE-SR	3	0.03
Stokes Bluff	ESOP	1	<MDA
	DOE-SR		NS
Hwy. 17	ESOP	1	<MDA
	DOE-SR	3	0.03
Average[2]	ESOP	2	0.05
	DOE-SR	5	0.07
Standard Deviation[2]	ESOP	2	0.003
	DOE-SR	5	0.05

Table 4
Cesium-137 Activity Levels in Edible Catfish
pCi/g

Location	Agency	# of samples	Result
NSBLD	ESOP	1	<MDA
	DOE-SR	3	<MDA
Upper Three Runs	ESOP	1	<MDA
	DOE-SR	3	0.03
Beaver Dam Creek	ESOP	1	<MDA
	DOE-SR	3	0.06
Fourmile Branch	ESOP	1	<MDA
	DOE-SR	3	<MDA
Steel Creek	ESOP	1	0.05
	DOE-SR	3	<MDA
Lower Three Runs	ESOP	1	0.04
	DOE-SR	3	0.06
Hwy. 301	ESOP	1	<MDA
	DOE-SR	3	0.02
Stokes Bluff	ESOP	1	<MDA
	DOE-SR		NS
Hwy. 17	ESOP	1	<MDA
	DOE-SR	3	<MDA
Average[2]	ESOP	2	0.04
	DOE-SR	4	0.04
Standard Deviation[2]	ESOP	2	0.001
	DOE-SR	4	0.02

Notes: DOE-SR data from SRNS 2014
DOE-SR results are averages
[2]Calculated using detections only
NS - Not sampled

Fish Monitoring
2013 SCDHEC and DOE-SR Data Comparison

Table 5
Strontium-89,90 Activity Levels in Non-edible Bass
pCi/g

Location	Agency	# of samples	Result
NSBLD	ESOP	1	0.19
	DOE-SR	3	1.13
Upper Three Runs	ESOP	1	0.22
	DOE-SR	3	1.23
Beaver Dam Creek	ESOP	1	0.22
	DOE-SR	3	0.87
Fourmile Branch	ESOP	1	0.22
	DOE-SR	3	0.61
Steel Creek	ESOP	1	0.25
	DOE-SR	3	0.61
Lower Three Runs	ESOP	1	0.23
	DOE-SR	3	0.70
Hwy. 301	ESOP	1	0.24
	DOE-SR	3	0.66
Stokes Bluff	ESOP	1	0.12
	DOE-SR		NS
Hwy. 17	ESOP	1	0.22
	DOE-SR	3	0.59
Average[2]	ESOP	9	0.21
	DOE-SR	8	0.80
Standard Deviation[2]	ESOP	9	0.04
	DOE-SR	8	0.25

Table 6
Strontium-89,90 Activity Levels in Non-edible Catfish
pCi/g

Location	Agency	# of samples	Result
NSBLD	ESOP	1	0.14
	DOE-SR	3	0.62
Upper Three Runs	ESOP	1	0.11
	DOE-SR	3	0.99
Beaver Dam Creek	ESOP	1	0.19
	DOE-SR	3	1.10
Fourmile Branch	ESOP	1	0.15
	DOE-SR	3	0.94
Steel Creek	ESOP	1	0.33
	DOE-SR	3	0.80
Lower Three Runs	ESOP	1	0.14
	DOE-SR	3	0.72
Hwy. 301	ESOP	1	0.34
	DOE-SR	3	0.64
Stokes Bluff	ESOP	1	0.11
	DOE-SR		NS
Hwy. 17	ESOP	1	0.11
	DOE-SR	3	0.44
Average[2]	ESOP	9	0.18
	DOE-SR	8	0.78
Standard Deviation[2]	ESOP	9	0.09
	DOE-SR	8	0.22

Notes: DOE-SR data from SRNS 2014
DOE-SR results are averages
[2]Calculated using detections only
NS - Not Sampled

Fish Monitoring Data
2013 SCDHEC and DOE-SR Data Comparison

Table 7
Mercury Levels in Edible Bass
mg/kg

Location	Agency	# of samples	Result
NSBLD	ESOP	1	<PQL
	DOE-SR	1	0.27
Upper Three Runs	ESOP	1	0.22
	DOE-SR	1	NS
Beaver Dam Creek	ESOP	1	0.25
	DOE-SR	1	NS
Fourmile Branch	ESOP	1	<PQL
	DOE-SR	1	0.44
Steel Creek	ESOP	1	0.16
	DOE-SR	1	NS
Lower Three Runs	ESOP	1	0.31
	DOE-SR	1	0.23
Hwy. 301	ESOP	1	0.24
	DOE-SR	1	0.47
Stokes Bluff	ESOP	1	0.63
	DOE-SR		NS
Hwy. 17	ESOP	1	0.75
	DOE-SR	1	NS
Average[2]	ESOP	7	0.37
	DOE-SR	4	0.35
Standard Deviation[2]	ESOP	7	0.23
	DOE-SR	4	0.12

Table 8
Mercury Levels in Edible Catfish
mg/kg

Location	Agency	# of samples	Result
NSBLD	ESOP	1	<PQL
	DOE-SR	1	0.13
Upper Three Runs	ESOP	1	<PQL
	DOE-SR	1	0.13
Beaver Dam Creek	ESOP	1	<PQL
	DOE-SR	1	NS
Fourmile Branch	ESOP	1	<PQL
	DOE-SR	1	0.13
Steel Creek	ESOP	1	<PQL
	DOE-SR	1	NS
Lower Three Runs	ESOP	1	<PQL
	DOE-SR	1	0.21
Hwy. 301	ESOP	1	<PQL
	DOE-SR	1	0.14
Stokes Bluff	ESOP	1	0.13
	DOE-SR		NS
Hwy. 17	ESOP	1	0.22
	DOE-SR	1	NS
Average[2]	ESOP	2	0.18
	DOE-SR	5	0.15
Standard Deviation[2]	ESOP	2	0.06
	DOE-SR	5	0.03

Notes: DOE-SR data from SRNS 2014
[2]Calculated using detections only
PQL - Practical Quantitation Limit
mg/kg - milligrams per kilogram
DOE-SR results converted from ug/g (microgram per gram)
NS - Not sampled

2013 Fish Monitoring Summary Statistics

Tritium Levels (pCi/L) in Savannah River Fish, 2013

Edible	N (ND)	Average	Standard Deviation	Median	Maximum	Minimum
Bass	3 (6)	465	375	258	899	239
Catfish	4 (5)	546	589	277	1598	242

Non-detections (ND) excluded from computations
Tritium reported as activity in the water extracted from tissue

Cesium-137 Levels (pCi/g - Wet) in Savannah River Fish, 2013

Edible	N (ND)	Average	Standard Deviation	Median	Maximum	Minimum
Bass	2 (7)	0.05	0.004	0.05	0.050	0.045
Catfish	2 (7)	0.04	0.001	0.04	0.045	0.043

Non-detections (ND) excluded from computations

Strontium-89,90 Levels (pCi/g - Wet) in Savannah River Fish, 2013

Non-edible	N (ND)	Average	Standard Deviation	Median	Maximum	Minimum
Bass	9 (0)	0.21	0.04	0.22	0.25	0.12
Catfish	9 (0)	0.18	0.09	0.14	0.34	0.10

Mercury Levels (mg/kg) in Savannah River Fish, 2013

Edible	N (ND)	Average	Standard Deviation	Median	Maximum	Minimum
Bass	7 (2)	0.37	0.23	0.25	0.16	0.75
Catfish	2 (7)	0.18	0.06	0.18	0.22	0.13

Non-detections (ND) excluded from computations

List of Acronyms

DOE-SR	Department of Energy-Savannah River
ESOP	Environmental Surveillance and Oversight Program
Hwy. 17	United States Highway 17
LLD	Lower Limit of Detection
MDA	Minimum Detectable Activity
MDC	Minimum Detectable Concentration
NSBLD	New Savannah Bluff Lock & Dam
SCDHEC	South Carolina Department of Health and Environmental Control
SRS	Savannah River Site
Hwy. 301	United States Highway 301
USEPA	United States Environmental Protection Agency

Units of Measure

mg/kg	milligrams/kilogram
pCi/g	picocuries/gram
pCi/L	picocuries/liter
±	plus or minus (one standard deviation unless stated otherwise)

REFERENCES

Cummins, C.L. 1994. Radiological Bioconcentration Factors for Aquatic, Terrestrial, and Wetland Ecosystems at the Savannah River Site (U). Prepared for the United States Department of Energy, Savannah River Site. Aiken, South Carolina.

Savannah River Nuclear Solutions, LLC (SRNS). 2014. Savannah River Site Environmental Report for 2013. Savannah River Site Aiken, SC. SRNS-STI-2014-00006.

South Carolina Department of Health and Environmental Control (SCDHEC). 2010. 2010 South Carolina Fish Consumption Advisories. Division of Health Hazard Evaluation. Columbia, South Carolina.

SCDHEC. 2011. Monitoring of Fish in the Savannah River Quality Assurance Project Plan, Bureau of Environmental Services, Environmental Surveillance and Oversight Program, Aiken, South Carolina.

United States Environmental Protection Agency (USEPA). 2000. Guidance for Assessing Chemical Contaminant Data for use in Fish Advisories, Vol. 1.

USEPA. 2010. US EPA Information. www.epa.gov/mercury/.

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2013 Game Animal Radiological Monitoring Adjacent to SRS

Environmental Surveillance and Oversight Program

98GA001
Jeffrey Joyner, Project Manager
January 01, 2013 - December 31, 2013

Midlands EQC Region - Aiken
206 Beaufort Street N.E.
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D H E C
PROMOTE PROTECT PROSPER
South Carolina Department of Health and Environmental Control

Table of Contents

1.0 PROJECT SUMMARY

The South Carolina Department of Health and Environmental Control (SCDHEC) Environmental Surveillance and Oversight Program (ESOP) conducts independent non-regulatory oversight of game animal monitoring activities within a five-mile study area around the Savannah River Site (SRS). The game animal project addresses concerns of potentially contaminated white-tailed deer and feral hogs migrating off the SRS, and can provide valuable information concerning the potential off-site exposure to cesium-137 (Cs-137) by analyzing samples collected off-site. White-tailed deer and feral hogs have shown the highest potential of the mammalian species for a human exposure pathway from Cs-137 (Haselow 1991). SCDHEC analyzed muscle tissue collected in 2013 for Cs-137 from 25 deer and four hogs collected from area hunters via hunting clubs, plantations, and Crackerneck Wildlife Management Area within a five-mile study area adjacent to the SRS (Section 4.0, Map 1). Additionally, 10 deer tissue samples were collected and analyzed from a background location 85 miles southeast of the SRS in Beaufort County, South Carolina. Sample size, location, and collection dates were dependent on the participating hunters.

The Department of Energy-Savannah River (DOE-SR) has annual hunts open to members of the general public to control the site's deer and feral hog population and to reduce animal/vehicle accidents. Before any animal is released to a hunter, SRS personnel monitor Cs-137 levels for exposure limit considerations to ensure established administrative dose limits are not exceeded. During the 2013 annual on-site hunts, DOE-SR split twenty three samples with ESOP for a analytical data comparison.

DOE-SR does not collect game animal samples within the SCDHEC study area, and off-site hunter doses are based on DOE-SR models. Therefore, no direct comparisons could be made between SCDHEC and DOE-SR data. The SCDHEC Critical Pathway Dose report addresses dose based on collected samples and is compared to DOE-SR modeled dose for off-site hunters.

White-tailed deer and feral hogs have access to a number of contaminated areas on and off the SRS and are a vector for the redistribution of contaminants (primarily Cs-137) to off-site locations. A five-mile study area was established based on a typical white-tailed deer upper limit home range to ensure that potentialy contaminated deer residing at or near the SRS boundry would be included in the sample set. Consumption of these wildlife species can result in the transfer of contaminants to humans. Cesium-137 is of concern because of the 30 year half-life, its availability to game animals, and associated health risk to humans (Haselow 1991).

Cesium-137 is readily incorporated into the human body because of its similarity to potassium-40 (K-40) in physiological processes (Davis 1963). Cesium-137 concentrates in animal skeletal muscles that are selectively consumed by hunters (Brisbin et al. 1975). Cesium-137 emits both beta and gamma radiation, contributing to both internal and external radiation exposure, which may be associated with gastrointestinal, genetic, hematopoietic, and central nervous system damage (Bond et al. 1965). Because of these concerns, Cs-137 will be the focus isotope of this report.

2.0 RESULTS AND DISCUSSION

Cesium-137

Cesium-137 and the naturally occurring isotopes K-40 and lead-214 (Pb-214) were the only isotopes detected in game samples collected in 2013. Naturally occurring isotopes will not be discussed in this report. Cesium-137 concentrations from deer collected in the SRS perimeter study area are shown in (Section 5.0, Figure 1). Analytical results are listed in Appendix A – ESOP Data.

Cesium-137 activities from the 25 SCDHEC perimeter deer samples ranged from < Minimum Detectible Activity (MDA) to 2.53 picocuries per gram (pCi/g), with an average of 0.58 (± 0.70) pCi/g (Section 6.0). Cesium-137 activities from the four SCDHEC perimeter hog samples ranged from 0.76 to 1.31 pCi/g with an average of 1.04 (± 0.23) pCi/g (Section 6.0). All SCDHEC hunt zone averages were within one standard deviation of the overall perimeter average. Results from the 10 background samples ranged from 0.11 pCi/g to 0.81 pCi/g, with an average of 0.26 (± 0.21) pCi/g.

SCDHEC and DOE-SR Cesium-137 Data Comparison

DOE-SR reported an approximate field measurement range of 1.00 pCi/g to 3.09 pCi/g with a field gross average of 1.12 pCi/g from 156 deer and and a range of 1.00 pCi/g to 5.19 pCi/g with an field gross average of 1.32 pCi/g from 62 feral hogs harvested on the SRS in 2013 (SRNS 2014). Average perimeter, background, and DOE-SR on-site Cs-137 levels for the past five years (Section 6.0) are indicated in Section 5.0, Figure 2. The five-year Cs-137 averages between SCDHEC and DOE-SR may differ for various reasons. The DOE-SR data is acquired in the field by using a portable sodium iodide detector while SCDHEC data are analytical results. Also, the SCDHEC data presents a challenge for direct comparisons to DOE-SR data because the perimeter area is heavily baited. Therefore, the uptake of Cs-137 by these animals will be reduced based on the increased K-40 levels in the corn from fertilizers (Heckman 1992).

During the 2013 annual on-site hunts, DOE-SR split twenty-three samples with ESOP for an analytical data comparison. Cesium-137 activities ranged from 0.14 pCi/g to 2.22 pCi/g with an average of 1.21 pCi/g for DOE-SR data. Cesium-137 activities ranged from 0.12 pCi/g to 2.19 pCi/g with an average of 1.25 pCi/g for ESOP data.

3.0 CONCLUSIONS AND RECOMMENDATIONS

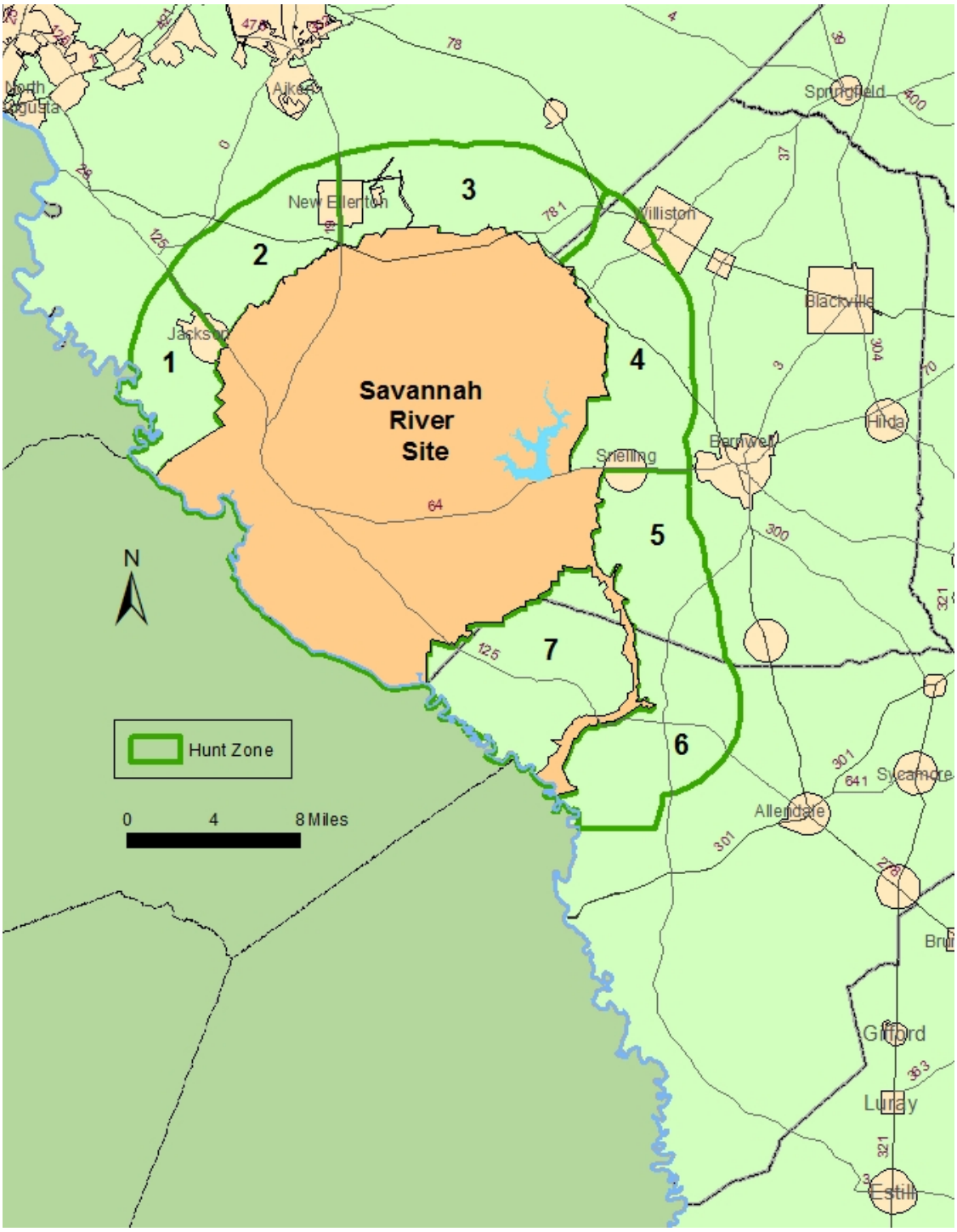
Historic SRS operations released known Cs-137 contamination to Steel Creek, Par Pond, Lower Three Runs, their floodplains, and the Savannah River swamp (Till et al 2001), all of which impact hunt zones four, five, six, and seven (Section 4.0, Map 1). Although a portion of Cs-137 was deposited on the SRS from site operations, levels found in the study area and background location are likely results of above ground nuclear weapons testing (Haselow 1991). DOE-SR does not collect game animal samples within the SCDHEC study area, and off-site hunter doses are based on DOE-SR models from animals collected on the SRS.

Age, sex, body weight, soil type, diet, and collection location may affect the Cs-137 activities found in white-tailed deer and hogs (Haselow 1991). The differences in average activities (Section 5.0, Figure 2) are possibly a combination of one or more of the above factors. A hunter consuming deer from the SRS, the study area, or background locations would most likely ingest a portion of the activity associated with these animals. Refer to the ESOP Critical Pathway Dose report for a better understanding of the contamination found in game versus other food sources.

SCDHEC will continue to monitor Cs-137 levels in deer and hogs within the estabished study area and background locations to assess trends and human health impacts. SCDHEC will continue to pursue new hunters within the five-mile study area to ensure adequate sample numbers can be achieved each year. SCDHEC will also put additional efforts into trapping wild hogs within the study area.

4.0 Game Animal Radiological Monitoring Adjacent to SRS

Map 1. ESOP Hunt Zones Adjacent to SRS, 2013



5.0 Tables and Figures

Game Animal Radiological Monitoring Adjacent to SRS

Figure 1. SCDHEC Hunt Zone Average Cs-137 Concentration In Deer and Hogs, 2013

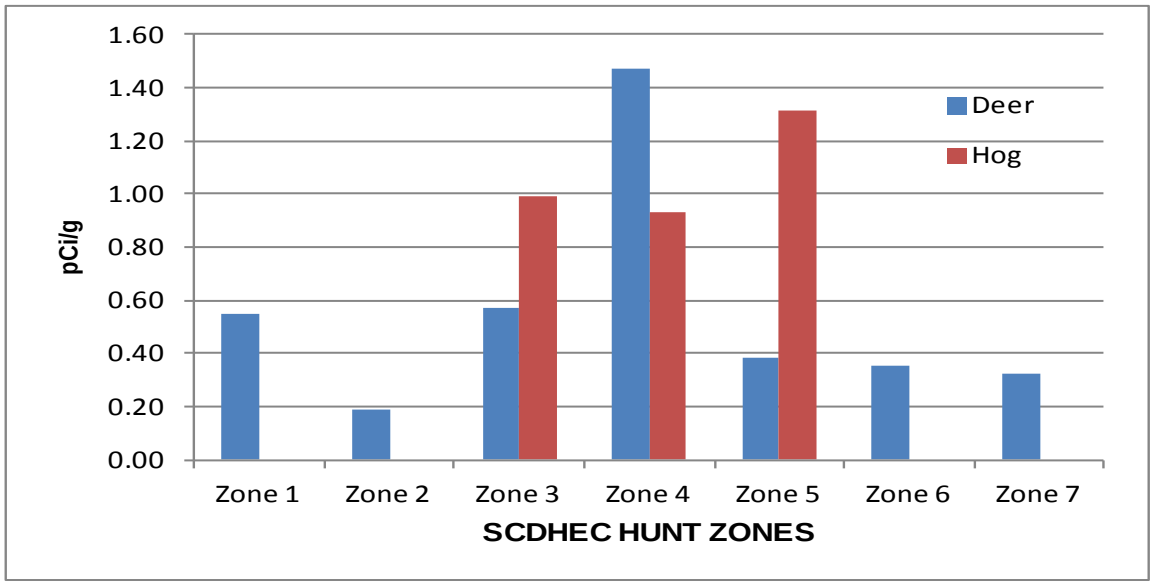
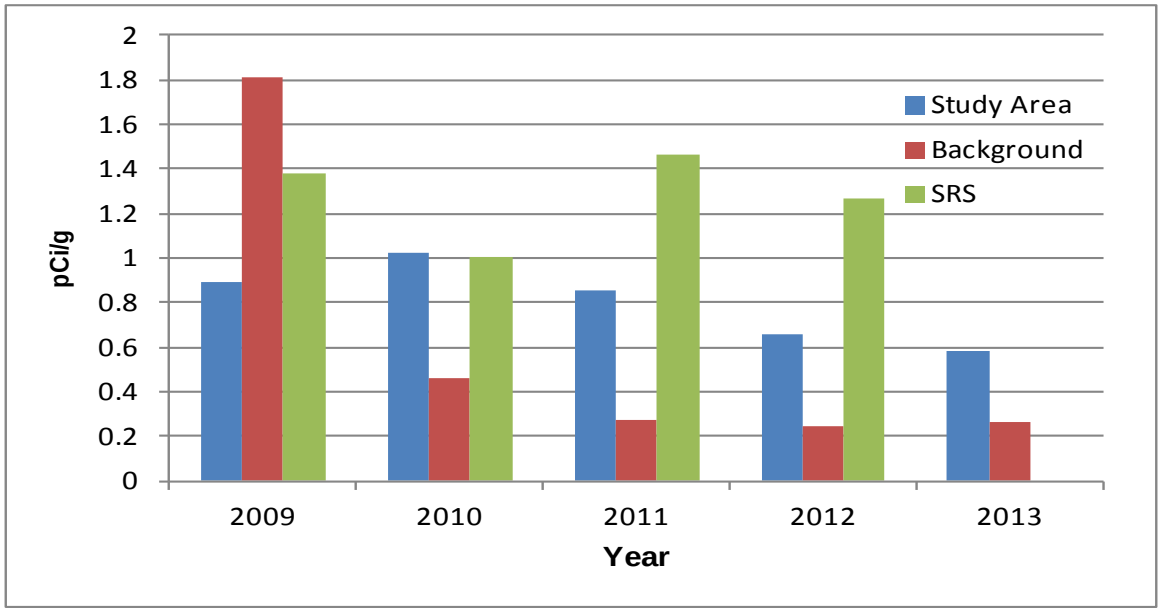


Figure 2. Average Cs-137 Concentration In Deer, 2009-2013



Background Locations
2009 - Carolina Sandhills National Wildlife Refuge
2010 - 2011 - Bamberg County
2012 - 2013 Pinckney Island National Wildlife Refuge

6.0 Summary Statistics

Game Animal Radiological Monitoring Adjacent to SRS

Notes:

1. N - Number of Samples
2. Std.Dev. - Standard Deviation
3. Min. - Minimum
4. Max. - Maximum
5. MDA - Minimum Detectable Activity
6. Average, Std.Dev., and Median calculated using detections only
7. NA - Not Available

Game Animal Radiological Monitoring Adjacent to SRS Summary Statistics

Cs-137 concentration (pCi/g wet weight) in deer and hogs collected in 2013

	N	Average	Std. Dev.	Median	Min.	Max.
Study Area Deer	25	0.58	0.70	0.37	<MDA	2.53
Study Area Hogs	4	1.04	0.23	1.05	0.76	1.31
Background Deer	10	0.26	0.21	0.18	0.11	0.81

Cs-137 concentration (pCi/g wet weight) in deer and hogs collected in 2013 SCDHEC Hunt Zones

Hunt Zone	N	Average	Std. Dev.	Median	Min.	Max.
Zone 1 Deer	4	0.55	0.18	0.55	<MDA	0.67
Zone 2 Deer	5	0.19	0.10	0.15	<MDA	0.33
Zone 3 Deer	3	0.57	0.44	0.54	0.14	1.02
Zone 3 Hogs	1	0.99	NA	0.99	0.99	0.99
Zone 4 Deer	4	1.47	1.21	1.50	0.37	2.53
Zone 4 Hogs	2	0.93	0.25	0.93	0.76	1.11
Zone 5 Deer	1	0.38	NA	0.38	0.38	0.38
Zone 5 Hogs	1	1.31	NA	1.31	1.31	1.31
Zone 6 Deer	5	0.35	0.45	0.19	0.04	1.12

Cs-137 concentration (pCi/g wet weight) in deer and hogs collected from 2009 - 2013

	Year	N	Average	Std.Dev	Median	Min.	Max.
Study Area Deer	2009	47	0.89	0.81	0.63	<MDA	3.13
Study Area Hogs	2009	7	0.05	0.01	0.05	<MDA	0.05
Background	2009	12	1.81	0.88	1.58	0.77	3.60
SRS Deer	2009	396	1.38	NA	NA	1.00	9.17
SRS Hogs	2009	78	1.06	NA	NA	1.00	2.78
Study Area Deer	2010	30	1.02	1.93	0.34	<MDA	9.96
Study Area Hogs	2010	4	1.33	1.23	1.26	<MDA	2.49
Background	2010	5	0.46	0.66	0.18	0.05	1.63
SRS Deer	2010	502	1.00	NA	NA	1.00	2.99
SRS Hogs	2010	107	1.00	NA	NA	1.00	2.14
Study Area Deer	2011	54	0.85	1.00	0.34	<MDA	4.31
Study Area Hogs	2011	6	0.51	0.12	0.51	<MDA	0.59
Background	2011	5	0.27	0.11	0.29	0.11	0.40
SRS Deer	2011	564	1.46	NA	NA	1.00	10.50
SRS Hogs	2011	156	1.75	NA	NA	1.00	11.50
Study Area Deer	2012	38	0.66	0.65	0.41	<MDA	2.29
Study Area Hogs	2012	7	1.87	1.77	0.78	0.42	3.86
Background	2012	25	0.24	0.10	0.24	0.04	0.45
SRS Deer	2012	543	1.27	NA	NA	1.00	12.60
SRS Hogs	2012	100	1.22	NA	NA	1.00	4.81
Study Area Deer	2013	25	0.58	0.70	0.37	<MDA	2.53
Study Area Hogs	2013	4	1.04	0.23	1.05	0.76	1.31
Background	2013	10	0.26	0.21	0.18	0.11	0.81
SRS Deer	2013	156	1.12	NA	NA	1.00	3.09
SRS Hogs	2013	62	1.32	NA	NA	1.00	5.09
Study Area Deer	2009 -2013	184	0.80	0.18	0.85	< MDA	9.96
Study Area Hogs	2009 -2013	28	0.96	0.71	1.04	<MDA	3.86
Background Deer	2009 -2013	57	0.61	0.68	0.27	0.04	3.6
SRS Deer	2009 -2013	2161	1.25	0.19	1.38	1.00	12.60
SRS Hogs	2009 -2013	503	1.27	0.3	1.06	1.00	11.50

Background Locations
2009 Carolina Sandhills National Wildlife Refuge
2010 - 2011 Bamberg County
2012 - 2013 Pinckney Island National Wildlife Refuge

LIST OF ACRONYMS

Cs-137	Cesium-137
DOE-SR	Department of Energy–Savannah River
ESOP	Environmental Surveillance and Oversight Program
MDA	Minimum Detectable Activity
Pb-214	Lead-214
K-40	Potassium-40
SCDHEC	South Carolina Department of Health and Environmental Control
SRS	Savannah River Site

UNITS OF MEASURE

pCi/g	picocuries per gram
±	plus or minus (one standard deviation unless stated otherwise)

REFERENCES

Bond, V.P., T.M. Fliedner, and J.O. Archambeau. 1965. Mammalian Radiation Lethality. Academic Press, New York, p. 340.

Brisbin, I.Lehr, Jr., and M.H. Smith. 1975. Radiocesium Concentrations in Whole-Body Homogenates and Several Body Compartments of Naturally Contaminated White-tailed Deer. In Mineral Cycling in the Southeastern Ecosystems, ERDA Symposium Series, CONF-740513, National Technical Information Service, Springfield, Virginia, p. 542.

Davis, J.J. 1963. Cesium and its Relationships to Potassium in Ecology, in Radioecology. Colorado State University, Fort Collins, Colorado, pp. 539-556.

Haselow, L.A. 1991. The Relationship of Radiocesium and Potassium In The Nutritional Ecology of White-tailed Deer From the Savannah River Site. Masters Thesis, Purdue University, p. 1.

Heckman JR, Kamprath EJ. 1992. Potassium Accumulation and Corn Yield Related to Potassium Fertilizer Rate and Placement, pp. 141-149.

Savannah River Nuclear Solutions, LLC (SRNS). 2014. Savannah River Site Environmental Report for 2013. Savannah River Site Aiken, SC. SRNS-STI-2014-00006.

Till JE, et al. 2001. Savannah River Site Environmental Dose Reconstruction Project, Phase II: Source Term Calculation in Ingestion Pathway Data Retrieval, Evaluation of Materials Released From the Savannah River Site. RAC Report No. 1-CDC-SRS-1999-Final. Risk Assessment Corporation (RAC).

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Section 5 2013 Critical Pathway / Dose

Chapter 13 Critical Pathway / Dose Report

2013 Critical Pathway Dose Report

Environmental Surveillance and Oversight Program

01DM003 and 01CP001
Greg Mason, Project Manager
January 01, 2013 - December 31, 2013

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South Carolina Department of Health
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Table of Contents

1.0 PROJECT SUMMARY

The South Carolina Department of Health and Environmental Control (SCDHEC) Environmental Surveillance and Oversight Program (ESOP) monitored the Savannah River Site (SRS) and adjacent areas under an Agreement in Principle with the United States Department of Energy (USDOE). Atmospheric pathway and liquid pathway discharges from SRS were monitored by the Department of Energy – Savannah River (DOE-SR) contractor Savannah River Nuclear Solutions (SRNS) Environmental Monitoring Section (EMS). DOE-SR and SCDHEC used data from their monitoring activities to calculate the potential radiation dose in millirem (mrem) to the surrounding public.

SCDHEC implemented a Radionuclide Dose Calculation Project/Critical Pathway Project to calculate the potential exposure or dose to the public within 50-miles of an SRS center-point. This study area was chosen for comparison to the DOE-SR 80-km (50-mile) radius dose results. Individual project managers chose differing sample locations/schemes within this study area to establish trends in media radionuclide concentrations. Radionuclide dose potential exposure to the public was calculated by SCDHEC from radionuclide concentration activities found in various media that may impact the public (Section 5.0).

A comparison of similar SCDHEC and DOE-SR media resulted in an evaluation of both programs based on media potential exposure in mrem (Section 2.0). Summary statistics (Section 6.0), and figures (Section 4.0) illustrate the trends and central tendencies in the critical pathway potential dose exposures. The critical pathway dose is calculated (Section 4.0) on average exposed individual (AEI) and maximally exposed individual (MEI) bases. The AEI and MEI bases are summarized in Section 4.0, Table 1, which presents the total dose detected per media in 2013 by SCDHEC. Most of the total dose detected comes from the ingestion route through wild game and vegetation consumption.

It is important for the reader to note the differences in DOE-SR and SCDHEC critical pathway dose estimations. Some DOE-SR dose calculations use computer models based on estimates of known releases within the report year. SCDHEC annual dose estimates are based solely on field sample data that allow calculation of an AEI dose per radionuclide per media and represent accumulated dose over several years.

Also, SCDHEC calculates an upper bound of potential dose, the MEI, which is based on the single highest maximum dose per radionuclide per media that may result in exposure throughout the year as if that maximum is somehow stored and used throughout the year. A one time filling of a water cistern with Savannah River water for consumption during a MEI dose event is an example of storage dose for an ingestion potential MEI. The MEI calculation also represents an upper bound estimate of potential accumulated exposure that may not have been detected.

MEI data is assigned to the maximally exposed individual, conceptualized by SCDHEC as a survivalist who is exposed to all media maximums as if the MEI exposure occurred throughout the entire year. An alternate possibility existed that all potential exposure was not detected, but this was taken into account with the ESOP MEI calculation and any additional DOE-SR release estimates greater than the SCDHEC sample estimates (Section 4.0, Tables 1 and 3). The health of the public and environment are protected when all of these estimates are below established protective dose standards/limits for the various radionuclides and pathways of exposure.

The DOE Order 5400.5 (USDOE 1993) dose limits to yearly releases do not apply to accumulated dose in environmental samples. However, they do provide a comparison basis that illustrates environmentally accumulated dose totals over several years are less than the yearly DOE-SR release limits (10 mrem air, 4 mrem liquid, and 100 mrem total for all radionuclides released in a given year; SRNS 2014).

The 2013 media calculations were represented on an AEI basis (average potential dose if exposed to all media sampled) and on a MEI (upper bound) basis of potential exposure per media, per radionuclide (Section 4.0, Table 1). The MEI (10.716 mrem in 2013) basis provides a radiation exposure limit based on the single highest potential dose in media. An individual's average exposure should be less than or closer to the AEI media total (3.940 mrem in 2013). Individual exposures may be far less than the AEI total due to temporal factors and the lack of contact by an individual with all media collected.

The SCDHEC MEI plus DOE-SR total (18.7 mrem) is based on the total of the highest possible exposure from environmental media (MEI column, Section 4.0 Table 1), plus all other dose modeled or detected by DOE-SR that has the potential to impact the public (Section 4.0, Table 4). For example, the SCDHEC dose estimates are only from dose detected offsite and the addition of onsite DOE-SR dose estimates includes most of the total potential dose from all public exposure sources.

The 2013 dose of 10.716 mrem as determined by SCDHEC was primarily due to cesium-137 (CS-137; Section 4.0, Table 3). Cs-137 accounted for 87.78 percent of the AEI dose contribution and 92.48 percent of the MEI dose contribution during 2013. Contrary to prior years, these SCDHEC field collections represent a yearly, not accumulated, dose. Any correlation between SCDHEC dose data (accumulated environmental dose) and DOE-SR dose data would be due to the dominant radionuclide dose contributors Cs-137, strontium-90 (Sr-90), and tritium (H-3) to exposure via comparable media.

The following comparisons to DOE-SR annual release limits are not explicitly applicable since dose found in media represents many years of dose accumulation, but the comparison is made to show that even the accumulated dose in the environment is less than the annual DOE-SR standard release limits for the air, liquid, and all-pathway categories (SRNS 2014). The SCDHEC 2013 conservative estimate for all-sources AEI exposures from the combined atmospheric and liquid pathways, 3.94 mrem, and the liquid pathway, 0.559 mrem, were beneath the respective 10 mrem and 4 mrem annual DOE-SR release limits (Section 4.0, Table 2; SRNS 2014). An upper bound 2013 MEI (excluding NORM detections) accumulated dose potential (18.9 mrem) calculated from the combined data of DOE-SR and SCDHEC was also strictly not applicable to the 100-mrem DOE-SR annual release limit to the public (Section 4.0, Table 3; SRNS 2014).

2.0 RESULTS AND DISCUSSION

The SCDHEC MEI is a subsistence and survivalist type of individual who resides in the downriver swamp area below all SRS contributions to the Savannah River, visits the entire 50-mile perimeter study area, and receives the MEI dose based on the single highest detection per radionuclide per media detected in the environment. The 2013 data and dose results are

discussed under the following headings in this section: the 2013 AEI and MEI Dose, the 2013 Added Dose Basis, Critical Pathways 2013 Summary, DOE-SR and SCDHEC 2013 Comparisons, and the Dose Critique. The statistical summary covers the 2004-2013 period, whereas other headings discuss only 2013 data. Not all media were collected throughout this summary period (2004-2013). See Section 6.0, Summary Statistics Table 2 for the total years of collection for the individual media.

The critical pathways were analyzed both on a mrem basis and percentage of dose basis (Section 6.0, Table 1). Percentages denote relative importance, whereas mrem denotes potential exposure levels. The dose critique attempts to indicate the limits of this dose estimate and why any DOE-SR and SCDHEC estimates may or may not be similar.

The 2013 AEI and MEI Dose

The basis for dose calculations is not limited to any particular pathway(s) of dose exposure based on lifestyle or media encountered, but is simply a tabulation of all detected dose found in all media sampled regardless of applicability to an individual. Table 1 in Section 4.0 summarizes all SCDHEC detections by media on an AEI and MEI detection basis. Contrary to prior years, in order to facilitate comparison with DOE-SR data, the background dose was not subtracted from the results.

The AEI dose is a conservative estimate based on maximum consumption rates (MCRs), represented by the MCR column in the data tables, and average dose per media (Section 5.0, Data). In 2013 the calculated AEI dose was 3.940 mrem (Section 4.0, Table 1), with 3.851 mrem from food dose. If wild game is not consumed, the AEI dose falls to 0.773 mrem. The AEI dose skews high, as only detections are used in the dose calculations: non-detections are excluded from the statistical analyses. For a typical person in the study area, the dose they receive will be considerably lower than the AEI dose.

In 2013 the total calculated MEI dose was 10.716 mrem, of which 10.452 mrem was attributable to food consumption. If wild game is not consumed, the MEI dose falls to 1.396 mrem. The MEI basis column uses the single highest detection for a media radionuclide and calculates dose as if the high dose occurrence was somehow stored and the exposure continued throughout the year (Section 5.0). If the individual did not store the media at the location, date, and time of ESOP sample collection, and achieve a full year's exposure to that media, then the MEI estimate represents a sizable overestimate (upper bound based on data exteme).

Only speciated doses for specific radionuclides were included in the estimated doses for 2013 (see the Dose Critique section). The use of detections only in determining AEI dose per radionuclide per media, the calculation of dose based on the MEI detection for each radionuclide/media, and conservative consumption references provided a protective dose estimate. Each media radionuclide dose, excluding naturally occurring radioactive material (NORM), was considered as part of a different critical pathway with contributions through the inhalation, ingestion, and direct exposure routes.

The SCDHEC MEI grand total (18.7 mrem) that includes added dose from DOE-SR (8.0 mrem) was based on the total of all SCDHEC MEI (10.716 mrem) detections plus any additional exposure estimates by DOE-SR (Section 4.0, Table 4). This combined onsite and offsite MEI

dose was an improbable dose based on maximums that could potentially be consumed by only one individual. All other individuals would receive the AEI dose or less. Most of this dose came from wild game consumption.

The MEI dose can be received by only one individual, since that individual had to consume the specific dose basis animals. Two elevated dose bases (AEI and MEI) were used because they were measured and protective without the inclusion of screening value assumptions for alpha and beta. The assumption of all alpha as plutonium-239 (Pu-239) and all beta as strontium-90 may double the calculated dose without evidence for that assumption in speciated data. These dose assignments were discontinued in 2008 and replaced by calculating an MEI dose potential from the single highest detection per radionuclide per media.

The 2013 Added Dose Basis

Section 4.0, Table 4.0 includes data from Table 6-5 of the SRS Environmental Report that can be added to give a total combined SCDHEC plus DOE-SR onsite and offsite dose potential of 18.69 mrem for the upper bound MEI estimate (SRNS 2014). This addition of dose detections other than SCDHEC detections from other environmental programs helped to extend the MEI potential dose limit on a definable basis. The main contributors to this combined onsite and offsite maximum dose estimate were the DOE-SR onsite hunter dose (5.0 mrem), and the SCDHEC offsite wild game dose (9.320 mrem). The onsite DOE-SR hunter would have to consume the highest dose game animals harvested onsite in 2013, and the same hunter would also have to receive and consume all of the highest dose offsite SCDHEC MEI game animals to achieve just the hunter portion of the combined onsite and offsite dose potential. Thus, the achievement of this maximum dose estimate by the MEI is highly unlikely.

A consumption factor of 3.65 kg/yr was used to calculate dose for edible fungi in 2013 for the avid wild mushroom consumer (Botsch 1999). Therefore, the potential dose from consuming wild mushrooms was added for the wild mushroom consumer and the SCDHEC MEI. The 2013 edible fungi dose maximum (0.363 mrem) was well below the 1998 food protective action guideline of 500 mrem to the whole body (USDHHS 1998).

Critical Pathways 2013 Summary

All SCDHEC dose detections occurred in the atmospheric and liquid pathways from the food ingestion, air and dust inhalation, direct exposure, public water supply ingestion, and the nonpotable drinking water ingestion routes. Percentage comparisons of critical pathways in 2013 denoted their relative importance to overall dose exposure (Section 4.0, Tables 1 and 3). The 2004-2013 Statistics Summary Section 6.0 covers the overall media trends. The AEI data represented the typical yearly dose levels while the MEI data represented the extreme data points, or one time dose extreme, that occurred sometime during the year. The MEI dose was very conservative since it was based on single high detections per radionuclide per media as if they were stored and constantly used throughout the year.

The Atmospheric Pathway 2013 Summary

The SCDHEC 2013 atmospheric pathway contributed dose to the individual through the inhalation of air and resuspended soil, ingestion of food and game, and direct exposure

subpathways. Section 4.0, Table 2 clearly illustrates the dominance of the atmospheric pathway, contributing 85.82 percent of dose, over the liquid pathway, which contributed 14.18 percent of dose in 2013 routes of exposure for the AEI. For the MEI, the percentages were 92.01 percent of dose contributed by the atmospheric pathway and 7.99 percent of dose contributed by the liquid pathway.

Section 4.0, Tables 1 and 3 illustrate that most of the dose exposure in 2013 was due to Cs-137, 3.458 mrem total, in wild game, fish, soil, and fungi. Sr-89/90 was the second highest dose exposure in 2013 at 0.345 mrem, and tritium third at 0.136 mrem. Cs-137, Sr-89/90, and tritium were each found in both the the atmospheric and the liquid pathways.

The Liquid Pathway 2013 Summary

The SCDHEC 2013 liquid pathway estimated AEI dose to the individual was through the ingestion of fish, groundwater, surface water, public river water supplies, swimming ingestion, inhalation, and direct exposure routes and pathways (Section 4.0, Table 1). Riverbank soil is an example of a media that can impact both atmospheric (through inhalation of resuspended dry sediments) and liquid pathways (through ingestion and direct contact), dependent on how the exposure occurred.

The liquid pathway contributions to dose exposure were second to those contributed by the atmospheric pathway. In 2013, the liquid pathway contribution to the AEI was 0.559 mrem, accounting for 14.18 percent of dose. The contribution to the MEI dose was 0.856 mrem, at 7.99 percent. A review of the Section 5.0 data shows Sr-89/90 to be the primary contributor to dose from fish in the liquid pathway.

The Food Pathway

The food pathway was covered under the atmospheric and liquid pathways except for these few additional observations. The annual 2013 SCDHEC AEI food pathway dose order, highest to lowest for averages, was hog, deer, fish, edible vegetation, fungi, and milk. Single high detections can occur in any of the game, fish, or wild fungi and vegetation samples, and cause a reversal of the rank order of media in any year.

The 2013 MEI food pathway order was deer, hog, fish, fungi, edible vegetation, and milk. Most of this dose was due to Cs-137 in wild game for the AEI and the MEI, at 3.167 mrem and 9.320 mrem respectively. The food pathway contained all detected radionuclides, including Cs-137, Sr-89/90, and tritium, which contributed to dose exposure.

2004-2013 Summary Statistics

Section 6.0, Table 1 summarizes dose associated with all media on an AEI basis from 2004-2013. The critical pathway basis of comparison for SCDHEC detected dose comes from accumulated releases of radionuclides that were deposited outside of SRS during 2004-2013 and within 50-miles of the SRS center-point. Table 1 illustrates the dominance of the atmospheric pathway dose (66.90 percent) over the liquid pathway (33.10 percent). The food subpathway (93.28 percent) was the dominant route of exposure for accumulated dose, with the water subpathway being second at 5.95 percent.

Section 4.0, Figures 1, 2, and 3 and Section 6.0, Tables 1 and 2 illustrate the various pathways of dose exposure. The total detected AEI basis critical pathway dose, 3.940 mrem, is just slightly greater than half the 7.00 mrem dose an individual typically receives from living in a brick house for one year (Wahl 2011). Section 4.0, Figures 1, 2, and 3 illustrate the media exposure trends via line graphs.

The predominant source of exposure from 2004-2013 was wild game, which includes deer and hog. In total it accounted for 9.689 mrem, which amounts to 48.59 percent of the accumulated AEI exposure (19.939 mrem) during that time period. Following wild game were fish (5.467 mrem; 27.42 percent), fungi (2.112 mrem; 10.59 percent), and edible vegetation (1.101 mrem; 5.52 percent). Furthermore, wild game accounted for 72.64 percent of the accumulated dose from the atmospheric pathway (Section 6.0, Table 1) and 52.10 percent of the food subpathway (Section 4.0, Figure 2).

The predominant routes of accumulated exposure for water sources were nonpotable drinking water from the Savannah River (0.428 mrem; Section 6.0, Table 1), DNR wells (0.236 mrem), which serve as a private well proxy, and public system drinking water from the Savannah River (0.226 mrem). The primary routes for minor sources of acculumulated dose were direct exposure from farm soil (0.059 mrem), accidental ingestion from swimming (0.050 mrem), and direct exposure from wading (0.024 mrem). Combined, the water and minor dose subpathways account for only 6.72 percent of accumulated dose.

Section 6.0, Table 2 medians, which represent the midpoint of a body of data thus minimizing the influence of the extremes, should provide the most relevant central tendency for environmental media exposure estimates over the period 2004-2013. The median is still protective because the statistics are based on detections only (Gilbert 1987). The dominant sources of accumulated exposure on an AEI median basis were fish (4.918 mrem), wild game (4.705 mrem), and fungi (2.203 mrem) (Section 6.0, Table 2; Median Yearly Dose accumulated over a ten year period). These three media accounted for 91.08 percent of accumulated AEI dose on a median basis.

The primary contributors to the water sources accumulated AEI dose on a median basis were nonpotable drinking water from the Savannah River (0.367 mrem), public system drinking water from the Savannah River (0.180 mrem), and nonpotable drinking water from rainwater (0.140 mrem; 6.0, Table 2; Median Yearly Dose accumulated over a ten year period). Accidental ingestion from swimming (0.036 mrem), direct exposure from soil (0.020 mrem), and inhalation of air (0.015 mrem) were the primary contributors to the minor sources accumulated AEI dose.

DOE-SR and SCDHEC 2013 Comparisons

DOE-SR calculates potential doses to members of the public from atmospheric and liquid releases, as well as from special-case exposure scenarios, on an annual basis (SRNS 2014). These include liquid pathway and air pathway doses, an all-pathway dose, a sportsman dose, onsite and offsite hunter doses, and an offsite fisherman dose. The DOE-SR dose estimates are analogous to SCDHEC dose estimates as follows, although it must be noted that there are differences between DOE-SR and SCDHEC sampling and dose estimation protocols:

- The DOE-SR all-pathway dose and the sum of the SCDHEC milk, air, vegetation, and the highest public water system AEI doses. These serve as an estimate of the dose a typical member of the public in the study area, an individual who doesn't consume wild game or gather edible mushrooms, could receive from SRS activities during a given year.

- The sum of the DOE-SR all-pathways, sportsman, Savannah River swamp hunter, and Savannah River swamp fisherman doses and the SCDHEC MEI. These serve as an upper bound estimate of the dose a survivalist type of individual who consumes fish from the Savannah River, wild game, and, in the case of the SCDHEC MEI dose, wild mushrooms, could receive in a given year.

The DOE-SR All-Pathway and the SCDHEC Public Scenario basis were the most relevant dose estimates that represent the potential dose exposure for the general public in 2013. The DOE-SR representative person all-pathway dose for 2013 was 0.19 mrem, a decrease from 0.26 mrem in 2012. The sum of the SCDHEC milk, air, vegetation, and the highest public water system AEI doses was 0.15 mrem, an increase from 0.04 mrem in 2012. Although an increase in the SCDHEC typical public dose estimate was indicated, the dose estimate for 2013 is only 0.15 percent of the DOE all-pathway dose standard of 100 mrem/yr (SRNS 2014).

The sum of the DOE-SR all-pathways, sportsman, Savannah River swamp hunter, and Savannah River swamp fisherman doses was 14.2 mrem in 2013, of which the single largest contributor was the onsite hunter, at 5.0 mrem. The SCDHEC MEI dose estimate for 2013, derived from offsite measurements only, was 10.7 mrem. With the DOE-SR onsite hunter added to the SCDHEC MEI, the total combined dose estimate was 15.7 mrem.

Dose Critique

The median may be a more applicable reference for deciding the true central tendency in environmental data when media sample numbers are relatively large in size and based on detections only (Gilbert 1987). Random sampling in most SCDHEC media revealed that the environmental data detections are asymmetric and skewed to the left (most detections are low and near the origin) and the median of the population probably tends to be larger than the true mean. Most sampling resulted in less than minimum detectable activity (<MDA) determinations and were not included in the above SCDHEC statistics that used detections only. The use of detections only in statistics was protective, and biases the measures central tendency higher, which was the primary basis for concluding that the median was probably closer to the true central tendency.

The DOE-SR study area shows a gradual downward exposure trend that may be attributable to the shift in SRS' mission, from production to cleanup and environmental remediation. All dose was summarized by average, standard deviation, and median. The median may be a better indicator of the central tendency in environmental media dose compared to average dose for large sample numbers due to:

1) the decrease in the central tendency for the bulk of the data without extremes;
2) the added conservancy present in selected dose factors;
3) the addition of dose based on single highest detections such as hog and deer worst-case game animal consumption;

4) the use of "detections only" for statistical analyses when many sample results were less than the detection limit;
5) the assignment of the higher dose to dual radionuclide determinations (e.g., the assignment of dose based on Sr-90 when the detection is for Sr-89/90 or total strontium);
6) the use of zero mrem as background subtraction for <MDA data averages;
7) the influence or potential of false positives;
8) and while the median does represent the bulk of the data, the application of statistical methods for eliminating extremes without an assignable cause does not preclude the variation in the natural environment.

The NORM averages and maximums were not included in the dose estimates since this dose was part of the 310 mrem expected NORM dose for the study area. The yearly dose averages were based on SCDHEC detections only and are inflated since most sample results were <MDA. The MDA values are below typical South Carolina background detections and would not add dose to the MEI. The justification for using detections only was to allow for undetected radionuclides and media. The justification for selecting higher source consumption levels was due to the conceptualization of the SCDHEC MEI as a survivalist type who consumed natural media at a greater than typical use rate. The basis for both considerations was to be protective of the public and environment.

The inclusion of alpha and beta assumed dose in the past was excessive and not supported by media radionuclide species detections. The inclusion of calculations based on a single highest maximum detection for each radionuclide/media was a more definable basis for establishing an upper bound rather than the dose assumption of unknown alpha as Pu-239 and unknown beta as Sr-90. This upper bound is not practically achieveable by the MEI due to the unlikely exposure to all maximums at a constant rate throughout the year (via storage of media). However, since most of the dose was due to wild-type food (whether animal or plant) consumption containing Cs-137, then a single individual who ate all of the worst case deer, hog, and edible plant and mushrooms could approach the MEI dose if these contaminated media were stored and consumed over the entire year.

The SCDHEC 2007 Critical Pathway Dose Report noted that 38.50 percent of the dose was assigned and represented a potential dose overestimate that may in fact be NORM detections (alpha and beta). Also, only 44.25 percent of the detected dose above background was potentially from SRS, if all NORM potentials were excluded. The SCDHEC dose calculations since then were still protective due to the use of detections only in determining dose, the calculation of a maximum dose for the MEI based on a single maximum detection for each radionuclide/media, and the use of very conservative consumption rates.

The AEI was given prominence as protective for general dose considerations, and the reader should be aware that the AEI dose estimate was conservative or biased high due to the use of detections only in calculations and the use of very conservative consumption rates for the SCDHEC AEI. For example, the omission of <MDA assignments from calculations would raise any calculated number to a higher value. Alternatively, <MDA actually represents an undetermined low number that may be zero or any number up to the given MDA value for that analysis.

All detected dose was assigned either to the AEI or the MEI (Section 4.0, Table 1 and Section 5.0 Data). The SCDHEC MEI was primarily a sportsman scenario because most potential dose was found in game animals and fish. However, the wild edible mushroom and plant consumer potential dose would add significant additional dose to the survivalist. The MEI by definition would consume all maximum activity per radionuclide per media and defined a limit of potential dose based on detections only. This was done since SCDHEC sampling was limited and did not necessarily include the true yearly MEI exposure (due to undetected dose and/or dose accumulations) for the exceptional individual who may receive the MEI dose resident in the 50-mile perimeter study area. Thus, the dose limiting factors were biased high to be protective of the public and the environment, but realistic or limiting in that only measured radionuclides were used in calculations.

Specific radionuclide (speciated) doses were used in the estimated dose for 2013 except for the dose assignments of total strontium as Sr-90. The use of detections only, the calculation of dose based on a single maximum for each radionuclide/media, and high consumption levels, provide an elevated dose basis that is protective without the inclusion of screening value assumptions for alpha and beta. SCDHEC field detection dose accumulations from 2004 through 2013 and DOE-SR yearly releases were not directly comparable and yet the potential MEIs calculated from both programs were close primarily due to the dominance of Cs-137 in the wild food pathway.

This project used dose instead of risk so that direct comparisons of dose magnitude can be made with similar media data published in the SRS Environmental Reports. Both the United States Environmental Protection Agency and SCDHEC use risk calculations when determining clean-up levels at Comprehensive Environmental Resource Compensation and Liability Act (CERCLA) and Resource Conservation Recovery Act sites. DOE-SR modeled radionuclide releases for a particular year were not directly comparable to SCDHEC yearly-detected dose in some media due to bioaccumulation that may have occurred during 2004-2013.

3.0 CONCLUSIONS AND RECOMMENDATIONS

A very conservative estimate by SCDHEC of the average DOE-SR perimeter accumulated dose potential was only 3.940 mrem in 2013 (Section 6.0, Table 1), with an average of 2.106 mrem per year in 2004-2013. The dose to the general public that did not consume wild game was 0.773 mrem in 2013. The median is viewed as the best representation of the central tendency over the period 2004-2013, and is still a protective estimate (see Dose Critique Section).

The MEI scenario includes all potential dose as a worst-case dose exposure. The SCDHEC MEI survivalist was a sportsman and a wild plant and mushroom consumer who received a maximum dose of 10.716 mrem in 2013 (Section 4.0, Table 1). The SCDHEC MEI dose estimate represents an upper bound of all SCDHEC detected dose potential and is not potentially achievable unless all dose maximums could somehow be stored and maintained as a constant exposure throughout the year. Only one individual could receive this dose, since most of the dose required that individual to consume all of the edible portion from the specific animals used as the dose basis.

The AEI dose (3.940 mrem in 2013; Section 4.0, Table 1) basis should apply to the rest of the population on an average potential basis and still be protective because it is based on detections only. Since even the AEI dose basis was protective and inflated, the median dose may represent

the typical individual who did not consume the animals containing the maximum dose. This AEI dose for the period 2004-2013 averaged 2.106 mrem per year (Section 6.0, Table 2), with a median total dose of 1.298 mrem.

Additional dose added primarily from DOE-SR onsite estimates for sportsmen increased the combined onsite and offsite dose potential to 18.69 mrem for the combined MEI. This improbable combined MEI potential accumulated dose was less than the DOE-SR 100 mrem annual dose release standard to the public in 2013 (Section 4.0, Table 4). Most of the dose in the DOE-SR and SCDHEC estimates was due to the bioaccumulation of Cs-137 in wild game.

The SCDHEC 2013 MEI dose estimates relative to the DOE standard atmospheric (0.008 mrem from air inhalation) and liquid (0.255 mrem from drinking water ingestion; Section 4.0, Table 1) pathways, excluding the atypical dose pathways, were less than the respective 10 mrem and 4 mrem DOE Order 5400.5 (USDOE 1993) limits despite dose additions from other years inherent in field collected media. The DOE limits apply only to yearly DOE releases and not to dose accumulated in the environment and are not applicable to SCDHEC field detections. The all-pathway DOE atmospheric and liquid estimates for the general public exclude atypical dose (game e.g.), which was captured under the total MEI estimate for comparison to the DOE defined dose limit for all annual dose releases to the public (100 mrem/yr; SRNS 2014).

The SCDHEC critical pathway estimates included atypical dose, which was primarily due to Cs-137 exposure from ingested game animals (deer and hog). Inhalation was 0.05 percent of the AEI dose to the critical pathway, food ingestion was 97.74 percent, water ingestion was 2.16 percent, and direct exposure was 0.03 percent in 2013 (numbers derived from Section 4.0, Table 1). The primary critical pathways for dose exposure were via atmospheric and liquid dose that was eventually ingested directly from food sources. The 2004-2013 statistics reduce sampling selection variations and gives a more accurate characterization of the central tendency potential in critical pathway dose (19.94 mrem of dose over a 10 year period; Section 6.0, Table 1).

The dose accumulations in the major critical pathways were atmospheric (66.90 percent or 13.34 mrem), and liquid (33.10 percent or 6.60 mrem; Section 6.0, Table 1). The observed potential dose for this 10 year period (19.94 mrem) can be broken down into the following subpathways: food ingestion (93.28 percent or 18.60 mrem), drinking water (5.95 percent or 1.19 mrem), direct exposure to soils and sediments (0.67 percent or 0.13 mrem), and direct inhalation (0.11 percent or 0.02 mrem). These exposures were well below all applicable limits.

The 2013 primary radionuclide dose contributors were Cs-137 (87.78 percent or 3.46 mrem) followed by contributions from strontium species (8.76 percent or 0.35 mrem), and tritium (3.44 percent or 0.14 mrem (Section 4.0, Table 1) on an AEI basis. For the MEI, the primary contributors to dose were Cs-137 (92.48 percent or 9.91 mrem), followed by the strontium species (4.31 percent or 0.46 mrem), and tritium (3.19 percent or 0.34 mrem). Cs-137 was the primary contributor to accumulated AEI dose in the 2004-2013 timeframe, primarily through the consumption of wild game.

Potential atmospheric and liquid release concerns that may play a relatively larger role in the dose to the surrounding public in the future may include the following:

1) releases of americium-241 (Am-241), plutonium and uranium radionuclides from the

Mixed Oxide Fuel Fabrication Facility through the air and surface water environmental mediums (Compagnie Generale des Martieres Nucleaires, Duke, Stone, & Webster 1998);

2) a relatively high concentration of tritium migrating from the E-Area to Upper Three Runs/Crouch Branch and Fourmile Branch (SRNS 2014) and/or the Savannah River.

These findings indicated that monitoring of bioaccumulation of radionuclides and the resulting dose should continue, especially within the food and wild game source subpathways. The down-gradient wells, surface water, sediments, plants, and animals should be carefully monitored for any signs of the contaminants that are present at basins, seepage areas, and the F and H-Area tank farms. Early detection is paramount to protecting the public and the environment if a release to offsite streams or groundwater occurs. SCDHEC will continue to monitor the SRS and adjacent area for the primary radionuclide contributors to dose potentially associated with DOE-SR operations.

4.0 Tables and Figures
2013 Critical Pathway Dose Report

4.0 Tables and Figures
2013 Critical Pathway Dose Report

Table 1. SCDHEC Dose Estimates for all Media: AEI and MEI

Pathway	Route	Source of Exposure	AEI	MEI
Atmospheric	Inhalation	Surface Soil Resuspension	0.000	0.000
Atmospheric	Inhalation	H-3 Inhalation	0.002	0.008
AEI%	**0.00**	**Air Inhalation Total**	**0.002**	**0.008**
Liquid	Ingestion	Fish	0.487	0.617
Atmospheric	Ingestion	Cow Milk	0.005	0.006
Atmospheric	Ingestion	Wild Game	3.167	9.320
Atmospheric	Ingestion	Vegetation (Leafy and Fruit)	0.119	0.145
Atmospheric	Ingestion	Fungi	0.073	0.363
Atmospheric	Ingestion	Soil Ingestion with Food	0.000	0.000
AEI%	**97.82**	**Food Ingestion Total**	**3.851**	**10.452**
Liquid	Ingestion	Public System Drinking Water from Sav. River	0.021	0.043
Liquid	Ingestion	Public System Drinking Water from Groundwater	0.015	0.018
Liquid	Ingestion	DNR Wells-Private System Proxy	0.000	0.000
Liquid	Ingestion	Nonpotable Drinking Water (SW)	0.034	0.152
Atmospheric	Ingestion	Nonpotable Drinking Water (Rainwater)	0.014	0.016
Liquid	Ingestion	Ingestion from Swimming	0.001	0.025
AEI%	**2.16**	**Drinking Water Total**	**0.085**	**0.255**
Liquid	Direct	Direct Exposure from Swimming	0.000	0.000
Liquid	Direct	Direct Exposure-Boating/Fishing	0.000	0.000
Liquid	Direct	Direct Exposure from living in a Boat or House	0.000	0.000
Liquid	Direct	Direct Exposure from Wading	0.000	0.000
Atmospheric	Direct	Direct Exposure from Farm Soil	0.001	0.001
AEI%	**0.03**	**Direct Exposure Total**	**0.001**	**0.002**
		Overall Total Dose	**3.940**	**10.716**

Table 2. SCDHEC Dose Estimates for the Atmospheric and Liquid Pathways: AEI and MEI

Critical Pathway Summary (mrem)	AEI	MEI
The Atmospheric Pathway Totals (APW) From All Sources (mrem)	3.381	9.860
The Liquid Pathway Totals (LPW) From All Sources (mrem)	0.559	0.856
ALL-Sources Critical Pathways Percent Contributions (%)	AEI	MEI
Atmospheric (APW) Pathway	APW%	APW%
Percentage Totals for Perimeter Dose From All-Sources	85.82	92.01
Liquid (LPW) Pathway	LPW%	LPW%
Percentage Totals for Perimeter Dose From All-Sources	14.18	7.99

Notes:
1. APW is the Atmospheric Pathway.
2. LPW is the Liquid Pathway.

4.0 Tables and Figures
2013 Critical Pathway Dose Report

Table 3. 2013 Dose by Isotope: AEI and MEI in mrem

Dose by Isotope Percentages: 2013				
Pathway	Route	Source of Exposure	Percentage of AEI	Percentage of MEI
Atmospheric	**Inhalation**	**Surface Soil Resuspension**		
Isotope	AEI Dose	MEI Dose		
Cs-137	0.000	0.000	100.00	100.00
Atmospheric	**Inhalation**	**H-3 Inhalation**		
Isotope	AEI Dose	MEI Dose		
H-3	0.002	0.008	100.00	100.00
Liquid	**Ingestion**	**Fish**		
Isotope	AEI Dose	MEI Dose		
H-3	0.004	0.009	0.86	1.42
Cs-137	0.222	0.231	45.52	37.37
Sr-89/90	0.261	0.378	53.62	61.20
Atmospheric	**Ingestion**	**Cow Milk**		
Isotope	AEI Dose	MEI Dose		
H-3	0.004	0.004	73.20	69.77
Sr-89/90	0.001	0.002	26.80	30.23
Atmospheric	**Ingestion**	**Wild Game**		
Isotope	AEI Dose	MEI Dose		
Cs-137	3.167	9.320	100.00	100.00
Atmospheric	**Ingestion**	**Vegetation (Leafy and Fruit)**		
Isotope	AEI Dose	MEI Dose		
H-3	0.040	0.066	33.54	45.46
Sr-89/90	0.079	0.079	66.46	54.54
Atmospheric	**Ingestion**	**Fungi**		
Isotope	AEI Dose	MEI Dose		
H-3	0.000	0.000	0.16	0.03
Cs-137	0.069	0.360	94.95	98.98
Sr-89/90	0.004	0.004	4.90	0.98
Pu-238	0.000	0.000	0.00	0.00
Pu-239/240	0.000	0.000	0.00	0.00
Atmospheric	**Ingestion**	**Soil Ingestion with Food**		
Isotope	AEI Dose	MEI Dose		
H-3	0.000	0.000	100.00	100.00
Liquid	**Ingestion**	**Public System DW from Sav. River**		
Isotope	AEI Dose	MEI Dose		
H-3	0.021	0.043	100.00	100.00
Liquid	**Ingestion**	**Public System DW from Groundwater**		
Isotope	AEI Dose	MEI Dose		
H-3	0.015	0.018	100.00	100.00
Liquid	**Ingestion**	**Nonpotable Drinking Water (SW)**		
Isotope	AEI Dose	MEI Dose		
H-3	0.034	0.152	100.00	100.00
Atmospheric	**Ingestion**	**Nonpotable Drinking Water (RW)**		
Isotope	AEI Dose	MEI Dose		
H-3	0.014	0.016	100.00	100.00
Liquid	**Ingestion**	**Water Ingestion from Swimming**		
Isotope	AEI Dose	MEI Dose		
H-3	0.001	0.025	100.00	100.00
Liquid	**Direct**	**Direct Exposure from Swimming**		
Isotope	AEI Dose	MEI Dose		
H-3	0.000	0.000	100.00	100.00
Liquid	**Direct**	**Direct Exposure-Boating/Fishing**		
Isotope	AEI Dose	MEI Dose		
H-3	0.000	0.000	100.00	100.00
Liquid	**Direct**	**Direct Exposure-Boat or House**		
Isotope	AEI Dose	MEI Dose		
H-3	0.000	0.000	100.00	100.00
Liquid	**Direct**	**Direct Exposure from Wading**		
Isotope	AEI Dose	MEI Dose		
Cs-137	0.000	0.000	99.86	99.81
Pu-238	0.000	0.000	0.10	0.12
Pu-239/240	0.000	0.000	0.05	0.07
Atmospheric	**Direct**	**Direct Exposure from Farm Soil**		
Isotope	AEI Dose	MEI Dose		
Cs-137	0.001	0.001	100.00	100.00
		Total Dose Percentage due to H-3	**3.44**	**3.19**
		Total Dose Percentage due to Cs-137	**87.78**	**92.48**
		Total Dose Percentage due to Sr-89/90	**8.76**	**4.31**
		Total Dose Percentage due to Pu-238	**0.00**	**0.00**
		Total Dose Percentage due to Pu239-240	**0.00**	**0.00**

Note: These are percentages of dose per isotope, per exposure source.The total percentage for each exposure will be one hundred percent (percentages may appear to be slightly above or below one hundred percent due to rounding error).

4.0 Tables and Figures
2013 Critical Pathway Dose Report

2013 Added Dose Basis				
Pathway	**Media Comparison Additional Dose**	**DOE-SR[1]**	**SCDHEC[2]**	Add to SCDHEC[3]
All-Pathway	Liquid (PWS plus Air Table 1) plus Airborne[4]	0.10	0.69	0.00
	Irrigation Pathway[5]	0.09	0.19	0.00
Sportsman	Onsite Hunter	5.0	NS	5.0
	Creek Mouth Fish	0.21	0.62	0.00
	Offsite Hog	3.3	4.7	0.00
	Offsite Deer	2.5	4.7	0.00
	Hunter Soil Exposure[7]	2.9	0.0	2.9
	Fisherman Soil Exposure[6]	0.07	0.00	0.07
Mushroom Consumer	Edible Fungi[8]	NS	0.363	0.00
Totals	**SCDHEC MEI[9]**	NA	10.716	NA
	Total Difference to be added for MEI	NA	8.0	8.0
	SCDHEC plus DOE-SR MEI Additions[10]	NA	18.7	NA

Notes:

1 - DOE-SR data primarily from Table 6-5 (SRNS 2013).

2 - SCDHEC Maximums or single highest detection basis for all media per route of exposure (Table 1).

3 - MEI all-source 2013 dose additions. Some DOE-SR offsite dose is based on computer modeling.

4 - Air inhalation plus LPW water source ingestion (PWS).

5 - Other Highest Irrigation food pathway potentials - milk, vegetable, and surface water ingestion sources

6 - LPW soil and sediment sources (location differences).

7 - APW soil sources were from Creek Plantation (DOE-SR) and other soil and sediment (SCDHEC).

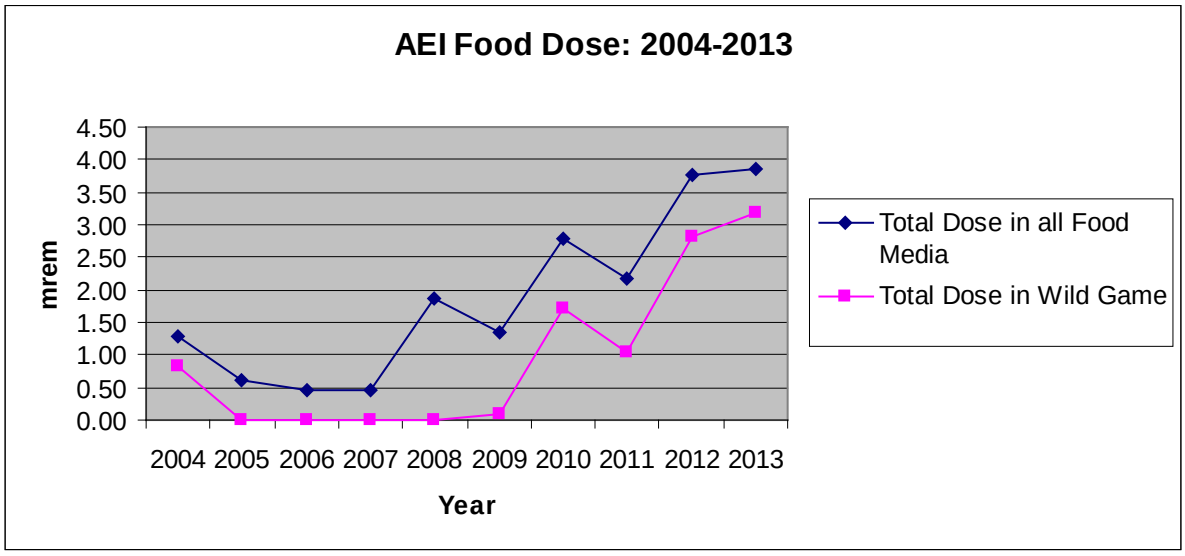
8 - Edible fungi dose from Cs-137 bioconcentration was highest in *Cantharellus* and *Boletus* spp.

9 - This comes from Section 4.0 Table 1-Overall Total Dose, MEI Column-It is not a summation of the SCDHEC column.

10 - Biased high primarily due to single maximums (SCDHEC), assigned dose (DOE-SR), and released dose basis. Not all released dose is absorbed, and explains why field measurements do not detect all dose released. On-site Turkey is included in the Onsite Hunter dose.

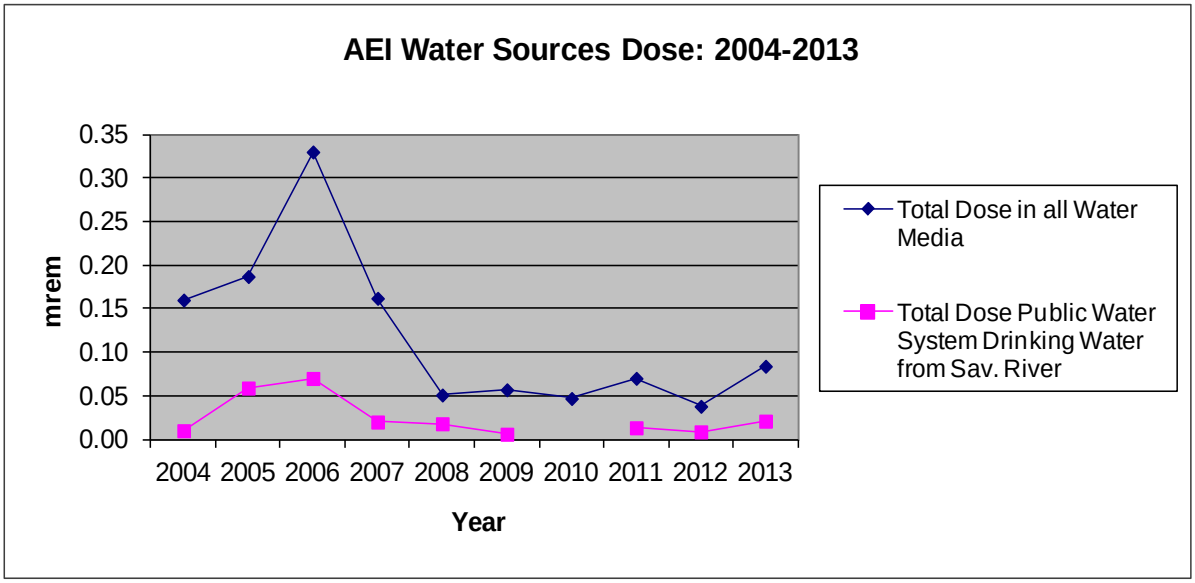
4.0 Tables and Figures
2013 Critical Pathway Dose Report

Figure 1. AEI Cumulative Food Dose: 2004-2013



Note: This graph shows the total food AEI dose trend and the trend for the primary contributor to the dose.

Figure 2. AEI Cumulative Water Dose: 2004-2013

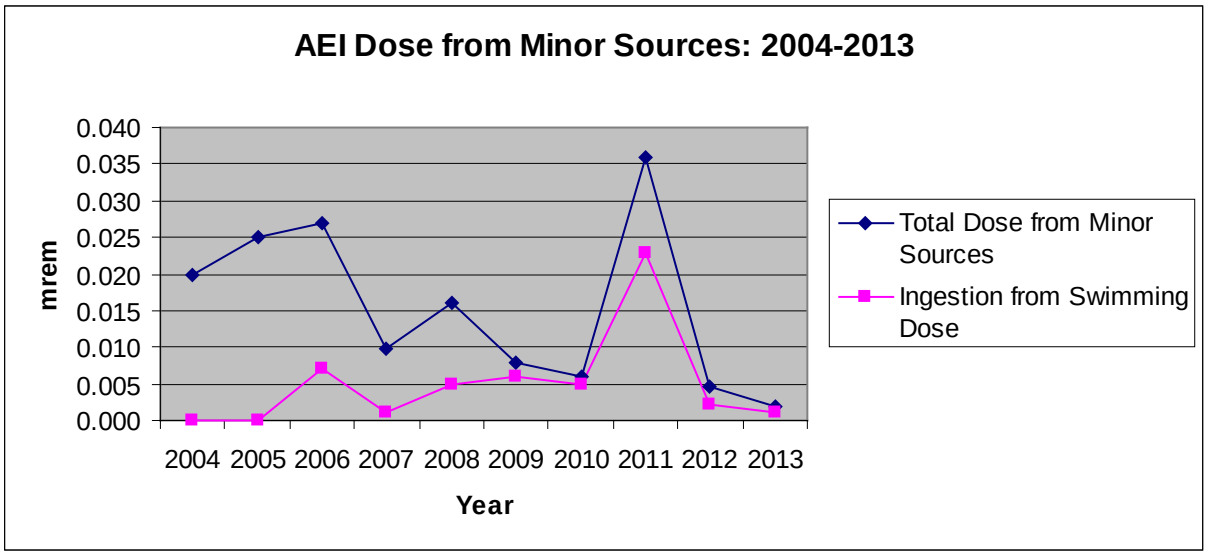


Notes:

1. This graph shows the total water AEI dose trend and the trend for the primary contributor to the dose.
2. Public water system drinking water from the Savannah River was not sampled in 2010.

4.0 Tables and Figures
2013 Critical Pathway Dose Report

Figure 3. AEI Cumulative Dose from Minor Sources: 2004-2013



Note: This graph shows the total food AEI dose trend and the trend for the primary contributor to the dose.

5.0 Data
2013 Critical Pathway Dose Report

5.0 Data
2013 Critical Pathway Dose Report

2013 AEI Fish Dose

Potential Dose from Fish Ingestion (AEI)						Total Dose	mrem
Media	Radionuclide	Activity	MCR	Dose	Bkg (pCi/g)		
Fish		pCi/g	kg/yr	mrem			
Bass	H-3	0.465	48.2	0.0014	<LLD		
	Cs-137	0.048	48.2	0.1157	0.0620		
	Sr-89/90	0.212	48.2	0.1222	0.0980		
Bass Dose Average				0.0798		Bass	0.2394
Catfish	H-3	0.546	48.2	0.0017	<LLD		
	Cs-137	0.044	48.2	0.1060	0.0520		
	Sr-89/90	0.179	48.2	0.1032	0.0930		
Catfish Dose Average				0.0703		Catfish	0.2109
Trout	H-3	0.348	48.2	0.0011	<LLD		
Trout Dose Average				0.0011		Trout	0.0011
Red Drum	Sr-89/90	0.062	48.2	0.0358			
Trout Dose Average				0.0358		Trout	0.0358
Average Dose All Fish types (Detections only)				0.0645		All Fish	0.4871

2013 MEI Fish Dose

Potential Dose from Fish Ingestion (MEI)						Total Dose	mrem
Media	Radionuclide	Activity	MCR	Dose	Bkg (pCi/g)		
Fish		pCi/g	kg/yr	mrem			
Bass	H-3	0.899	48.2	0.0028	<LLD		
	Cs-137	0.051	48.2	0.1222	0.0620		
	Sr-89/90	0.251	48.2	0.1447	0.0980		
Bass Dose Average				0.0899		Bass	0.2697
Catfish	H-3	1.598	48.2	0.0049	<LLD		
	Cs-137	0.045	48.2	0.1085	0.0520		
	Sr-89/90	0.342	48.2	0.1972	0.0930		
Catfish Dose Average				0.1035		Catfish	0.3106
Trout	H-3	0.348	48.2	0.0011	<LLD		
Trout Dose Average				0.0011		Trout	0.0011
Red Drum	Sr-89/90	0.062	48.2	0.0358			
Trout Dose Average				0.0358		Trout	0.0358
Average Dose All Fish types (Detections only)				0.0831		All Fish	0.6171

5.0 Data
2013 Critical Pathway Dose Report

2013 AEI Milk Dose

Potential Dose from Fish Ingestion (AEI)						Total Dose	mrem
Media	Radionuclide	Activity	MCR	Dose	Bkg.		
		pCi/L	kg/yr	mrem	pCi/L		
Milk	H-3	258	230.0	0.0038	237		
	Sr-89/90	0.506	230.0	0.0014	0.350		
	I-131	There were no detections in 2013.					
Milk Dose Average				0.0026		All Milk Sum	0.0052

2013 MEI Milk Dose

Potential Dose from Fish Ingestion (MEI)						Total Dose	mrem
Media	Radionuclide	Activity	MCR	Dose	Bkg.		
		pCi/L	kg/yr	mrem	pCi/L		
Milk	H-3	278	230.0	0.0041	237		
	Sr-89/90	0.645	230.0	0.0018	0.350		
	I-131	There were no detections in 2013.					
Milk Dose Average				0.0029		All Milk Sum	0.0059

2013 AEI Wild Game Dose

Avg. Potential Dose From Game (AEI)				Total Dose	mrem
Media	Radionuclide	Dose (mrem)	Bkg. (mrem)		
Avg. Deer	Cs-137	0.857	0.209		
Avg. Hog	Cs-137	2.31	None Collected		
Game Dose Average		1.58		Game Sum	3.17

2013 MEI Wild Game Dose

Avg. Potential Dose From Game (MEI)				Total Dose	mrem
Media	Radionuclide	Dose (mrem)	Bkg. (mrem)		
Avg. Deer	Cs-137	4.67	0.209		
Avg. Hog	Cs-137	4.65	None Collected		
Game Dose Average		4.66		Game Sum	9.32

5.0 Data
2013 Critical Pathway Dose Report

2013 AEI Edible Vegetation Dose

Potential Dose in Edible Vegetation (AEI)						Total Dose	mrem
Media	Radionuclide	Activity	MCR	Dose	Bkg.		
		pCi/g	kg/yr	mrem	pCi/g		
All Leafy	H-3	7.300	73.0	0.0341	<MDA		
	Cs-137	There were no detections in 2013.					
	SR-89/90	0.091	73.0	0.0790	<MDA		
All Leafy Vegetables Average				0.0341		Leafy Vegetables	0.1132
All Fruit	H-3	0.325	276	0.0057	<MDA		
	Cs-137	There were no detections in 2013.					
	Sr-89/90	There were no detections in 2013.					
Fruit nonNORM Average				0.0057		Fruit	0.0057
Fungi	H-3	0.487	3.65	0.0001	0.7040		
	Cs-137	0.380	3.65	0.0694	0.0210		
	SR-89/90	0.082	3.65	0.0036	NS		
	Pu-238	0.004	3.65	0.0000	NS		
	Pu-239/40	0.001	3.65	0.0000	NS		
Fungi Average				0.0146		Fungi	0.0730
Combined Vegetation Average				0.0182		Vegetation Sum	0.1920

2013 MEI EdibleVegetation Dose

Potential Dose in Edible Vegetation (MEI)						Total Dose	mrem
Media	Radionuclide	Activity	MCR	Dose	Bkg.		
		pCi/g	kg/yr	mrem	pCi/g		
All Leafy	H-3	12.400	73.0	0.0580	<MDA		
	Cs-137	There were no detections in 2013.					
	SR-89/90	0.091	73.0	0.0790	<MDA		
All Leafy Vegetables Average				0.0580		Leafy Vegetables	0.1370
All Fruit	H-3	0.446	276	0.0079	<MDA		
	Cs-137	There were no detections in 2013.					
	Sr-89/90	There were no detections in 2013.					
Fruit nonNORM Average				0.0079		Fruit	0.0079
Fungi	H-3	0.487	3.65	0.0001	0.7040		
	Cs-137	1.970	3.65	0.3595	0.0210		
	SR-89/90	0.082	3.65	0.0036	NS		
	Pu-238	0.004	3.65	0.0000	NS		
	Pu-239/40	0.001	3.65	0.0000	NS		
Fungi Average				0.0726		Fungi	0.3632
Combined Vegetation Average				0.0462		Vegetation Sum	0.5081

5.0 Data
2013 Critical Pathway Dose Report

2013 AEI Ingestion from Surface Water and Wells Dose

Ingestion from Surface Water and Wells						Total Dose	mrem
Source	Radionuclide	Activity	MCR	Dose	Bkg		
Savannah River Sourced Drinking Water		pCi/L	L/yr	mrem	pCi/L		
SW	H-3	453	730	0.0212	277	SRSDW	0.0212
Groundwater Sourced Drinking Water		pCi/L	L/yr	mrem			
GW	H-3	319	730	0.0149	<LLD		
DNR Groundwater		pCi/L	L/yr	mrem			
GW	H-3	<LLD	730	0.0000	<LLD	GSDW	0.0149
Nonpotable Drinking Water		pCi/L	L/yr	mrem			
SW	H-3	736	730	0.0344	306	NPDW	0.0344
Rainwater	H-3	290	730	0.0136	NA	NPDW	0.0136
Nonpotable Average Dose Potential from all sources.				0.0240		Total	0.0841

2013 MEI Ingestion from Surface Water and Wells Dose

Ingestion from Surface Water and Wells					
Source	Radionuclide	Activity	MCR	Bkg	Dose
		pCi/L	L/yr	pCi/L	mrem
Savannah River Sourced Drinking Water	H-3	923	730	277	0.0432
Groundwater Sourced Drinking Water	H-3	387	730	<LLD	0.0181
DNR Groundwater	H-3	<LLD	730	<LLD	0.0000
Nonpotable Drinking Water (SW)	H-3	3260	730	306	0.1525
Nonpotable Drinking Water (Rainwater)	H-3	346	730	NA	0.0162
				Total Dose	0.2299

5.0 Data
2013 Critical Pathway Dose Report

2013 AEI Accidental Water Ingestion and Direct Exposure Dose

Streams and Savannah River Surface Water Samples-Average						Total Dose	mrem
Source	Radionuclide	Activity	MCR	Dose	Bkg		
Surface Water Swimming		pCi/L	hrs/yr	mrem	pCi/L		
Ingestion	H-3	1812	91	0.0011	306	Surface Water Swimming	0.0011
Incidental ingestion of water while swimming at Savannah River Site Creek Mouths							
Surface Water Immersion		pCi/L	hrs/yr	mrem	pCi/L		
Immersion	H-3	1812	91	0.0000	306	Surface Water Immersion	0.0000
Direct exposure to the skin while swimming at SRS Creek Mouths.							
Surface Water Shine		pCi/L	hrs/yr	mrem	pCi/L		
Boating	H-3	1812	192	0.0000	306	Surface Water Shine (Boating)	0.0000
Direct exposure to skin from SRS Creek Mouth Water while Boating or Fishing.							
Surface Water Shine		pCi/L	hrs/yr	mrem	pCi/L		
Resident	H-3	1812	4380	0.0000	306	Surface Water Shine (Resident)	0.0000
Direct exposure to skin from surface water while living in a boat or swamp house.						Total	0.0011

2013 MEI Accidental Water Ingestion and Direct Exposure Dose

Streams and Savannah River Surface Water Samples-Maximum					
Source	Radionuclide	pCi/L	L/yr	Bkg	mrem
		Activity	MCR	pCi/L	Dose
Surface Water Swimming	H-3	43364	91	306	0.0253
Surface Water Immersion	H-3	43364	91	306	0.0000
Surface Water Shine (Boating)	H-3	43364	192	306	0.0000
Surface Water Shine (Resident)	H-3	43364	4380	306	0.0000
				Total Dose	0.0253

2013 AEI Sediment at Creek Mouths and Boat Landings Dose

Sediment at Creek Mouths and Boat Landings						Total Dose	mrem
Source	Radionuclide	Activity	MCR	Dose	Bkg.		
Sediment Dose		pCi/g	hrs/yr	mrem	pCi/g		
Creek Mouths	Cs-137	0.437	91	0.0001	0.138		
	Pu-238	0.013	91	0.0000	NA		
	Pu-239/240	0.007	91	0.0000	NA	Creek Mouths	0.0001
Boat Landings	Cs-137	0.300	91	0.0000	0.138	Boat Landings	0.0000
Average Dose from Sediment				0.0000		Overall	0.0001

2013 MEI Sediment at Creek Mouths and Boat Landings Dose

Sediment at Creek Mouths and Boat Landings				
Source	Radionuclide	Activity	MCR	Dose
		pCi/g	hrs/yr	mrem
Creek Mouths	Cs-137	1.342	91	0.0002
	Pu-238	0.056	91	0.0000
	Pu-239/240	0.034	91	0.0000
Boat Landings	Cs-137	1.183	91	0.0001
			Total Dose	0.0003

5.0 Data
2013 Critical Pathway Dose Report

2013 AEI Surface Soil Ingestion Dose

Surface Soil Ingestion						Total Dose	mrem
Surface Soil (SS)		Activity (pCi/g)	MCR (mg/day)	Dose (mrem)	Bkg (pCi/g)		
Ingestion	Cs-137	0.097	100	0.0002	0.072		
Soil Ingestion Average Dose				0.0002			
						Total Surface Soil Ingestion	0.0002

Note: This represents soil inadvertently consumed with plants.

2013 MEI Surface Soil Ingestion Dose

Surface Soil Detections					
Source	Radionuclide	Activity	MCR	Bkg	Dose
Surface Soil Ingestion	Cs-137	0.224	100	0.072	0.0004

Note: This represents soil inadvertently consumed with plants.

2013 AEI Soil Shine Dose

Soil Shine						Total Dose	mrem
Surface Soil		Activity (pCi/g)	MCR (hrs/yr)	Dose (mrem)	Bkg (pCi/g)		
Shine	Cs-137	0.097	4380	0.0006	0.072		
Shine or Direct Exposure from Farm Soil Average				0.0006			
						Total Surface Soil Shine	0.0006

2013 MEI Soil Shine Dose

Soil Shine					
Source	Radionuclide	Activity	MCR	Bkg	Dose
Surface Soil (SS)	Cs-137	0.224	4380	0.072	0.0014

2013 AEI Atmospheric Inhalation Dose

Atmospheric Inhalation Average						Total Dose	mrem
Surface Soil Resuspension and Air Inhalation							
Surface Soil Resuspension		Activity (pCi/g)	MCR (m^3/yr)	Dose (mrem)	Bkg (pCi/g)		
Inhalation	Cs-137	0.097	8000	0.0000	0.072	Surface Soil Resuspension	0.0000
Air Inhalation (Silica Gel)		Activity (pCi/m^3)	MCR (m^3/yr)	Dose (mrem)	Bkg (pCi/g)		
Inhalation	H-3	4.621	8000	0.0024	NA	Air Inhalation	0.0024
Atmospheric Inhalation Average Dose				0.0012		Total Atmospheric Inhalation	0.0024

2013 MEI Atmospheric Inhalation Dose

Atmospheric Inhalation					
Source	Radionuclide	Activity	MCR	Bkg	Dose
Surface Soil Resuspension	Cs-137	0.224	8000	0.072	0.0000
Air Inhalation (Silica Gel)	H-3	15.20	8000	NA	0.0078

6.0 Summary Statistics
2013 Critical Pathway Dose Report

Notes: Refer to the acronym section for definitions.

6.0 Summary Statistics
2013 Critical Pathway Dose Report

Table 1. 2004-2013 AEI Exposure per Media: Total AEI Dose and Percentage

Pathway	AEI Media Cateories	2013	2004-2013 Sum	2004-2013 AEI % Basis	Number of Years
Atmospheric	Surface Soil Resuspension Inhalation	0.000	0.000	0.00	5
Atmospheric	H-3 Inhalation	0.002	0.021	0.11	10
Liquid	Fish	0.487	5.467	27.42	10
Atmospheric	Cow Milk	0.005	0.229	1.15	10
Atmospheric	Wild Game	3.167	9.689	48.59	10
Atmospheric	Vegetation (Leafy and Fruit)	0.119	1.101	5.52	10
Atmospheric	Fungi	0.073	2.112	10.59	6
Atmospheric	Soil Ingestion with Food	0.000	0.000	0.00	5
Liquid	Public System Drinking Water From the Sav. River	0.021	0.226	1.13	9
Liquid	Public System Drinking Water from Groundwater	0.015	0.168	0.84	10
Liquid	DNR Wells	0.000	0.236	1.18	10
Liquid	Nonpotable Drinking Water (Savannah River)	0.034	0.428	2.15	10
Atmospheric	Nonpotable Drinking Water (Rainwater)	0.014	0.128	0.64	10
Liquid	Ingestion from Swimming	0.001	0.050	0.25	10
Liquid	Direct Exposure from Swimming	0.000	0.000	0.00	4
Liquid	Direct Exposure from Boating/Fishing	0.000	0.000	0.00	4
Liquid	Direct Exposure from Living in a Boat or House	0.000	0.000	0.00	4
Liquid	Direct Exposure from Wading	0.000	0.024	0.12	10
Atmospheric	Direct Exposure from Farm Soil	0.001	0.059	0.30	10
	Totals	3.940	19.939	100	NA

Notes:
1. The 2013 column is dose in mrem during 2013.
2. The 2004-2013 column is total dose in mrem over the 2004-2013 ten year period.
3. The AEI % basis column is the percentage of 2004-2013 dose due to a given media.
4. Number of years refers to the number of years data was available for 2004-2013.

Table 2. 2004-2013 AEI Exposure per Media: Average and Median Yearly Dose

Pathway	AEI Media Cateories	Avg. Yearly Dose	SD	Median Yearly Dose
Atmospheric	Surface Soil Resuspension Inhalation	0.000	0.000	0.000
Atmospheric	H-3 Inhalation	0.002	0.003	0.002
Liquid	Fish	0.547	0.245	0.492
Atmospheric	Cow Milk	0.023	0.063	0.003
Atmospheric	Wild Game	0.969	1.220	0.471
Atmospheric	Vegetation (Leafy and Fruit)	0.079	0.116	0.020
Atmospheric	Fungi	0.352	0.354	0.220
Atmospheric	Soil Ingestion with Food	0.000	0.000	0.000
Liquid	Public System Drinking Water From the Sav. River	0.025	0.023	0.018
Liquid	Public System Drinking Water from Groundwater	0.017	0.020	0.010
Liquid	DNR Wells	0.024	0.047	0.007
Liquid	Nonpotable Drinking Water (Savannah River)	0.043	0.030	0.037
Atmospheric	Nonpotable Drinking Water (Rainwater)	0.013	0.005	0.014
Liquid	Ingestion from Swimming	0.005	0.007	0.004
Liquid	Direct Exposure from Swimming	0.000	0.000	0.000
Liquid	Direct Exposure from Boating/Fishing	0.000	0.000	0.000
Liquid	Direct Exposure from Living in a Boat or House	0.000	0.000	0.000
Liquid	Direct Exposure from Wading	0.002	0.003	0.001
Atmospheric	Direct Exposure from Farm Soil	0.006	0.008	0.002
	Totals	2.106	NA	1.298

Notes:
1. Average yearly dose is the yearly AEI average in mrem for the 2004-2013 time period.
2. Median yearly dose is median AEI dose in mrem for the 2004-2013 time period.

LIST OF ACRONYMS

AEI	Average Exposed Individual
AVG	Average
Bkg	Background
CERCLA	Comprehensive Environmental Resource Compensation and Liability Act
COGEMA	Compagnie Generale des Martieres Nucleaires
DOE-SR	Department of Energy - Savannah River
DNR	Department of Natural Resources
EMS	Environmental Monitoring Section
ESOP	Environmental Surveillance and Oversight Program
LLD	Lower Limit of Detection
LPW	Liquid Pathway
MCR	Maximum consumption rate
MDA	Minimum Detectable Activity
MEI	Maximum Exposed Individual
NA	Not Applicable
NS	Not Sampled
NORM	Naturally Occurring Radioactive Material
PWS	Public Water System
SCDHEC	South Carolina Department of Health and Environmental Control
SD	Standard Deviation
SRS	Savannah River Site
SRNS	Savannah River Nuclear Solutions
USDOE	United States Department of Energy
USEPA	United States Environmental Protection Agency
VEGP	Vogtle Electric Generating Plant

UNITS OF MEASURE

hrs/yr	hours per year
kg/yr	kilograms per year
L/yr	liters per year
m^3/yr	cubic meters per year
mrem	millirem or milliroentgen equivalent man
mg/day	milligrams per day
pCi/g	picocuries per gram
pCi/L	picocuries per liter
pCi/m^3	picocuries per cubic meter
±	plus or minus

REFERENCES

Botsch. 1999. Investigation of the Radiation Exposure of Inhabitants of Contaminated Areas in Northern Ukraine. Center for Radiation Protection and Radioecology, University of Hanover, Germany and the State Agroecological Academie of Ukraine, Ukraine.

Duke, Cogema, Stone & Webster (COGEMA). 1998. Mixed Oxide Fuel Fabrication Facility Environmental Report. Charlotte, North Carolina. Docket number 070-03098.

Gilbert. 1987. Statistical Methods For Environmental Pollution Monitoring, Richard O. Gilbert. Pacific Northwest Laboratory. John Wiley & Sons, Inc. 1987, ISBN 0-471-28878-0.

South Carolina Department of Health and Environmental Control (SCDHEC). 1999-2013. South Carolina Department of Health and Environmental Control Environmental Data Reports, Bureau of Environmental Services, Environmental Surveillance and Oversight Program, Aiken, South Carolina .

SCDHEC. 2013. 2013 Critical Pathway Dose Project Plan, Bureau of Environmental Services, Environmental Surveillance and Oversight Program, Aiken, South Carolina.

Savannah River Nuclear Solutions, LLC (SRNS). 2010-2013. Savannah River Site Environmental Reports for 2009-2011. Savannah River Site, Aiken, SC.

SRNS. 2014. Savannah River Site Environmental Report for 2013. Savannah River Site, Aiken, SC. SRNS-STI-2013-00200.

United States Department of Energy (USDOE). 1993. United States Department of Energy, USDOE Order 5400.5, Change 2, Radiation Protection of the Public and the Environment. https://www.directives.doe.gov/directives-documents/5400-series/5400.05-BOrder-c2.

United States Department of Health and Human Services (USDHHS). 1998. Accidental Radioactive Contamination of Human Food and Animal Feeds: Recommendations for State and Local Agencies. Radiation Programs Branch, Food and Drug Administration, Center for Devices and Radiological Health, Rockville, Maryland.

Wahl. 2011. Answer to Question #9778 Submitted to "Ask the Experts." Retrieved from http://hps.org/publicinformation/ate/q9778.html.