ESOP

Environmental Surveillance and Oversight Program

2016 DATA REPORT

Healthy People. Healthy Communities.

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Introduction

In 1950, the U.S. Atomic Energy Commission established the Savannah River Site with the mission (1954-1992) of producing nuclear materials, primarily tritium and plutonium. The Savannah River Site (SRS) is a Department of Energy (DOE) facility located approximately 20 miles from Aiken, South Carolina. SRS boundaries lie within Aiken, Allendale, and Barnwell counties and span approximately 310 square miles. During the course of normal operations, radionuclides were released into the surface water, groundwater, soils and atmosphere. Although the reactors are no longer operating, work continues at SRS with the primary focus being on cleaning up legacy wastes and remediating areas associated with former operations.

Due to the large number of contaminants that could be potentially released from SRS, the Centers for Disease Control and Prevention (CDC) performed a site assessment to determine the potential health effects of any released radionuclides to the off-site public. The five production reactors (R, K, P, L, and C) were the primary sources for key radiological contaminant releases. All of the radiological releases originated from processes associated with the reactor areas and the separations areas. However, there are additional areas of releases as a result of the varied processes at SRS.

Tritium was one of the principle nuclear materials produced at SRS to multiply the firepower of plutonium in nuclear weapons (Till et al. 2001). Tritium releases originated from processes associated with the reactors, separations areas, D-Area, and tritium facilities. The two main types of tritium releases came from direct site facility releases and migration from seepage basins in the separations areas, the burial ground, and the K-Area containment basin. In the early operational years, nearly 100 percent of the releases to streams were related to direct releases. Tritiated water is more hazardous biologically than tritium gas and reacts chemically in living cells, the same as nonradioactive water (CDC SRSHES 1997).

Alpha-emitting and Beta-emitting radionuclides were also released to liquid effluent. Alpha-emitting radionuclide releases from M-Area primarily affected Tim's Branch, which ultimately flows into Upper Three Runs Creek. Fourmile Branch is the stream most affected by alpha- and beta-emitting releases coming from the separations areas, and releases from the reactor areas affected all streams with the exception of Upper Three Runs Creek (Till et al. 2001). Steel Creek, Pen Branch, and Lower Three Runs Creek were mainly affected by beta-emitting 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 was manufactured on SRS in H-Area from fuel rods and in F-Area from targets (Till et al. 2001). Releases at SRS occurred primarily through the discharge of liquid effluent. Iodine-129 (I-129) is a fission product of reactor fuel that has a very long 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 separations areas ventilation systems, the aqueous environment from liquid waste in waste tanks, and the Solid Waste Disposal Facility (WSRC 1993a).

Strontium was a fission product in SRS reactors, subsequently released from F-area and H-area (WSRC 1998). SRS operations have also released strontium into the environment through normal site operations and equipment failure.

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Introduction

Routine operations at SRS have released cesium-137 (Cs-137) to the regional environment surrounding SRS. The most significant releases occurred during the early years of site operation when Cs-137 was released to seepage basins and site streams. The SRS facilities that have documented Cs-137 releases are the production reactors, separations areas, liquid waste facilities, the solid waste disposal facility, central shops, heavy water rework facility, Saltstone Facility, and the Savannah River National Laboratory (SRNL).

The Department of Energy (DOE) is self-regulating. Until 1995, the public had to rely solely on DOE to ensure their health and the environment was protected. The DOE formed an Agreement in Principal with the South Carolina Department of Health and Environmental Control (DHEC) to perform independent environmental monitoring and oversight of SRS, giving an extra source of information to the public regarding the effectiveness of the DOE monitoring activities. From this agreement, the Environmental Surveillance and Oversight Program (ESOP) of DHEC was initiated to supplement and compliment monitoring functions of this unique facility. DHEC monitoring provides an added protection due to the potential for catastrophic environmental releases that pose a threat to the state.

Program development at SRS is stable and evolves based on changing missions. The primary focus is on legacy waste and materials that are stored or have been disposed of on-site, and currently pose a potential for release to the environment. This report provides results of samples collected by DHEC related to the SRS, trending to document how contaminants are changing, and information on how these changes may impact the surrounding communities. DHEC's ESOP will continue its mission of monitoring and oversight around SRS to protect and promote the health of the public and the environment.

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Chapter 1 Radiological Atmospheric Monitoring on and Adjacent to SRS

1.1.0 PROJECT SUMMARY

Atmospheric transport has the potential to impact the citizens of South Carolina from releases associated with activities at SRS. The Atmospheric Monitoring project provides independent quantitative monitoring of atmospheric radionuclide releases associated with SRS and atmospheric media on a routine basis to measure radionuclide concentrations, as well as to identify trends that may require further investigation. Air monitoring capabilities in 2016 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). Radiological atmospheric monitoring sites were established to provide spatial coverage of the project area (Sections 1.4.0 Map). 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 (Section 1.5.0, Table 1). Five of the air monitoring stations are on or within two miles of the SRS perimeter, one is located at the center of the site, and two are within 25 miles of the site. DHEC emphasizes monitoring for radionuclides in atmospheric media around SRS at potential public exposure locations (Section 1.5.0, Table 2). Glass fiber filters are used to collect total suspended particulates (TSP). Particulates are screened weekly for gross alpha and gross beta-emitting activity. Precipitation, when present, is sampled and analyzed monthly for tritium. Silica gel distillates of atmospheric moisture are analyzed monthly for tritium. TLDs are collected and analyzed every quarter for ambient beta/gamma levels. First quarter filter samples are analyzed for plutonium-238 and 239/240 (Pu-238, Pu-239/40).

1.2.0 RESULTS AND DISCUSSION

Air Monitoring Summary Statistics can be found in Section 1.6.0 and all Air Monitoring Data can be found in the 2016 DHEC Data File.

1.2.1 Total Suspended Particulates

DHEC and the Department of Energy-Savannah River (DOE-SR) had gross alpha detections in 2016. The detections were in a range that is typically associated with naturally occurring alpha-emitting radionuclides, primarily as decay products of radon, and are considered normal (Kathren 1984). Section 1.5.0, Figure 1 shows average gross alpha activity for SRS perimeter locations and illustrates trends for the last five years of gross alpha values for DHEC and DOE-SR.

DHEC and DOE-SR had gross beta detections in 2016. Small seasonal variations at each monitoring location have been consistent with historically reported DHEC values (DHEC 2017). The EPA 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 picocuries per cubic meter (pCi/m^3) (EPA 2013). This tiering of definitive analyses is used for all total suspended particulate sampling associated with RadNet, which is a nationwide network of sampling stations that identify trends in the accumulation of long-lived radionuclides in the environment (EPA 2005). Section 1.5.0, Figure 2 shows average gross beta activity for the SRS perimeter locations and illustrates trending of gross beta values for DHEC and DOE-SR from the last five years.

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First and second quarter glass fiber filters were composited and analyzed for Pu-238, Pu-239/240, Cs-137, and Sr-89/90. No detections of either Pu-238, Pu-239/240, or Cs-137 occurred. There were two detections of Sr-89/90 found in second quarter composited filters from the Jackson (AAJAK) and Burial Grounds (AABGN) air stations.

1.2.2 Ambient Beta/Gamma

DHEC conducts ambient beta/gamma monitoring through the deployment of TLDs around the perimeter of SRS. 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). In 2016, ambient beta/gamma yearly totals ranged from 59.6 (TLD-6) to 114.4 (TLD-17) mrem at the site perimeter. Section 1.5.0, Figure 3 shows data trends at the SRS perimeter for average ambient beta/gamma values in TLDs for DHEC and DOE-SR.

1.2.3 Tritium

Tritium continues to be the predominant radionuclide detected in the perimeter samples. In 2016, DOE-SR released approximately 21,700 Ci of tritium from SRS (SRNS 2017). Most of the tritium detected in DHEC perimeter samples may be attributed to the release of tritium from tritium facilities, separation areas, and from diffuse and fugitive sources (SRNS 2017).

Tritium in Air

Tritium in air values reported by DHEC 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).

In 2016, the DHEC and DOE-SR average tritium activity was well below the EPA equivalent yearly average standard of 20,000 pCi/m^3 for airborne tritium activity (ANL 2007).

Average DHEC tritium in air activity was higher than the DOE-SR activity. 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 DHEC for 2016 was lower than reported in 2015 and has fluctuated over the last six years. DOE-SR also reported a slight decrease from 2015 to 2016 with fluctuations over the past six years. Section 1.5.0, Figure 4. illustrates data trends of atmospheric tritium activity for DHEC and DOE-SR as measured and calculated at the SRS perimeter.

Tritium in Precipitation

In 2016, DHEC and DOE-SR averages for tritium activity were well below the EPA standard of 20,000 picocuries per liter (pCi/L) in drinking water (EPA 2002d). Section 1.5.0, Figure 5 shows average tritium in precipitation activity for SRS perimeter locations and illustrates trending tritium in precipitation values for DHEC and DOE-SR from the last five years.

During the 2016 sampling period, tritium in precipitation ranged from less than the lower limit of detection (LLD) to 640.0 pCi/L. The maximum reported value for DHEC perimeter locations was collected at the JAK air station in June. The DHEC average measured activity for tritium in precipitation was 394.75 (±75.6) pCi/L. The DOE-SR average measured value for tritium activity in precipitation at the SRS perimeter was 160.0 (±137.2) pCi/L (SRNS 2017). The DHEC and

DOE-SR averages for tritium activity were well below the EPA standard of 20,000 pCi/L in drinking water (EPA 2002d). Section 1.5.0, Figure 5 shows average tritium in precipitation activity for SRS perimeter locations and illustrates trending tritium in precipitation values for DHEC and DOE-SR from the last five years.

1.3.0 CONCLUSIONS AND RECOMMENDATIONS

All DHEC data collected in 2016 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.

Due to continued releases from site facilities (tritium facilities, separations areas, etc.), DHEC will continue to collect weekly TSP for gross alpha/beta, monthly atmospheric and precipitation tritium samples, quarterly ambient beta/gamma samples, and yearly Pu-238/239 samples.

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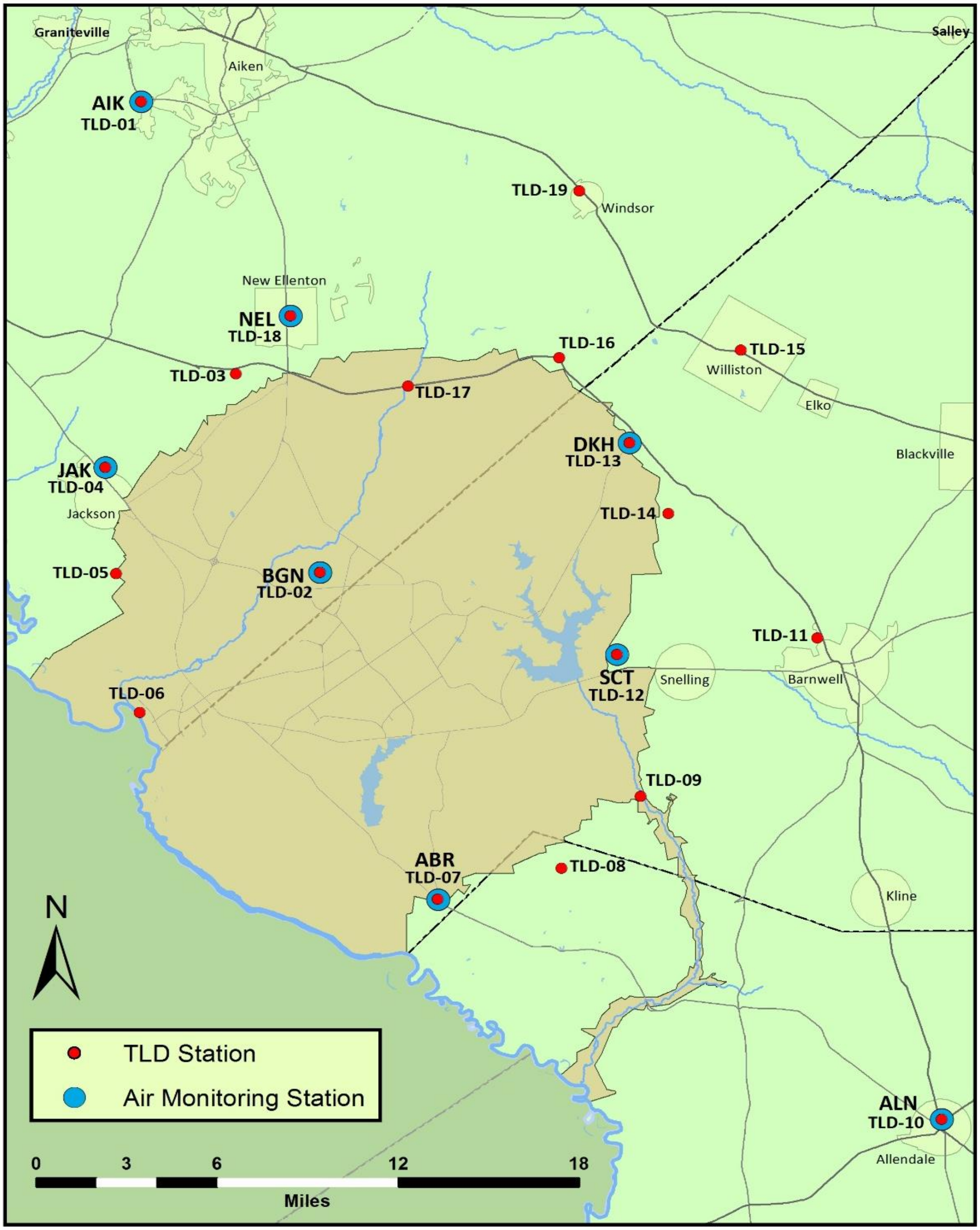
1.4.0 MAP

Radiological Atmospheric Monitoring Sample Locations



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1.5.0 TABLES AND FIGURES

Radiological Atmospheric Monitoring Locations

Table 1. TLD Sample Locations

Sample ID	Location	Proximity to SRS
TLD-01	Colocated with AIK Air Station	Within 25 miles of SRS
TLD-02	Colocated with BGN Air Station	Center of SRS
TLD-03	Green Pond Road	SRS Perimeter
TLD-04	Colocated with JAK Air Station	SRS Perimeter
TLD-05	Crackerneck Gate	SRS Perimeter
TLD-06	TNX Boat Ramp	SRS Perimeter
TLD-07	Colocated with ABR Air Station	SRS Perimeter
TLD-08	Junction of Millet Road and Round Tree Road	SRS Perimeter
TLD-09	Patterson Mill Road at Lower Three Runs Creek	SRS Perimeter
TLD-10	Colocated with ALN Air Station	Within 25 miles of SRS
TLD-11	Barnwell Airport	Within 25 miles of SRS
TLD-12	Colocated with SCT Air Station	SRS Perimeter
TLD-13	Colocated with DKH Air Station	SRS Perimeter
TLD-14	Seven Pines Road Colocated with SRS Air Station	SRS Perimeter
TLD-15	Williston Police Department	Within 25 miles of SRS
TLD-16	Junction of US-278 and SC-781	SRS Perimeter
TLD-17	US-278 near Upper Three Runs Creek	SRS Perimeter
TLD-18	Colocated with NEL Air Station	SRS Perimeter
TLD-19	Windsor Post Office	Within 25 miles of SRS

Table 2. Air Monitoring Stations

Sample ID	Location	Proximity to SRS
AIK	Aiken Elementary Water Tower	Within 25 miles of SRS
BGN	Burial Grounds North, SRS	Center of SRS
JAK	Jackson, S.C.	SRS Perimeter
ABR	Allendale Barricade	SRS Perimeter
ALN	Allendale, S.C.	Background
SCT	Snelling, S.C.	SRS Perimeter
DKN	Dark Horse	SRS Perimeter
NEL	New Ellenton, S.C.	SRS Perimeter

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Figure 1. DOE-SR and DHEC Comparison of Average Gross Alpha for Total Suspended Particulates at the SRS Perimeter (SRNS 2013-2017, DHEC 2014a, 2015-2017)

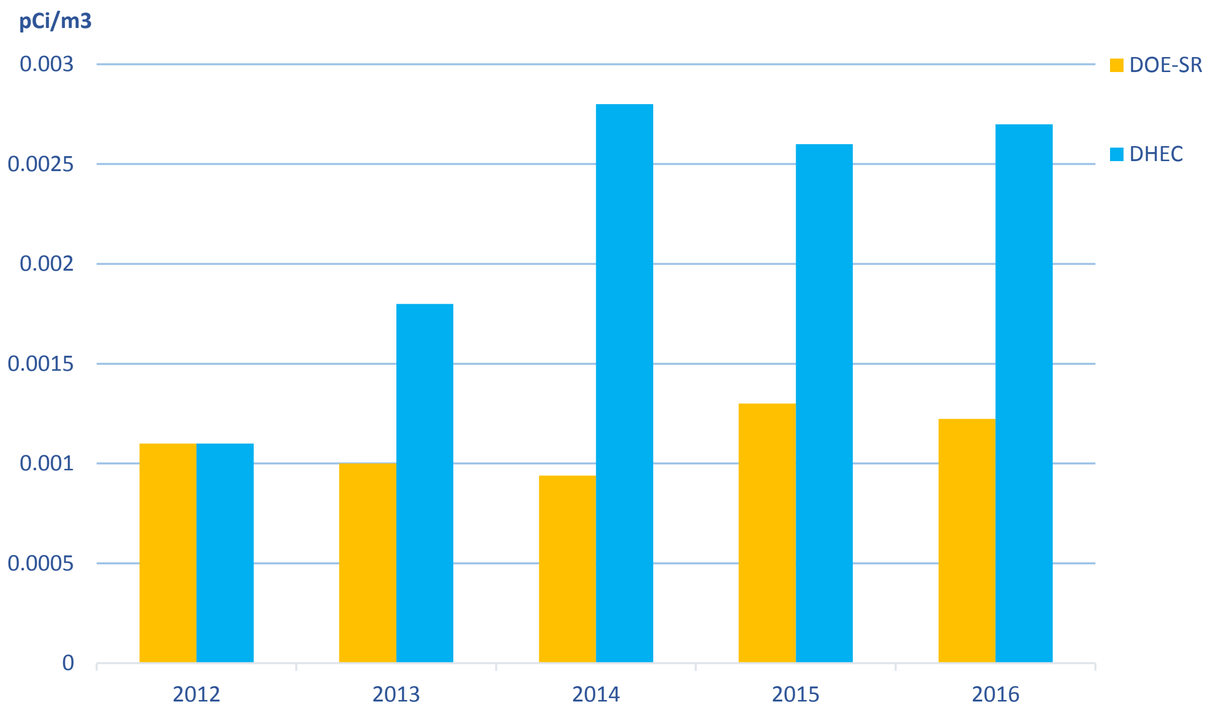

Figure 2. DOE-SR and DHEC Comparison of Average Gross Beta for Total Suspended Particulates at the SRS Perimeter (SRNS 2013-2017, DHEC 2014a, 2015-2017)

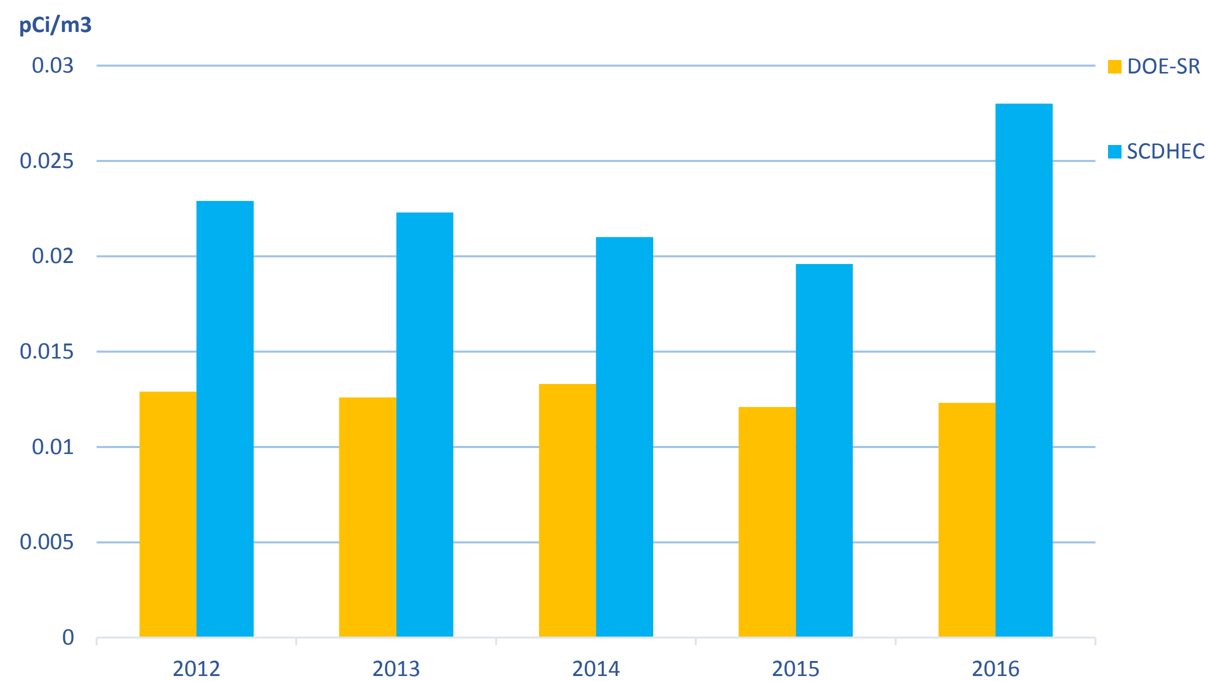

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Figure 3. DOE-SR and DHEC Comparison of Average Ambient Beta/Gamma in TLDs at the SRS Perimeter (SRNS 2013-2017, DHEC 2014a, 2015-2017)

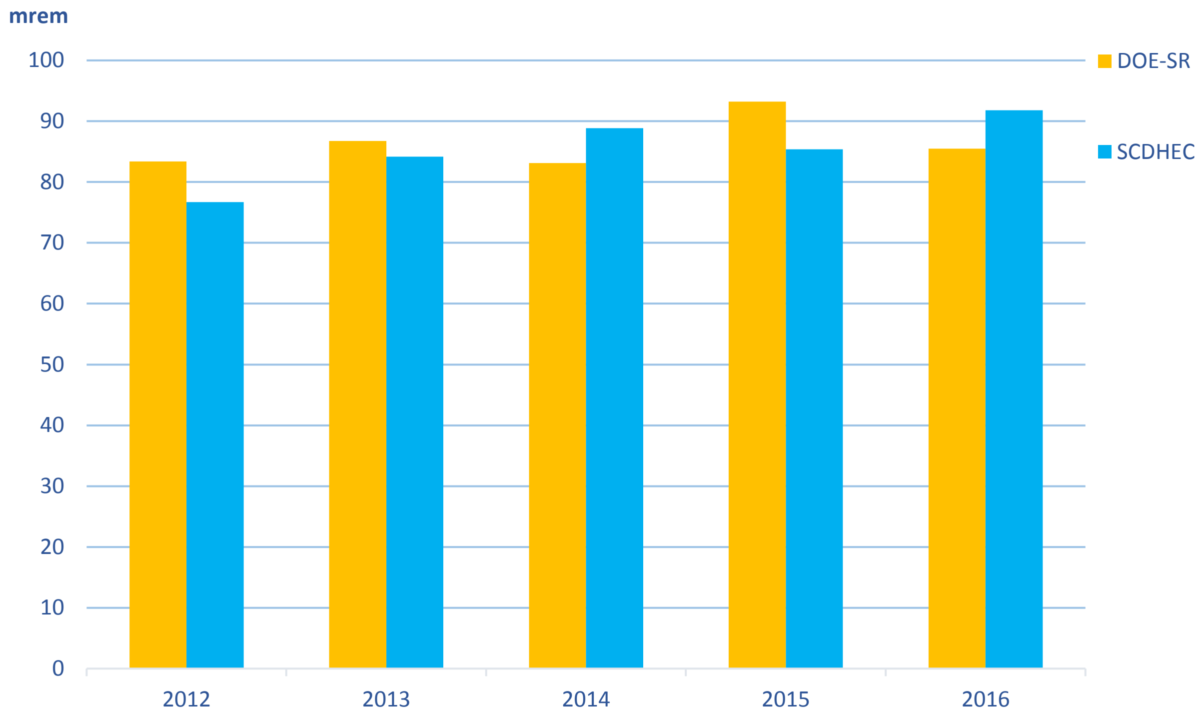

Figure 4. DOE-SR and DHEC Comparison of Average Tritium in Air at the SRS Perimeter (SRNS 2013-2017, DHEC 2014a, 2015-2017)

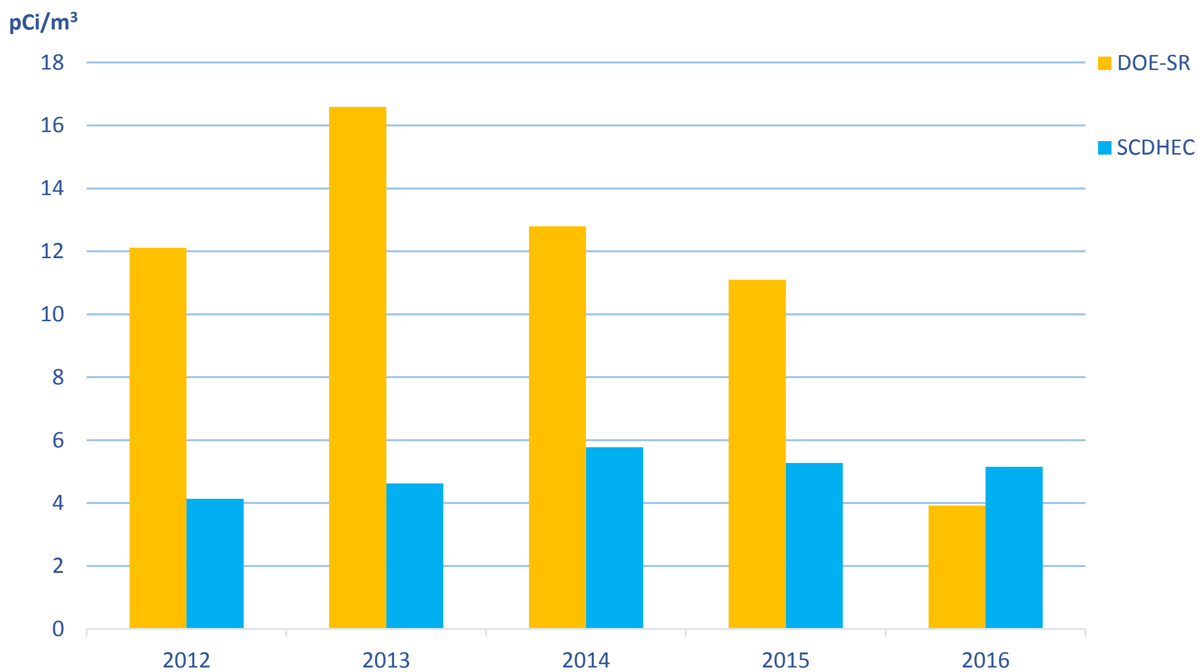

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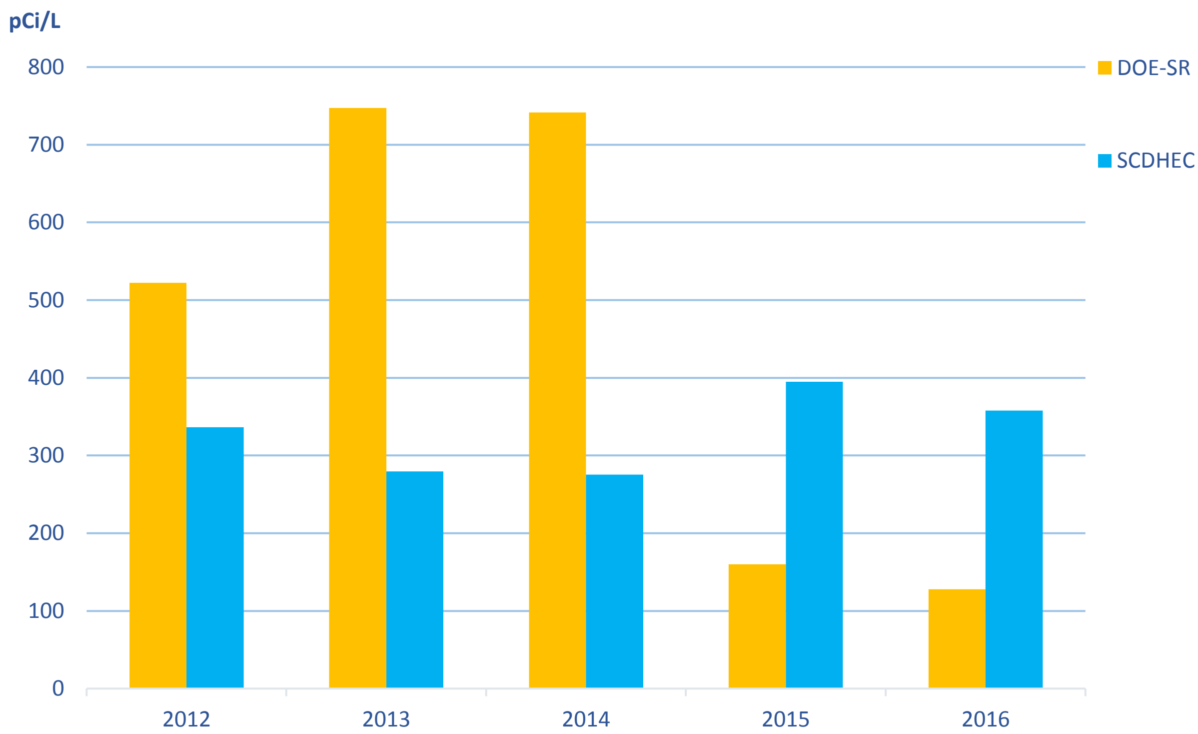
Figure 5. DOE-SR and DHEC Comparison of Average Tritium in Precipitation at the SRS Perimeter (SRNS 2013-2017, DHEC 2014a, 2015-2017)



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1.6.0 SUMMARY STATISTICS

2016 Ambient TLD Beta/Gamma Data

Sample ID	Average mrem	Standard Deviation mrem	Median mem	Minimum mrem	Maximum mrem
TLD-01	18.65	2.78	18.85	15.60	21.30
TLD-02	30.50	2.92	30.75	27.00	33.50
TLD-03	21.83	2.81	22.85	17.80	23.80
TLD-04	19.08	4.30	18.80	14.90	23.80
TLD-05	24.90	3.56	24.65	21.70	28.60
TLD-06	19.87	4.62	17.40	17.00	25.20
TLD-07	17.20	3.76	17.10	13.90	20.70
TLD-08	25.28	4.17	24.70	21.10	30.60
TLD-09	24.90	3.72	25.35	20.60	28.30
TLD-10	22.58	3.65	22.65	18.90	26.10
TLD-11	22.43	2.55	22.55	19.60	25.00
TLD-12	22.53	4.12	22.85	18.00	26.40
TLD-13	22.83	4.35	22.80	18.00	27.70
TLD-14	27.63	3.47	26.55	25.00	32.40
TLD-15	26.40	3.48	26.50	23.00	29.60
TLD-16	26.95	4.99	27.25	22.00	31.30
TLD-17	28.60	5.20	28.55	24.00	33.30
TLD-18	21.68	4.68	21.25	17.00	27.20
TLD-19	23.18	4.37	23.95	18.00	26.8 0

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SUMMARY STATISTICS

2016 Air Station Gross Alpha Data in pCi/m^3

Location	Average	Standard Deviation	Median	Minimum	Maximum	Number of Detects	Number of Samples
Allendale Barricade (ABR)	0.0026	0.0010	0.0026	0.0009	0.0054	48	52
Allendale, S.C. (ALN)	0.0030	0.0013	0.0027	0.0010	0.0059	52	52
Snelling, S.C. (SCT)	0.0027	0.0011	0.0024	0.0010	0.0056	52	52
Dark Horse (DKH)	0.0027	0.0011	0.0025	0.0010	0.0057	52	52
Aiken Elementary Water Tower (AIK)	0.0031	0.0012	0.0030	0.0010	0.0057	51	51
New Ellenton, S.C. (NEL)	0.0028	0.0012	0.0027	0.0010	0.0062	49	49
Jackson, S.C. (JAK)	0.0028	0.0010	0.0026	0.0006	0.0054	52	52
Burial Ground North (BGN)	0.0029	0.0012	0.0027	0.0006	0.0053	52	52

2016 Air Station Gross Beta Data in pCi/m^3

Location	Average	Standard Deviation	Median	Minimum	Maximum	Number of Detects	Number of Samples
Allendale Barricade (ABR)	0.0210	0.0073	0.0195	0.0067	0.0481	48	52
Allendale, S.C. (ALN)	0.0214	0.0078	0.0193	0.0103	0.0516	52	52
Snelling, S.C. (SCT)	0.0220	0.0072	0.0202	0.0122	0.0465	52	52
Dark Horse (DKH)	0.0215	0.0069	0.0198	0.0112	0.0457	52	52
Aiken Elementary Water Tower (AIK)	0.0237	0.0075	0.0222	0.0121	0.0481	51	51
New Ellenton, S.C. (NEL)	0.0220	0.0077	0.0203	0.0102	0.0495	49	49
Jackson, S.C. (JAK)	0.0224	0.0074	0.0209	0.0119	0.0496	52	52
Burial Ground North (BGN)	0.0232	0.0077	0.0215	0.0090	0.0510	52	52

SUMMARY STATISTICS

2016 Air Station Tritium Data in pCi/m³

Location	Average	Standard Deviation	Median	Minimum	Maximum	Number of Detects	Number of Samples
Allendale Barricade (ABR)	4.34	0.73	4.27	<LLD	5.65	4	12
Allendale, S.C. (ALN)	NA	NA	NA	<LLD	<LLD	0	12
Snelling, S.C. (SCT)	5.75	2.80	5.42	<LLD	12.32	9	12
Dark Horse (DKH)	5.06	1.86	4.03	<LLD	9.00	10	12
Aiken Elementary Water Tower (AIK)	ND	NA	NA	<LLD	<LLD	0	12
New Ellenton, S.C. (NEL)	5.36	1.07	5.39	<LLD	6.69	10	11
Jackson, S.C. (JAK)	5.26	1.40	4.80	<LLD	7.43	9	12
Burial Ground North (BGN)	199.77	125.01	155.06	69.40	501.00	12	12

2016 Tritium in Precipitation Data in pCi/L

Location	Average	Standard Deviation	Median	Minimum	Maximum	Number of Detects	Number of Samples
Allendale Barricade (ABR)	267	NA	NA	<LLD	267	1	12
Allendale, S.C. (ALN)	867.50	619.76	652.50	<LLD	1776.00	4	12
Snelling, S.C. (SCT)	449	NA	NA	<LLD	449	1	12
Dark Horse (DKH)	351	NA	NA	<LLD	351	1	12
Aiken Elementary Water Tower (AIK)	ND	NA	NA	NA	NA	0	12
New Ellenton, S.C. (NEL)	417.50	123.50	417.50	<LLD	541.00	2	12
Jackson, S.C. (JAK)	394	NA	NA	<LLD	394	1	12
Burial Ground North (BGN)	3355.09	3969.48	1640.00	768.08	12216.00	11	12

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Chapter 2 Ambient Groundwater Monitoring Adjacent to SRS

2.1.0 PROJECT SUMMARY

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

Monitoring these wells allows DHEC to evaluate groundwater quality adjacent to SRS, compare results with historical data, determine any potential SRS contaminant migration offsite, expand current ambient water quality databases, and provide the public with independently generated, region specific, groundwater quality information.

Groundwater samples are collected from wells within a 15-mile site boundary and background samples are collected from available municipal and private groundwater wells located between 30 and 100 miles from the SRS centerpoint. A 15-mile sampling perimeter was selected based on regional well availability, and comparative review of known or suspected sources of groundwater contamination and local groundwater flow patterns. The project map in Section 2.4.0 depicts the network groundwater well locations, the extent of the study area, and the wells sampled in 2016. DHEC evaluates five aquifer zones (Upper Three Runs, Gordon, Crouch Branch, McQueen Branch, and the Piedmont Hydrogeologic Province) from the water table.

2.2.0 RESULTS AND DISCUSSION

Groundwater Monitoring Summary Statistics can be found in Section 2.6.0 and all Groundwater Monitoring Data can be found in the 2016 DHEC Data File.

DHEC collected groundwater from seven private and municipal wells in 2016. Based on a review of the wet chemistry, metals, tritium, gross alpha, non-volatile beta, and gamma-emitting radioisotope analytical data provided by the DHEC analytical and radiological laboratories, various contaminants were detected in the groundwater wells sampled. See Section 2.5.0, Table 1 for a list of the network of sampling wells and their locations.

Contaminants commonly found in SRS groundwater include: volatile organic compounds (VOCs), metals, and tritium. In the event known contaminants are found in wells located within the DHEC sampling network, the affected wells would be investigated further to help determine the source.

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 DHEC, DNR, and the United States Geological Survey (USGS) have confirmed the presence of naturally occurring radionuclides in groundwater (ATSDR 2007).

Gross alpha was detected in one well and non-volatile beta was detected in another well sampled in 2016. Neither of these detections exceeded the United States Environmental Protection Agency (EPA) drinking water Maximum Contaminant Level (MCL) of 15 pCi/L for gross alpha and 50 pCi/L for non-volatile beta (EPA 2002d).

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There were no tritium or gamma detections in the groundwater samples in 2016.

The presence of metals and other nonradiological contaminants in the environment can be attributed to man-made processes (industrial manufacturing), agricultural activities, and the natural breakdown of mineral deposits. A review of detected metal and nonradiological contaminants indicates their limited presence and concentration is most likely due to the erosion of natural deposits and agricultural activities in the case of total nitrate/nitrite. Additionally, the position of these wells, as related to SRS's centrally located process areas suggests the theory of other natural and manmade sources.

In 2016 seven groundwater samples were collected for VOCs, nitrate/nitrite, metals, mercury, and turbidity. All detected non-radiological contaminants were below their respective MCLs and/or action levels except for in one well, PO6001, where lead was detected in a single sample at a concentration of 0.023 mg/L. The lead level detected in this well is above the EPA established action level for lead of 0.015 milligrams per liter (mg/L). Elevated lead levels in groundwater wells are often the result of naturally occurring lead deposits (ATSDR 2007).

2.3.0 CONCLUSIONS AND RECOMMENDATIONS

DOE-SR collects groundwater samples from a separate onsite monitoring well network, therefore, direct DHEC offsite groundwater comparisons could not be made. However, the 2016 SRS report identifies numerous areas of groundwater contamination throughout SRS property. Various contaminants such as VOCs, tritium, gross alpha/beta radionuclides, and strontium-90 have been found in these areas (SRNS 2017). Contaminants detected in the 2016 DHEC groundwater sampling event include gross alpha, gross non-volatile beta, barium, copper, nitrate/nitrite and lead.

Due to identified areas of groundwater contamination on SRS, DHEC will continue to monitor groundwater quality to identify any future SRS offsite contaminant migration.

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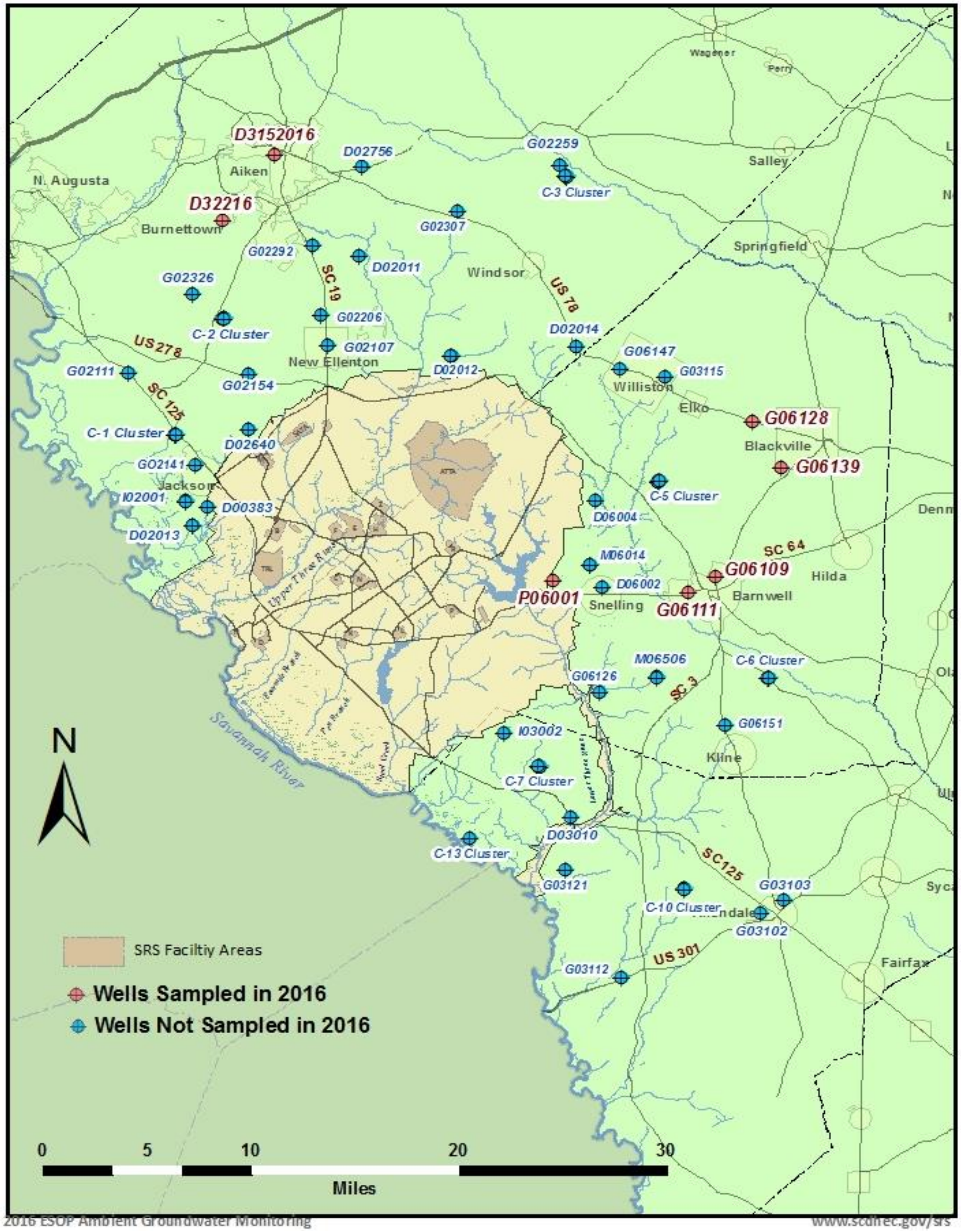
2.4.0 MAP

2016 Groundwater Sampling Locations



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2.5.0 TABLES AND FIGURES

Table 1. DHEC Groundwater Monitoring Well Network

Well Number	Well Name	Sample Year	Top of Casing Elevation (ft amsl)	Total Depth (ft bgs)	Aquifer
G02292	Hunter's Glen	2015	unknown	210	SP
G02206	Oak Hill Subdivision	2015	445	240	SP
G02107	New Ellenton	2015	421	425	CB
G02259	Aiken State Park	2015	262	*	SP
G02154	Talatha Water District	2015	250	185	CB
G02111	Beech Island Water District	2015	380	360	CB
G02326	ORA Site	2015	300	397	MB
D02014	Messer Well	2015	unknown	144	SP
D02013	Cowden Plantation, Well 2	2015	124	*	SP
I02001	Cowden Plantation, Well 1	2015	132	*	CB
D02011	Mettlen Well	2015	400	180	SP
D02012	Windsome Plantation, House Well	2015	260	*	SP
D02756	Montmorenci-Couchton WD, Well 2	2015	508	363	CB
D02640	Green Pond Road	2015	*	222	*
D00383	Brown Road	2015	*	*	*
D3152016	444 South Boundary Ave. SW	**2016**	*	200	*
D32216	1015 Richardsons Lake Road	**2016**	*	*	*
G06109	Barnwell, Hwy. 3	**2016**	230	146	UTR
G06111	Barnwell, Rose St.	**2016**	220	166	UTR
G06128	Edisto Station	**2016**	322	360	GOR
G06139	Barnwell State Park	**2016**	248	163	UTR
P06001	Allied General Nuclear, Well 1	**2016**	250	*	MB
I03002	Ingrim Residence	2017	*	*	UTR
M06004	Chem Nuclear WO0061	2017	254.52	401	CB
M06014	Chem Nuclear WO0071	2017	255.33	250	GOR
M06010	Chem Nuclear WO0069	2017	254.28	145	UTR
D03010	Martin Post Office	2017	108	105	UTR
I03002	Ingrim Residence	2017	*	*	UTR
G03102	Allendale, Water St.	2017	201	343	UTR
G03103	Allendale, Googe St.	2017	180	347	UTR
G03112	Allendale Welcome Center	2017	143	100	UTR
G06151	Chappels Labor Camp	2017	250	260	UTR
G03121	Archroma	2017	180	812	CB
G03115	Martin District Fire Department	2017	*	*	*
G06126	Starmet (Carolina Metals)	2017	200	323	GOR
D02241	Jackson	2017	225	105	SP
G06147	Williston, Halford St.	2017	352	530	CB
D06002	Moore Well	2017	240	*	UTR
D06004	J. Williams Well	2017	245	76.15	UTR

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Table 1. (continued) DHEC Groundwater Monitoring Well Netwok

Well Number	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
M02204	SCDNR Cluster C-02, AIK-818	2013	418.3	425	MB
M02205	SCDNR Cluster C-02, AIK-817	2013	418.9	535	MB
M02303	SCDNR Cluster C-03, AIK-847	2013	299	193	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
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
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
D00383	Brown Road	2014	*	*	*
D02640	Green Pond Road	2014	*	222	*

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

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2.6.0 SUMMARY STATISTICS

2016 Nonradiological Groundwater Data

mg/L	Average Concentration	Standard Deviation	Median	Minimum	Maximum	Number of Samples	Number of Detections
Barium	0.061	0.008	0.061	0.055	0.066	7	2
Copper	0.029	0.021	0.023	0.012	0.052	7	3
Lead	0.013	0.015	0.013	0.002	0.023	7	2
Nitrate/Nitrite	0.45	0.57	0.19	0.03	1.5	7	6

Note: Values are based upon detections only

2.7.0 Regional Geology

The study area, including SRS, is 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. For a more detailed review of regional geology and hydrogeology, refer to the DHEC 1997 Annual Report.

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Chapter 3 Radiological Monitoring of Drinking Water Adjacent to SRS

3.1.0 PROJECT SUMMARY

The Drinking Water Monitoring Project evaluates drinking water quality in communities that could potentially be impacted by SRS operations. DHEC 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 of SRS. Additionally, DHEC provides analytical data from this project for comparison to published DOE-SR data. The project objectives are to collect monthly composite drinking water samples from four Savannah River water-fed systems at one location upstream from SRS (North Augusta) as well as three locations downstream from SRS (Purrysburg Beaufort/Jasper (B/J), Chelsea B/J, and Savannah, Georgia). Additionally, semi-annual grab samples are collected from 19 selected public drinking water systems not served by the Savannah River, located outside of the SRS perimeter, and up to 30 miles from the center point of SRS (Section 3.4.0, Map and Section 3.5.0, Table 1).

In 2016, DOE-SR collected drinking water from two surface water-fed systems (North Augusta and Purrysburg B/J) that are colocated with the DHEC Savannah River-fed systems. Currently, DOE-SR does not conduct drinking water sampling from other public systems off SRS property. DHEC and DOE-SR analyze all samples for gross alpha, non-volatile beta, gamma-emitting radionuclides, and tritium.

3.2.0 RESULTS AND DISCUSSION

Drinking Water Monitoring Summary Statistics can be found in Section 3.6.0 and all Drinking Water Monitoring Data can be found in the 2016 DHEC Data File.

In 2016, DHEC and DOE-SR detected tritium above the LLD only in the Savannah River-fed systems downstream of SRS. The DHEC tritium detectable average for all systems downstream of SRS (Purrysburg B/J, Chelsea B/J and Savannah, Georgia), was 307 pCi/L and the DOE-SR average was 254 pCi/L. These activities are well below the EPA-established 20,000 pCi/L drinking water limit (EPA 2002d). Section 3.5.0, Figure 1 illustrates the DHEC trending data and Figure 2 illustrates DHEC and DOE-SR comparison for Savannah River water-fed systems over the past five years.

Gamma-emitting radionuclides of concern (Section 3.5.0, Table 2) were not detected above the LLD and have not been detected for any of the drinking water samples collected by DHEC or DOE-SR since 2002.

DHEC detected gross alpha in three samples from the drinking water systems not supplied by the Savannah River at an average of 4.42 pCi/L. DHEC did not detect gross alpha in the Savannah River fed-systems, however DOE-SR had one detection in the upstream location (North Augusta) of 0.28 pCi/L.

DHEC detected non-volatile beta at two sample locations from the drinking water systems not supplied by the Savannah River at an average of 5.48 pCi/L. DHEC and DOE-SR both had detections of gross beta in the upstream and downstream Savannah River-fed systems (Section 3.5.0, Table 3). Speciation is not conducted for gross alpha or non-volatile beta unless there is a detection above their respective EPA MCLs of 15 pCi/L and 50 pCi/L (EPA 2002d).

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Section 3.5.0, Figures 3 and 4 illustrate the trends in gross alpha and non-volatile beta activities over the past five years. Although there were several detections above the LLD during the 2016 reporting period, none of the analytes exceeded their respective EPA-established MCLs. Gross alpha and non-volatile beta, at their observed concentrations, are not considered to be known human health risks.

3.3.0 CONCLUSIONS AND RECOMMENDATIONS

Tritium continues to be the most abundant radionuclide detected in public drinking water supplies potentially impacted by SRS. Tritium was detected in both groundwater and surface water systems during 2016. Observed tritium activities were low when compared to the EPA MCL for tritium in drinking water, which is 20,000 pCi/L. Detections of gross alpha and non-volatile beta were all below their respective MCLs. DOE-SR does not sample systems not served by Savannah River water; therefore, it is of great importance that DHEC continues to monitor these off-site public water systems in the event these wells are impacted by contaminated groundwater from SRS.

The Drinking Water Monitoring Project continues to be an important source of essential data for assessing human health exposure pathways. DHEC will continue to monitor surface water quality due to the extent of the surface water contamination on SRS, and its potential to migrate and potentially impact drinking water systems downstream from SRS. Continued sampling will also provide the public with an independent source of radiological data for drinking water systems within the SRS study area.

DHEC continues to reevaluate the drinking water systems monitored by the drinking water project. Primary and background drinking water systems will be added and removed from the list of sampled drinking water systems as deemed necessary to maintain monitoring coverage. Sampling of background water systems will be done in the future, as they provide a more complete understanding of the distribution and nature of naturally occurring radionuclides in South Carolina drinking water systems.

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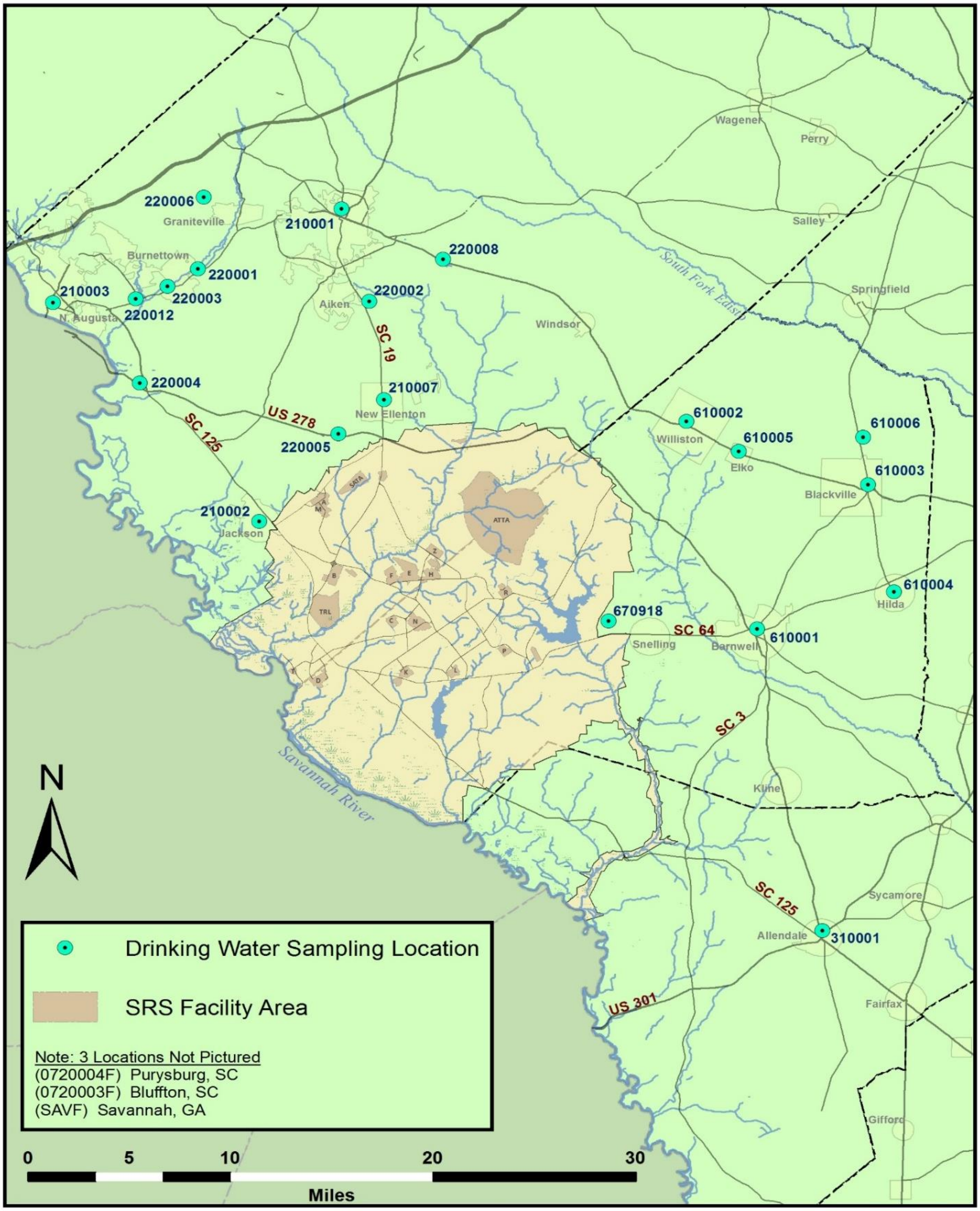
3.4.0 MAP

Drinking Water Sampling Locations



2016 ESOP Drinking Water Monitoring www.scdhec.gov/srs

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3.5.0 TABLES AND FIGURES

Table 1. Drinking Water Systems Sampled by DHEC

System Number	System Name	Number of Taps	Population
0210001	Aiken	19,444	42,286
0210002	Jackson	1,312	3,602
0210007	New Ellenton	2,417	5,763
0220001	Langley Water District	324	754
0220002	College Acres Public Water District	539	1,330
0220003	Bath Water District	315	755
0220004	Beech Island	3,320	7,916
0220005	Talatha Water District	727	1,698
0220006	Breezy Hill Water District	5,808	13,692
0220008	Montmorenci Water District	1,457	3,442
0220012	Valley Public Service Authority	2,959	6,828
0310001	Allendale	1,530	3,882
0610001	Barnwell	2,097	4,557
0610002	Williston	1,629	2,953
0610003	Blackville	1,208	2,973
0610004	Hilda	124	311
0610005	Elko	150	371
0670075	Healing Springs	1	6*
0670918	SCAT Park	11	125
0210003F	North Augusta	11,854	21,072
0720003F	Chelsea B/J	53,860	114,515
0720004F	Purrysburg B/J		
SAVF	Savannah	Unknown	168,958
	Total		
	Savannah River fed systems downstream from SRS	53,860+Savannah	283,473
	Systems not fed from the Savannah River downstream of SRS	57,226	124,316

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

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TABLES AND FIGURES

Table 2. Gamma Analyte Table

Radioisotope	Abbreviation
Actinium-228	Ac-228
Americium-241	Am-241
Beryllium-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
Plutonium-238	Pu-238
Plutonium-239/240	Pu-239/240
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 DHEC Data Comparisons

	DHEC Tritium	DOE-SR Tritium	DHEC Gross Alpha	DOE-SR Gross Alpha	DHEC Gross Non-volatile Beta	DOE-SR Non-volatile Beta
North Augusta	<LLD	<LLD	0.27	<LLD	4.71	1.86
Chelsea B/J	<LLD	NS	<LLD	NS	4.40	NS
Purrysburg B/J	309	254	<LLD	<LLD	3.94	1.62
Savannah	294	NS	<LLD	NS	ND	NS
Upstream Average	<LLD	<LLD	0.27	<LLD	4.71	1.86
Downstream Average	307	254	<LLD	<LLD	4.21	1.62

Notes.
1. NS is Not Sampled

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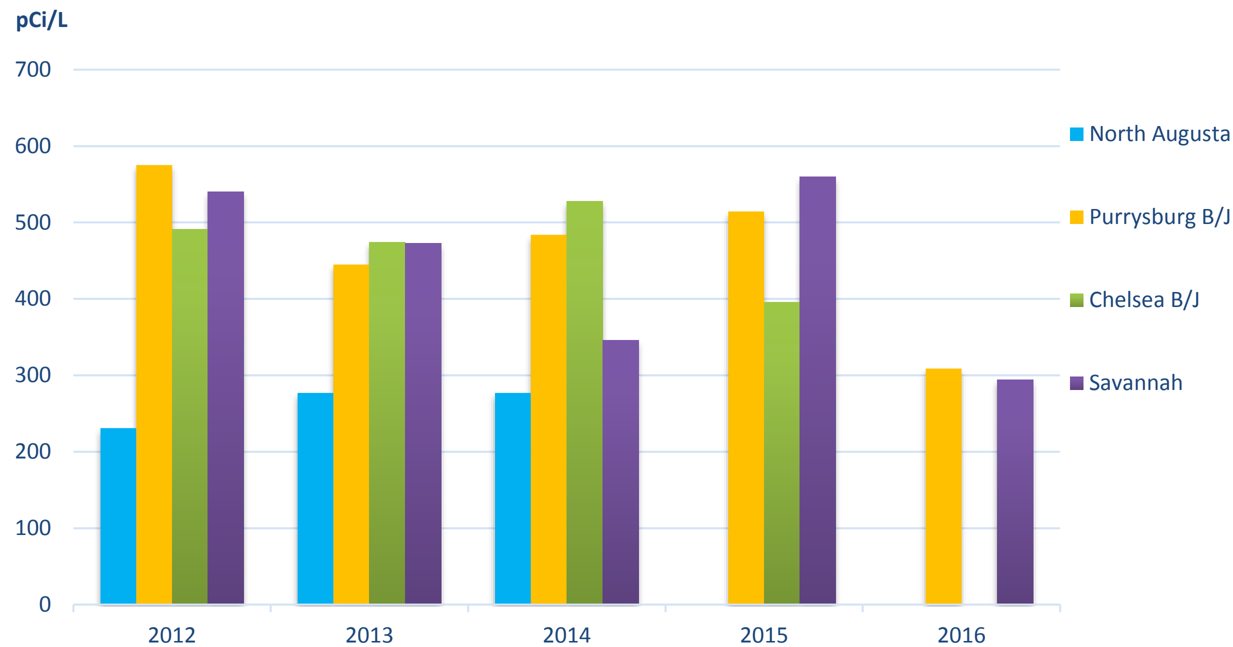
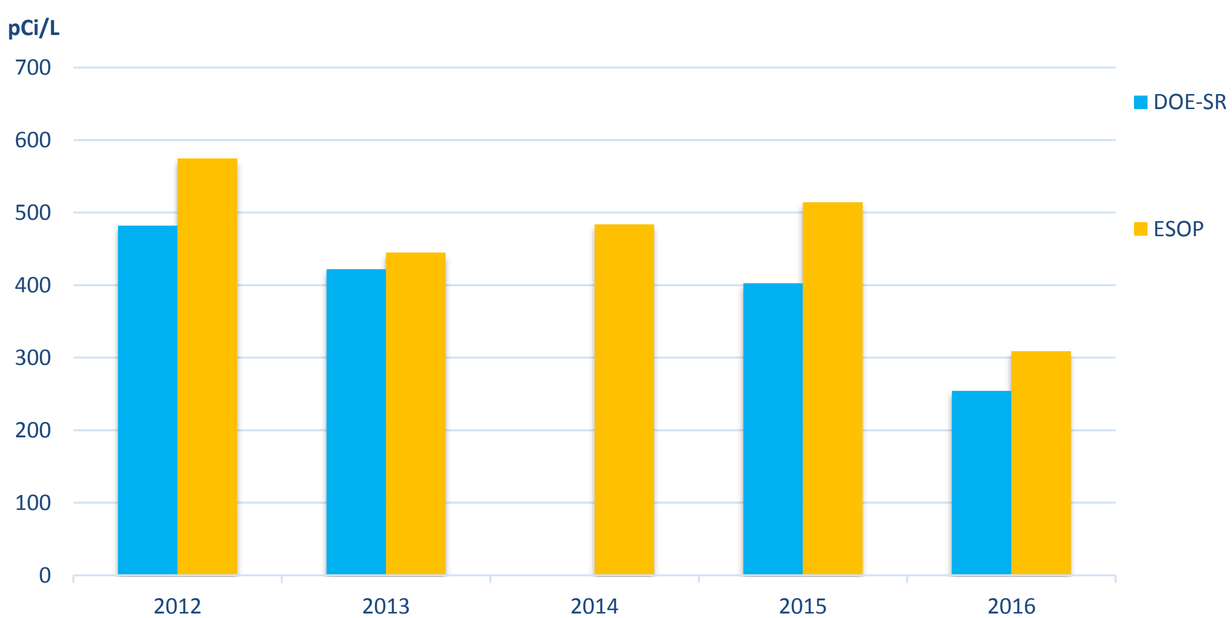
TABLES AND FIGURES

Figure 1. DHEC Yearly Tritium Averages in Savannah River Water Fed Systems (DHEC 2014a, 2015-2017)



Note: Tritium was not detected at North Augusta in 2015 and 2016, or Chelsea B/J in 2016.

Figure 2. DHEC and DOE-SR Tritium Detection Averages Purrysburg B/J (SRNS 2013-2017, DHEC 2014a, 2015-2017)



Note: DOE-SR did not sample Purrysburg B/J in 2014.

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TABLES AND FIGURES

Figure 3. DHEC Yearly Gross Alpha Averages in Drinking Water Systems (DHEC 2014a, 2015-2017)

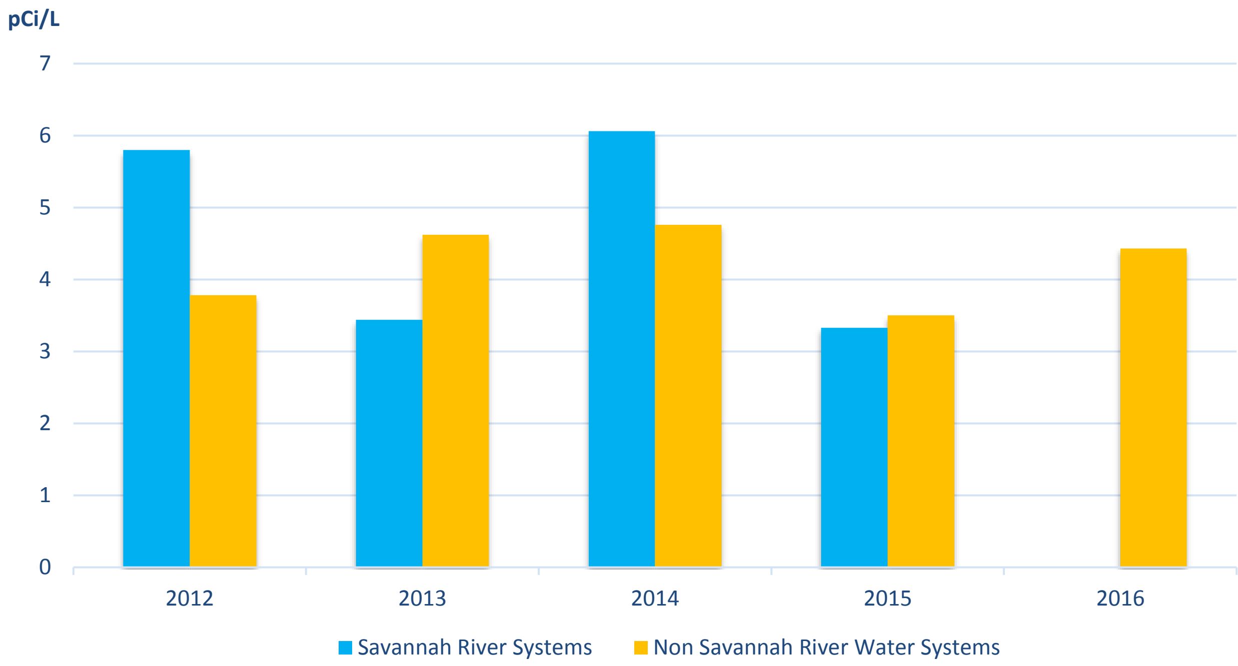
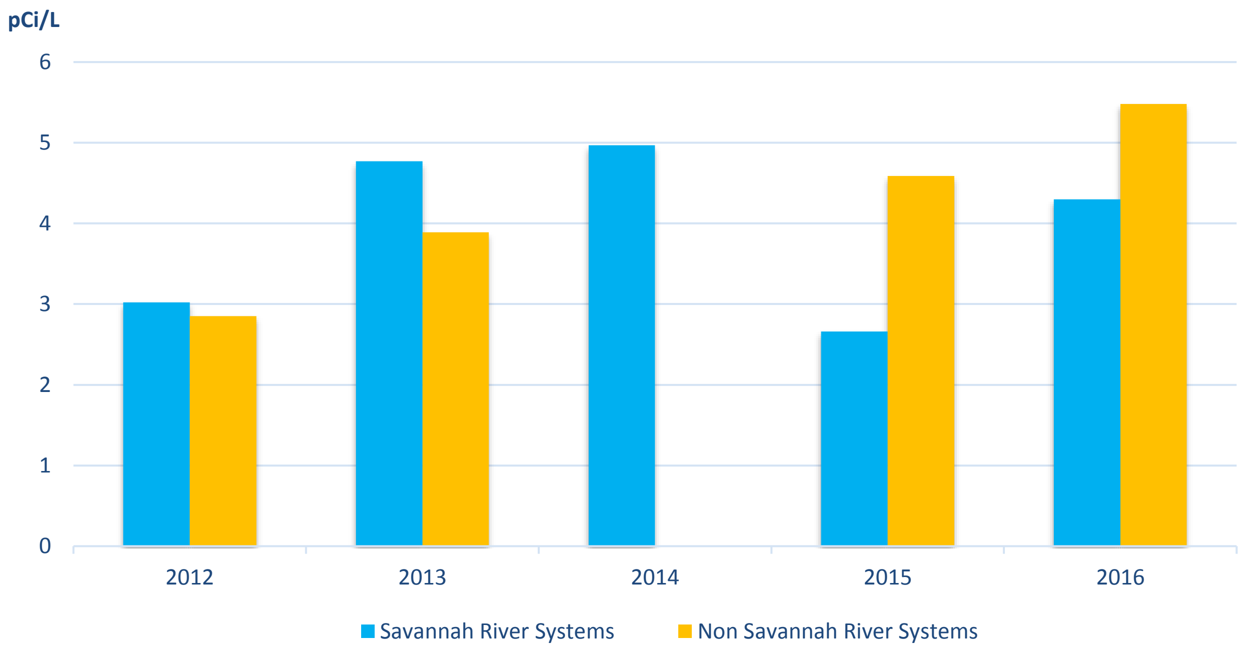


Figure 4. DHEC Yearly Non-Volatile Beta Averages in Drinking Water Systems (DHEC 2014a, 2015-2017)



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3.6.0 SUMMARY STATISTICS

2016 Savannah River Fed Water System Data

Gross Non-volatile Beta (pCi/L)							
System Name	Average	Standard Deviation	Median	Minimum	Maximum	Number of Detects	Number of Samples
North Augusta	4.71	NA	4.71	<LLD	4.71	1	10
Chelsea B/J	4.40	NA	4.52	<LLD	4.61	3	7
City of Savannah	ND	NA	ND	<LLD	<LLD	0	7
Purrysburg B/J	3.94	0.33	3.94	<LLD	4.17	2	10
Yearly Average of Detectable Gross Beta			4.30				
Standard Deviation			0.39				

Tritium (pCi/L)							
System Name	Average	Standard Deviation	Median	Minimum	Maximum	Number of Detects	Number of Samples
North Augusta	ND	NA	ND	<LLD	<LLD	0	4
Chelsea B/J	ND	NA	ND	<LLD	<LLD	0	4
City of Savannah	294	NA	294	<LLD	294	1	4
Purrysburg B/J	309	31.78	298	<LLD	365	5	7
Yearly Average of Detectable Tritium			307				
Standard Deviation			29.11				

Notes:

1. ND is Not Detected
2. NA is Not Applicable

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Chapter 4 Radiological Monitoring of Surface Water on and Adjacent to SRS

4.1.0 PROJECT SUMMARY

The focus of the Radiological Monitoring of Surface Water (RSW) project is monitoring and surveillance of the streams and creeks on SRS as well as the Savannah River. 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 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. DHEC supports DOE-SR’s objectives to ensure the primary goal of drinking water safety is established and met.

The RSW project collects surface water samples from 13 specific locations within and outside of the SRS boundary as part of an ambient sampling network (Section 4.4.0, Map). Section 4.5.0, Table 1, identifies sample ID, location, rationale, and frequency. Some locations were chosen because they are considered public access locations. All but one of the public access locations are downstream of SRS, providing a potential means for exposure to radionuclides. Jackson Boat Landing (SV-2010) is upstream from SRS activities and is a public access location.

Quarterly samples are collected for tritium analysis from the four creek mouths that flow from SRS directly into the Savannah River (Upper Three Runs 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 was 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 five SRS streams that flow to the Savannah River. Samples for tritium analysis are collected from seven locations with automatic water samplers. Additionally, a grab sample is collected from Johnson’s Boat Landing (SV-2080) and U.S. Highway 301 at the Savannah River (SV-118).

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 Upper Three Runs, Fourmile Branch, and Steel Creek. This monitoring was established for early detection of unplanned releases from SRS source term areas. An additional sample location was added in 2015 at McQueen Branch. This location was added to monitor the Saltstone low level waste operations. The McQueen Branch sample is a monthly composite that is collected by DOE and split with DHEC. These samples are collected as unofficial results for notification purposes only.

In August of 2007, DHEC began collecting ambient grab samples from a location on Lower Three Runs. This sampling was conducted in response to elevated tritium levels detected in groundwater samples near the Energy Solutions (formerly Chem-Nuclear) facility in Snelling, South Carolina. The purpose of adding this location was to differentiate any potential tritium contributions to Lower Three Runs from Energy Solutions and SRS activities.

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Quarterly sampling for I-129 and Tc-99 is conducted at the supplemental location on Fourmile Branch due to concerns that these are possible constituents related to effluent from the burial grounds, and that this effluent could enter the surface water.

4.2.0 RESULTS AND DISCUSSION

Radiological Monitoring of Surface Water Summary Statistics can be found in Section 4.6.0 and all Radiological Monitoring of Surface Water Data can be found in the 2016 DHEC Data File.

DHEC data from 2016 was compared to DOE-SR reported results (Section 4.5.0, Tables 3, 4, and 5). The DHEC and DOE-SR colocated sampling sites were Tims Branch at Road C, Upper Three Runs Creek at Road A, Fourmile Branch at Road A-12.2, Pen Branch at Road A-13.2, Steel Creek at Road A, Lower Three Runs Creek at Road B and the Savannah River at U.S. 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

In 2016, DHEC and DOE-SR had detections for tritium at all colocated sample locations except TB-5 near Road C, where DOE-SR reported no detections (Section 4.5.0, Table 3). DHEC average tritium activities at Jackson Boat Landing (SV-2010) and Upper Three Runs Creek at United States Forestry Service (USFS) Road 2-1 (SV-2027) were lower than average tritium activities at all the other ambient sample locations. These locations are upstream from SRS impacts and are considered background locations. DHEC and DOE-SR samples indicate that Fourmile Branch and Pen Branch have the highest average tritium activity of all SRS streams. The 2016 DHEC and DOE-SR tritium results appear to be consistent with historically reported data values (Section 4.5.0, Figures 2-7). Section 4.5.0, Figure 1 shows trending data for DHEC 2012-2016 tritium averages.

Tritium activity in the Savannah River at the creek mouths of the four SRS streams was monitored quarterly by DHEC in 2016. Samples collected at the creek mouth of Fourmile Branch (SV-2015) had the highest average tritium activity of all creek mouth locations.

Gamma

As part of a gamma spectroscopy analysis, samples were analyzed for gamma-emitting radionuclides (Section 4.5.0, Table 2). DHEC had Cs-137 detections from Fourmile Branch at Road C (SV-2044) with an average of 5.02 pCi/L. DHEC had no other gamma detections above the Minimum Detectable Activity (MDA) for analytes that are not Naturally Occurring Radioactive Material (NORM).

DOE-SR reported a single detection of Sr-89/90 of 1.17 pCi/L at the colocated sample site at Fourmile Branch. DOE-SR reported four single detections of Am-241 at DHEC colocated sites: Tims Branch near Road C, Upper Three Runs at Road A, Fourmile Branch at Road A, and Lower Three Runs at Road B. All detections yielded a value of 0.01 pCi/L (SRNS 2017).

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Alpha

In 2016, alpha-emitting radionuclides were detected at two of the nine DHEC locations where monthly composite samples were collected. DHEC detected gross alpha activity at two of the seven colocated sampling locations while DOE-SR detected activity at all seven colocated locations. DHEC and DOE-SR samples indicate that Tims Branch and Upper Three Runs Creek exhibit the highest alpha activity of the colocated locations (Section 4.5.0, Table 4).

Historically, SV-325 yields detections for alpha activity (DHEC 2014a, 2015-2017). 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 2016 average alpha activity at SV-325 was below the EPA MCL for drinking water of 15 pCi/L (EPA 2002c). Beginning in 2009, samples collected at this location exhibited particles of sediment and detritus. 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 planchette (EPA 2010). This sampling location is monitored for turbidity to ensure it is not a concern in collected samples.

Beta

Beta-emitting radionuclide activity was detected in four of nine locations where monthly composite samples were collected. DHEC detected gross beta activity at three of the seven colocated sampling locations while DOE-SR detected activity at all seven colocated locations (Section 4.5.0, Table 5). DHEC samples collected from Steel Creek exhibited the highest gross beta activity with a single detection of 5.05 pCi/L. DOE-SR samples collected from Fourmile Branch exhibited the highest gross beta average activity at 4.29 pCi/L (SRNS 2017).

EPA has established an MCL of 4 mrem per year for beta particle and photon radioactivity from man-made radionuclides in drinking water. The EPA screening MCL for gross beta-emitting particles for drinking water systems is 50 pCi/L minus natural potassium-40 (K-40) (EPA 2002c), and all averages were below this limit.

Iodine-129 and Technetium-99

I-129 and Tc-99 sampling of the supplemental location on Fourmile Branch was monitored on a quarterly basis by DHEC. There were I-129 detections in three of the four quarterly samples above the MDA at an average of 0.71 pCi/L. There was a Tc-99 detection in one of the four quarterly samples of 1.58 pCi/L. DHEC and DOE-SR do not have a collocated sampling site for I-129 and Tc-99. Therefore, these analytes were not compared.

Tc-99 and I-129 would be included under the EPA-established MCL of 4 mrem per year. The average concentration of Tc-99, which is assumed to yield 4 mrem per year, is 900 pCi/L. The average concentration of I-129, which is assumed to yield 4 mrem 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 mrem/year (EPA 2002c).

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4.3.0 CONCLUSIONS AND RECOMMENDATIONS

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

The 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 modifying 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, as well as past radioactive contamination that still exists due to unexpired half-lives.

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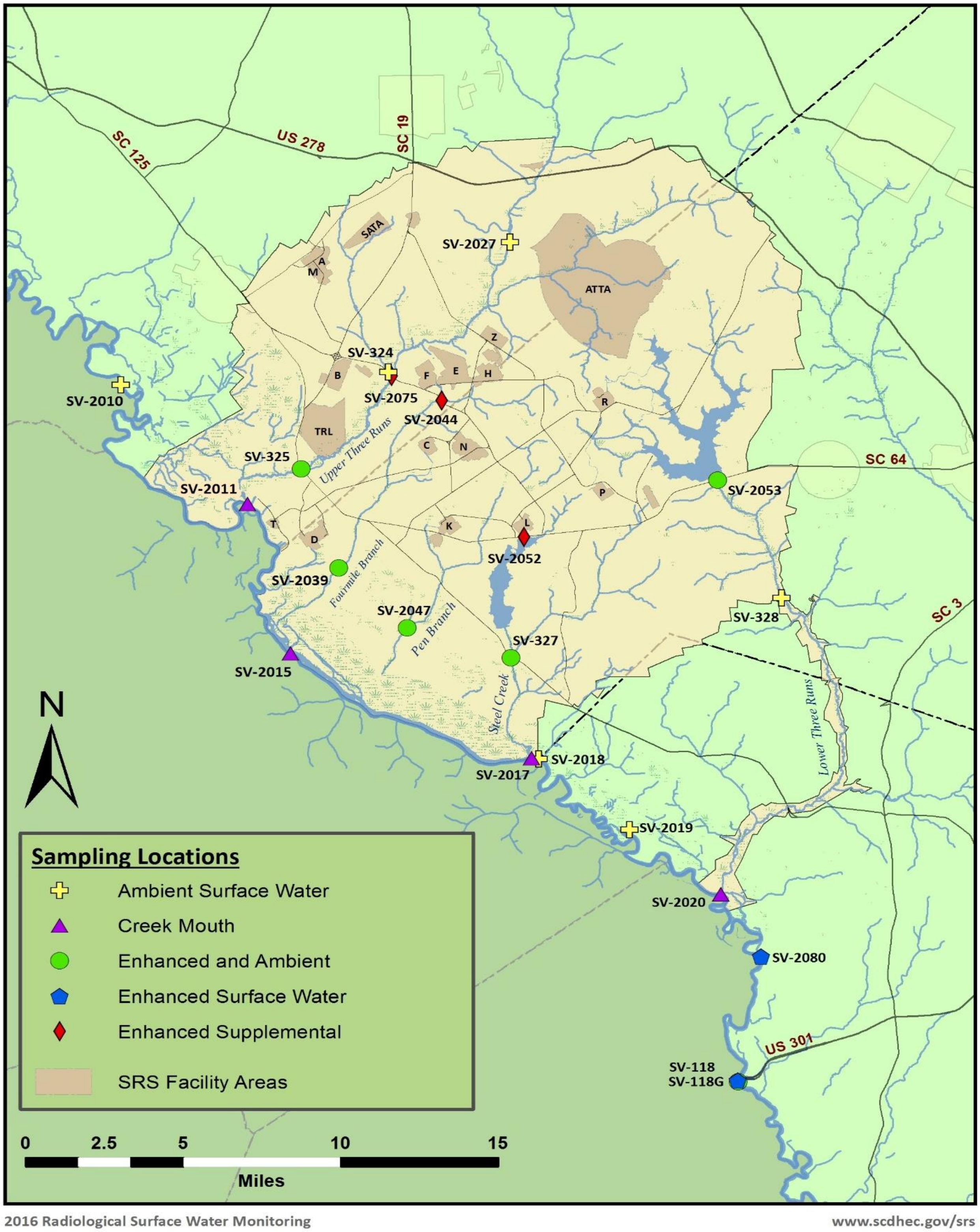
4.4.0 MAP

Radiological Surface Water Monitoring Locations



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4.5.0 TABLES AND FIGURES

Table 1. 2016 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; upstream of all SRS operations; Near Jackson population center; Up river control; River monitoring	Weekly tritium; Monthly Alpha, Beta, and Gamma composite
SV-324	Tims Branch at SRS Road C	Within SRS perimeter; Downstream of SRS operations areas; Tributary monitoring	Weekly tritium; Monthly Alpha, Beta, and Gamma composite
SV-325	Upper Three Runs Creek at S.C. 125 (SRS Road A)	Within SRS perimeter; Downstream of SRS operations areas; Tributary monitoring	Weekly tritium; Monthly Alpha, Beta, and Gamma composite
SV-2039	Fourmile Branch at Road A-12.2	Within SRS perimeter; Downstream of SRS operations areas; Tributary monitoring	Weekly tritium; Monthly Alpha, Beta, and Gamma composite
SV-2047	Pen Branch at Road A-13.2	Within SRS perimeter; Downstream of SRS operations areas; Tributary monitoring	Weekly tritium; Monthly Alpha, Beta, and Gamma composite
SV-327	Steel Creek at S.C. 125 (SRS Road A)	Within SRS perimeter; Downstream of SRS operations areas; Tributary monitoring	Weekly tritium; Monthly Alpha, Beta, and Gamma composite
SV-2018	Savannah River at RM 141 (Steel Creek Boat Landing)	Accessible to the public; Adjacent to SRS perimeter Downstream of SRS operations; River monitoring	Weekly tritium; Monthly Alpha, Beta, and Gamma composite
SV-2019	Savannah River at RM 134.5 (Little Hell Boat Landing)	Accessible to the public; Downstream of SRS operations and tributaries; River monitoring	Weekly tritium grab
SV-2080	Savannah River at RM 125 (Johnson's Boat Landing)	Accessible to the public; Downstream of SRS operations and tributaries; River monitoring	Tri-weekly tritium grab
SV-118	Savannah River at RM 118.8 (Hwy 301 Bridge)	Accessible to the public; Downstream of SRS operations and tributaries; River monitoring	Weekly tritium; Monthly Alpha, Beta, and Gamma composite
SV-328	Lower Three Runs Creek at Patterson Mill Road	Within SRS perimeter; Downstream of SRS operations and Par Pond; Tributary monitoring	Weekly tritium grab
SV-2053	Lower Three Runs Creek at Road B	Within SRS perimeter; Downstream of SRS operations and Par Pond; Tributary monitoring	Weekly tritium; Monthly Alpha, Beta, and 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 tritium grab

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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; Downstream of SRS operation areas; Tributary monitoring	Quarterly tritium
SV-2015	Fourmile Branch at RM 150.6	Accessible to public; Adjacent to SRS; Downstream of SRS operation areas; Tributary monitoring	Quarterly tritium
SV-2017	Steel Creek Mouth at RM 141.5	Accessible to public; Adjacent to SRS; Downstream of SRS operation areas; Tributary monitoring	Quarterly tritium
SV-2020	Lower Three Runs Creek at RM 129.1	Accessible to public; Adjacent to SRS; Downstream of SRS operation areas; Tributary monitoring	Quarterly tritium

Supplemental Locations

ID	Location	Rationale	Frequency
SV-2070	McQueen Branch	Downstream from Saltstone LLW Operations	Monthly gamma composite
SV-2075	Upper Three Runs Creek at Road C	Downstream from F-and H-Areas HLW Tanks	Weekly gamma composite
SV-2044	Fourmile Branch at Road C	Downstream from F-and H-Areas HLW Tanks	Weekly gamma composite
SV-2052	Steel Creek at the top of L-Lake	Downstream from P- and L- Areas	Weekly gamma composite

Notes:
1. ID is Sampling Location Identification Code Number
2. RM is River Mile
3. HLW is High Level Waste
4. LLW is Low Level Waste
5. Tri-Weekly Enhanced sample data is used for detection purposes only

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Table 2. Radiological Analytes for Gamma Spectroscopy Analysis

Radioisotope	Abbreviation
Actinium-228	Ac-228
Americium-241	Am-241
Beryllium-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
Plutonium-238	Pu-238
Plutonium-239/240	Pu-239/240
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

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Table 3. 2016 Tritium Data Comparison for DHEC 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	464	115	457	271	702	52	45
	TB-5	NA	NA	NA	<LLD	NA	12	0
Upper Three Runs Creek at Road A	SV-325	696	220	640	348	1,236	52	52
	U3R-4	598	165	541	416	943	12	12
Fourmile Branch at Road 12.2	SV-2039	30,016	5,614	31,149	8,329	38,788	52	52
	FM-6	26,467	3,789	26,250	21,600	32,400	12	12
Pen Branch at Road 13.2	SV-2047	14,607	4,253	14,910	6,269	20,515	52	52
	PB-3	13,023	3,591	14,250	7,190	17,100	12	12
Steel Creek at Road A	SV-327	2,063	492	2,077	1,037	3,345	52	52
	SC-4	1,713	340	1,835	1,110	2,250	12	12
Highway 301 Bridge at RM 118.8	SV-118	505	214	449	267	1,213	52	36
	RM 118	322	181	252	131	749	50	50
Lower Three Runs Creek at Road B	SV-2053	332	52	326	266	423	52	21
	L3R-1A	386	25	386	368	403	12	2

Notes:
1. Shaded areas represent DHEC data and unshaded areas represent DOE-SR data
2. DOE-SR data is from the SRS Environmental Data Report for 2016 (SRNS 2017)
3. ND is No Detects
4. NA is Not Applicable
5. <LLD is less than the Lower Limit of Detection

TABLES AND FIGURES

Table 4. 2016 Alpha Data Comparison for DHEC 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	3.37	0.99	3.23	1.90	4.41	12	5
	TB-5	3.87	3.93	2.15	0.82	14	12	12
Upper Three Runs Creek at Road A	SV-325	2.74	0.91	2.60	1.60	4.01	12	7
	U3R-4	3.25	3.35	1.83	1.15	13.1	12	12
Fourmile Branch at Road 12.2	SV-2039	ND	NA	NA	<MDA	<MDA	12	0
	FM-6	0.96	1.05	0.52	0.28	3.97	12	12
Pen Branch at Road 13.2	SV-2047	ND	NA	NA	<MDA	<MDA	12	0
	PB-3	0.68	0.55	0.40	0.26	1.75	12	8
Steel Creek at Road A	SV-327	ND	NA	NA	<MDA	<MDA	12	0
	SC-4	0.33	0.12	0.32	0.20	0.47	12	6
Highway 301 Bridge at RM 118.8	SV-118	ND	NA	NA	<MDA	<MDA	12	0
	RM 118	0.35	0.09	0.34	0.19	0.56	53	20
Lower Three Runs Creek at Road B	SV-2053	ND	NA	NA	<MDA	<MDA	12	0
	L3R-1A	0.20	0.00	0.20	0.20	0.20	12	2

Notes:
1. Shaded areas represent DHEC data and unshaded areas represent DOE-SR data
2. DOE-SR data is from the SRS Environmental Data Report for 2016 (SRNS 2017)
3. ND is No Detects
4. NA is Not Applicable
5. <MDA is less than the Minimum Detectable Activity

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Table 5. 2016 Beta Data Comparison for DHEC 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	ND	NA	NA	<MDA	<MDA	12	0
	TB-5	2.59	1.82	1.74	0.53	6.81	12	12
Upper Three Runs Creek at Road A	SV-325	ND	NA	NA	<MDA	<MDA	12	0
	U3R-4	1.88	1.63	1.40	0.72	6.76	12	12
Fourmile Branch at Road 12.2	SV-2039	4.77	NA	NA	<MDA	4.77	12	1
	FM-6	4.29	1.18	3.84	3.41	7.78	12	12
Pen Branch at Road 13.2	SV-2047	ND	NA	NA	<MDA	<MDA	12	0
	PB-3	1.15	0.49	1.03	0.54	1.99	12	10
Steel Creek at Road A	SV-327	ND	NA	NA	<MDA	<MDA	12	0
	SC-4	1.09	0.23	1.05	0.60	1.48	12	12
Highway 301 Bridge at RM 118.8	SV-118	4.63	NA	NA	<MDA	4.63	12	1
	RM 118	1.90	0.32	1.89	1.13	3.00	53	53
Lower Three Runs Creek at Road B	SV-2053	ND	NA	NA	<MDA	<MDA	12	0
	L3R-1A	1.34	0.36	1.24	0.85	1.89	12	12

Notes:
1. Shaded areas represent DHEC data and unshaded areas represent DOE-SR data
2. DOE-SR data is from the SRS Environmental Data Report for 2016 (SRNS 2017)
3. ND is No Detects
4. NA is Not Applicable
5. <MDA is less than the Minimum Detectable Activity

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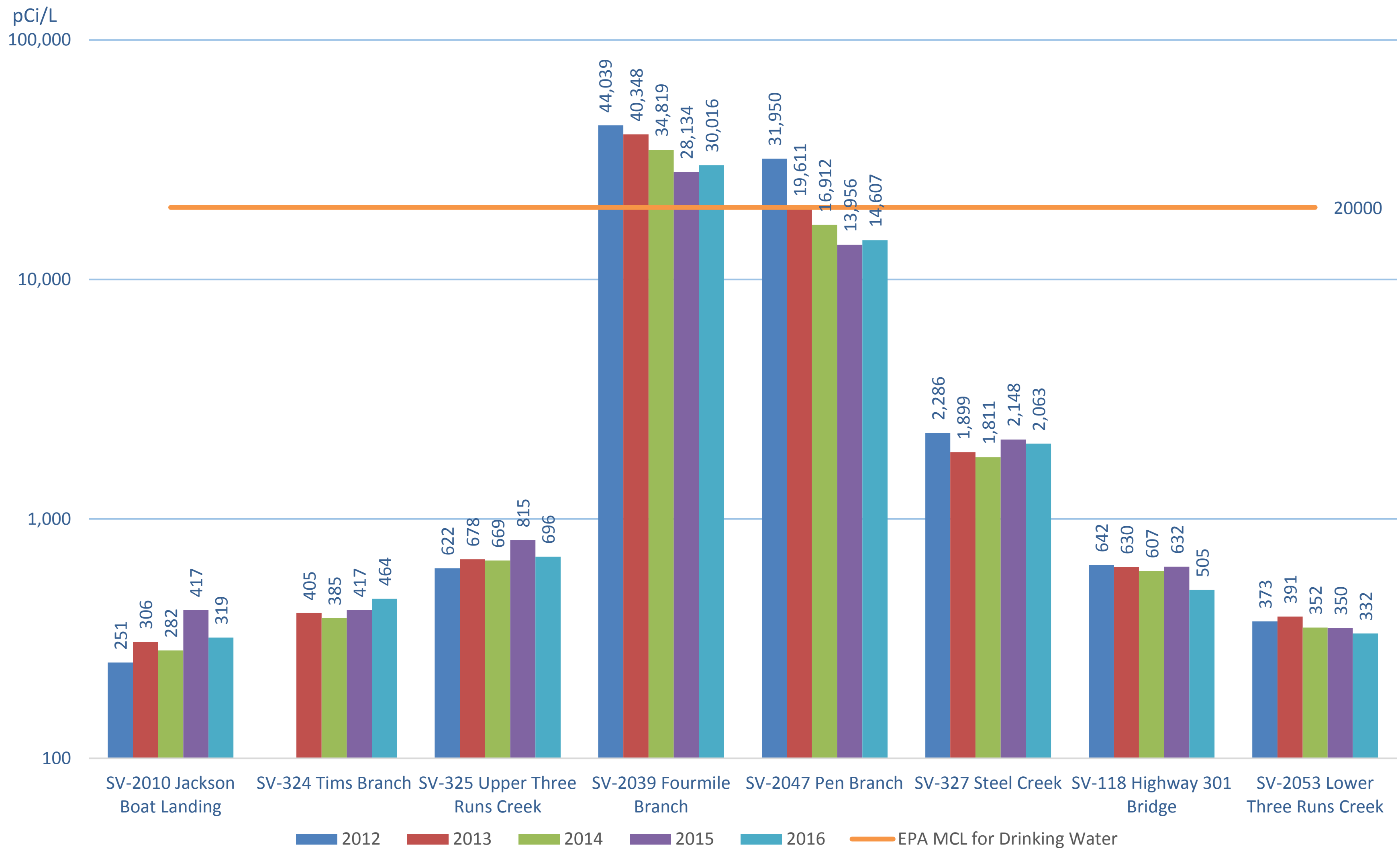
Figure 1. DHEC Average Tritium Data Trends for 2012-2016 (DHEC 2014a, 2015-2017)



Note: Tims Branch was not collected in 2012

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Figure 2. 2012-2016 Average Tritium Data Trends for DHEC and DOE-SR for Upper Three Runs Creek at S.C. Highway 125 (SRNS 2013-2017, DHEC 2014a, 2015-2017)

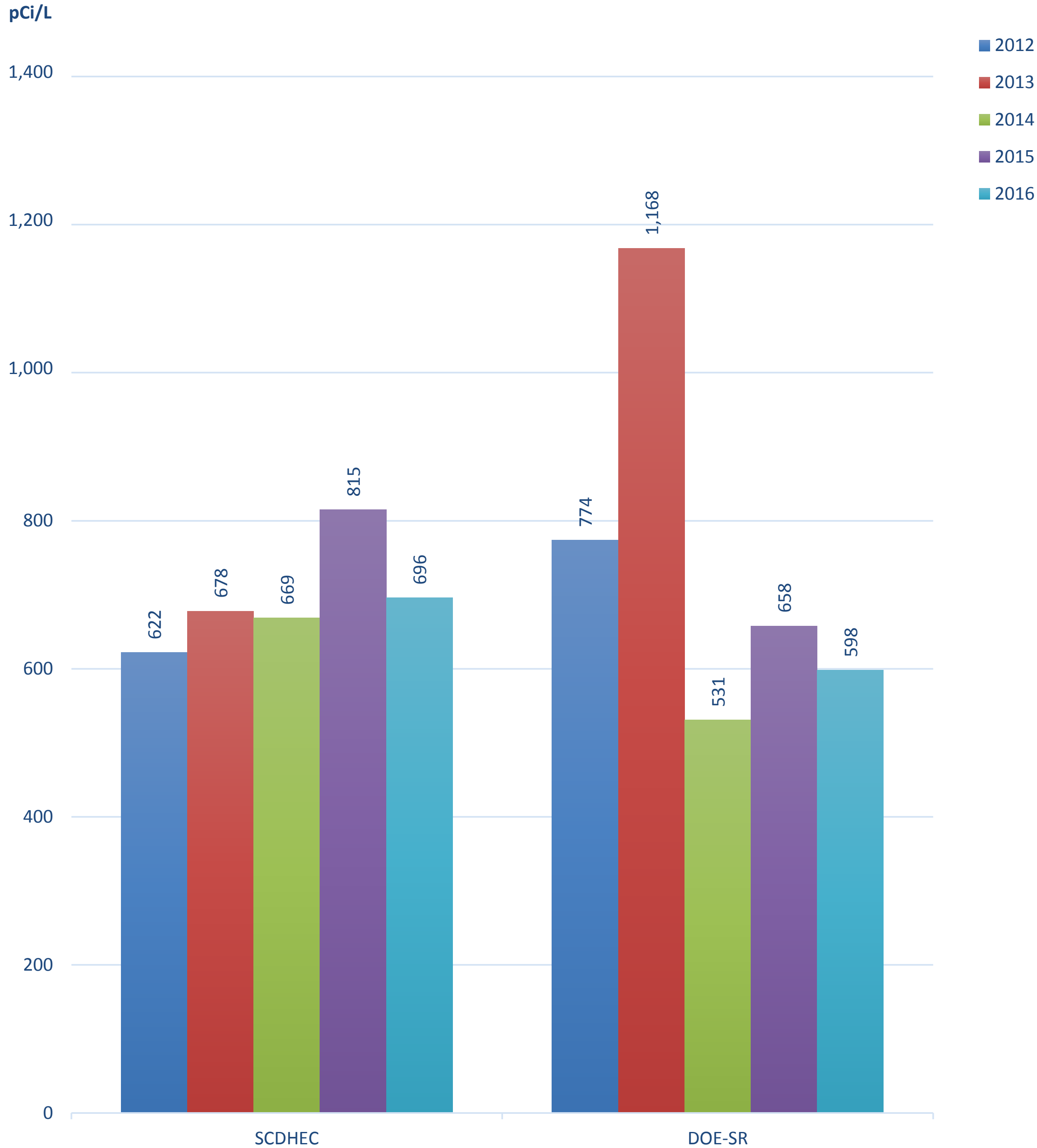

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Figure 3. 2012-2016 Average Tritium Data Trends for DHEC and DOE-SR for Fourmile Branch at USFS Road 12. (SRNS 2013-2017, DHEC 2014a, 2015-2017)

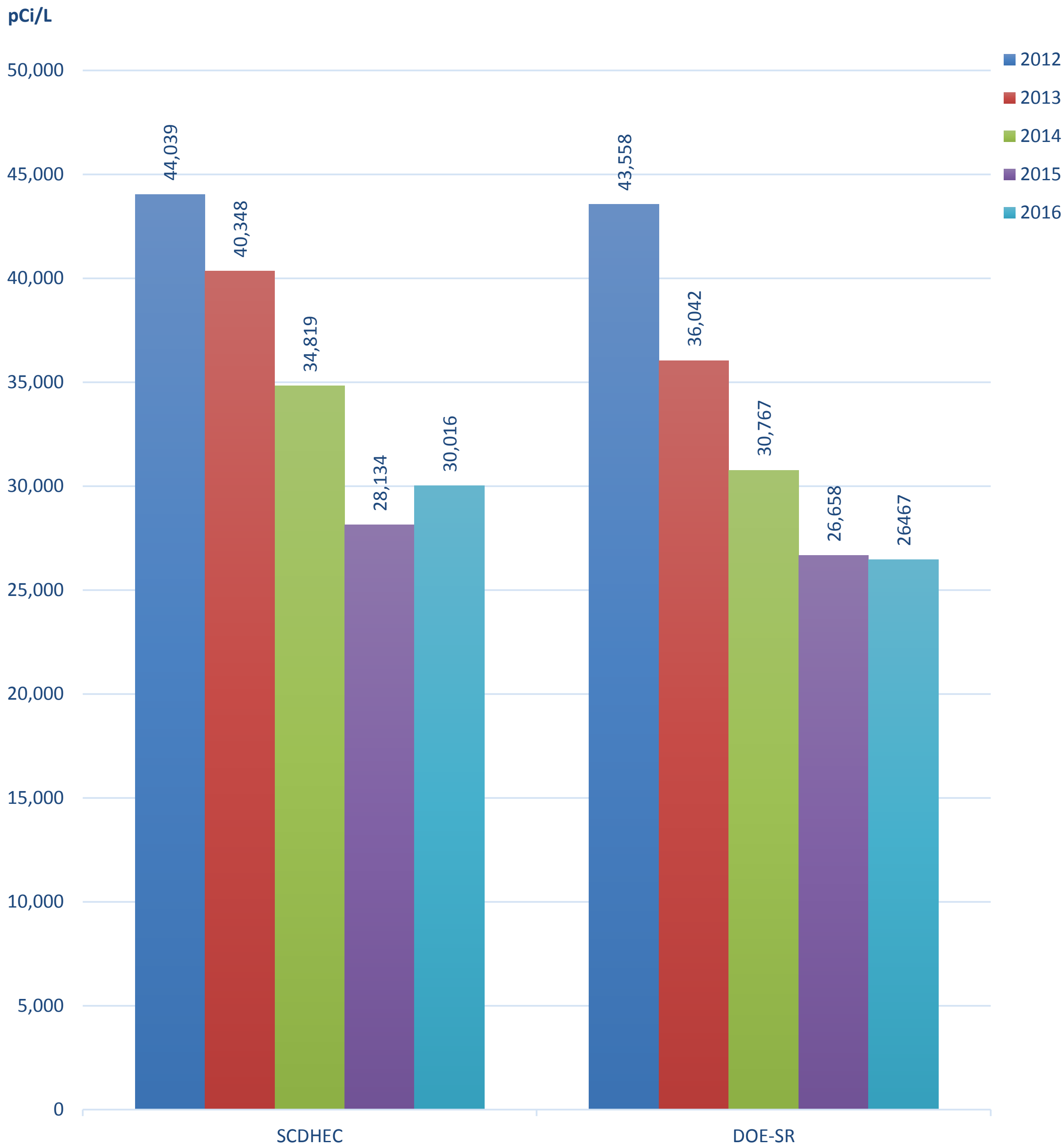

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Figure 4. 2012-2016 Average Tritium Data Trends for DHEC and DOE-SR for Pen Branch at USFS Road 13.2 (SRNS 2013-2017, DHEC 2014a, 2015-2017)

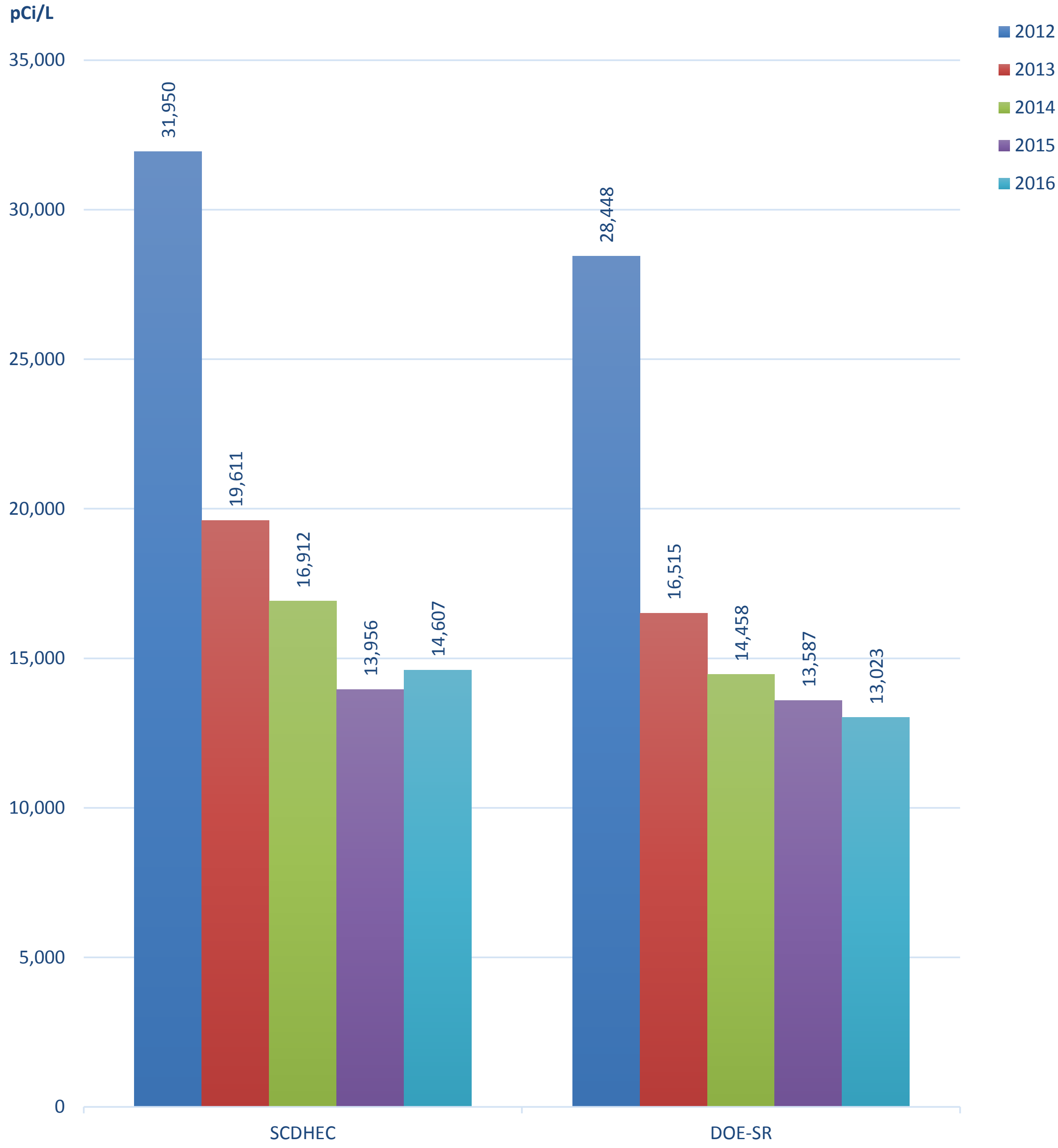

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Figure 5. 2012-2016 Average Tritium Data Trends for DHEC and DOE-SR for Steel Creek at S.C. Highway 125 (SRNS 2013-2017, DHEC 2014a, 2015-2017)

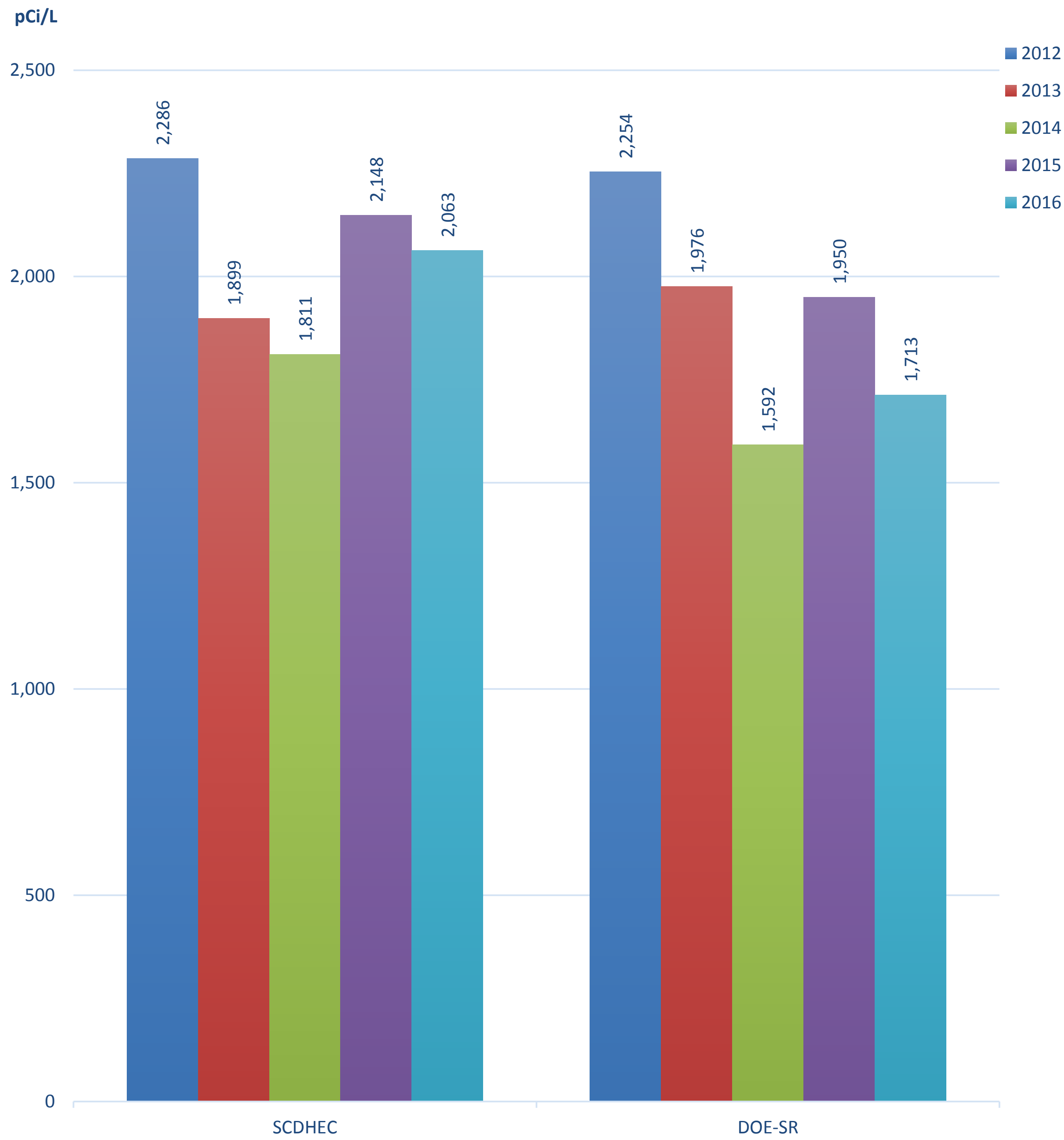

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Figure 6. 2012-2016 Average Tritium Data Trends for DHEC and DOE-SR for Lower Three Runs Creek at SRS Road B (SRNS 2013-2017, DHEC 2014a, 2015-2017)

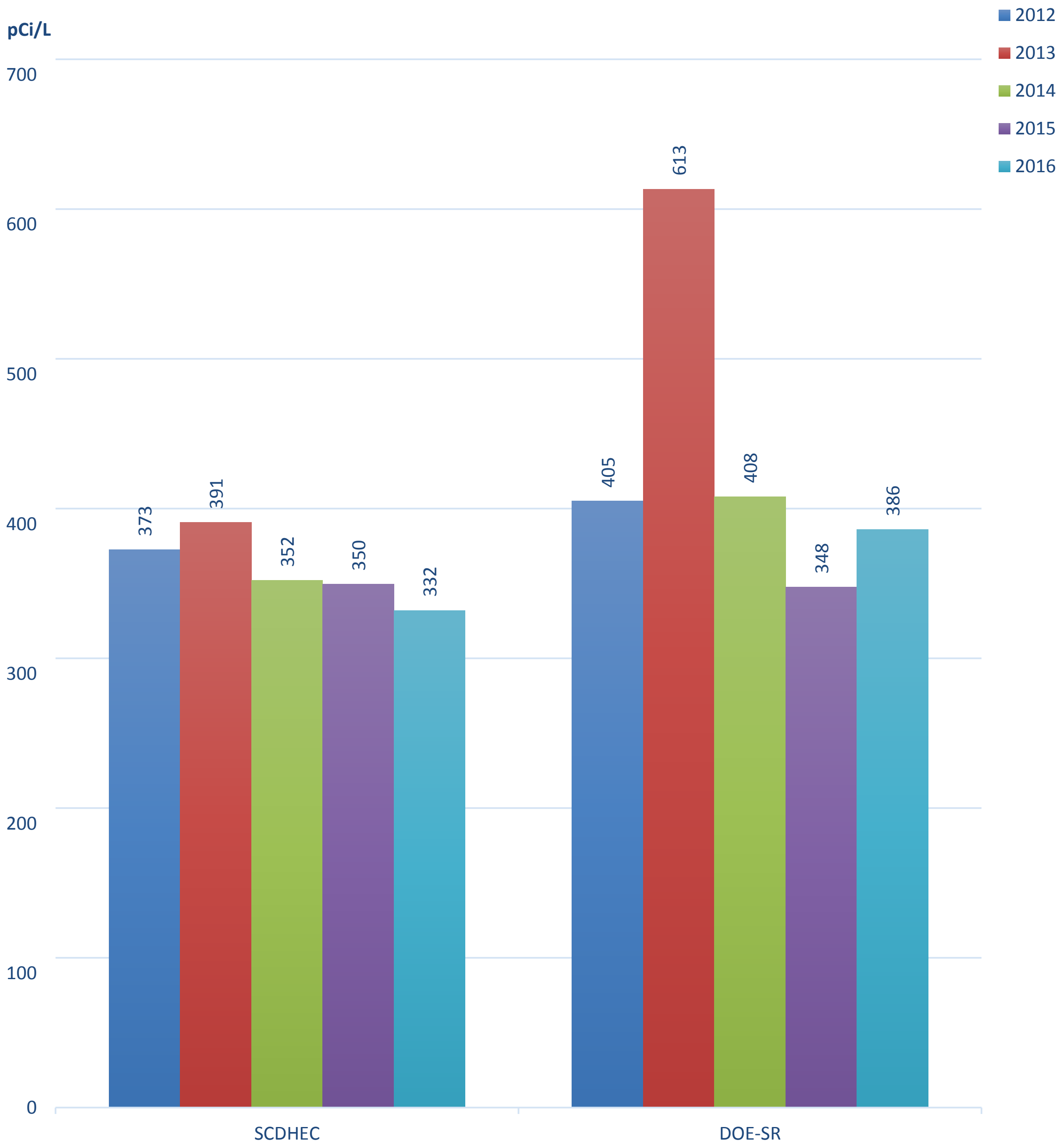

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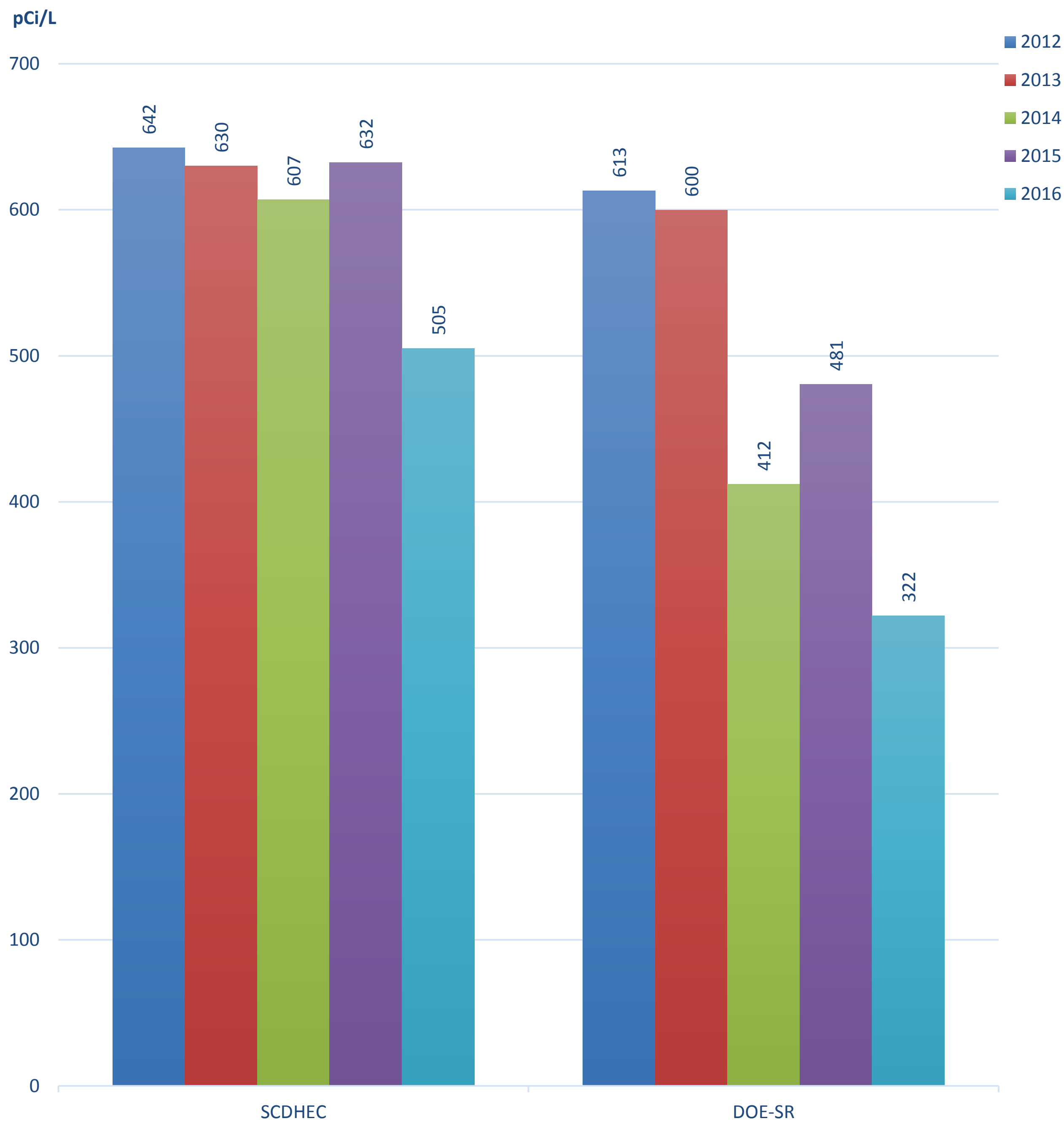
Figure 7. 2012-2016 Average Tritium Data Trends for DHEC and DOE-SR for the Savannah River at US Highway 301 Bridge (SRNS 2013-2017, DHEC 2014a, 2015-2017)



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4.6.0 SUMMARY STATISTICS

2016 Ambient Monitoring Data-Tritium

Sample Location	Average Concentration (pCi/L)	Standard Deviation	Median (pCi/L)	Minimum (pCi/L)	Maximum (pCi/L)	Number of Samples	Number of Detections
Jackson Boat Landing (SV-2010)	319	50	298	277	399	52	6
Tims Branch (SV-324)	464	115	457	271	702	52	45
Upper Three Runs Creek at S.C. 125 (SV-325)	696	220	640	348	1236	52	52
Fourmile Branch (SV-2039)	30,016	5,614	31,149	8,329	38,788	52	52
Pen Branch (SV-2047)	14,607	4,253	14,910	6,269	20,515	52	52
Steel Creek (SV-327)	2,063	492	2,077	1,037	3,345	52	52
Steel Creek Boat Landing (SV-2018)	875	845	496	299	3,235	52	47
Little Hell Boat Landing (SV-2019)	645	506	433	276	1,955	52	29
Highway 301 Bridge (SV-118)	505	214	449	267	1,213	52	36
Lower Three Runs Creek at Patterson Mill Rd. (SV-328)	1,709	619	1,610	764	3,410	52	52
Lower Three Runs Creek at Road B (SV-2053)	332	52	326	266	423	52	21
Upper Three Runs Creek at SRS Road 2-1 (SV-2027)	283	59	299	162	353	52	7

2016 Creek Mouth Data-Tritium

Sample Location	Average Concentration (pCi/L)	Standard Deviation	Median (pCi/L)	Minimum (pCi/L)	Maximum (pCi/L)	Number of Samples	Number of Detections
Upper Three Runs Mouth @ RM 157.4 (SV-2011)	590	107	553	509	747	4	4
Fourmile Branch Mouth @ RM 150.6 (SV-2015)	8,514	13,651	935	334	24,273	4	3
Steel Creek Mouth @ RM 141.5 (SV-2017)	5,305	5,829	2,598	2,003	14,020	4	4
Lower Three Runs Mouth @ RM 129.1 (SV-2020)	365	72	355	290	459	4	4

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SUMMARY STATISTICS

2016 Ambient Monitoring Data-Alpha

Sample Location	Average Concentration (pCi/L)	Standard Deviation	Median (pCi/L)	Minimum (pCi/L)	Maximum (pCi/L)	Number of Samples	Number of Detections
Jackson Boat Landing (SV-2010)	<MDA	NA	NA	<MDA	<MDA	12	0
Tims Branch (SV-324)	3.37	0.99	3.23	1.90	4.41	12	5
Upper Three Runs Creek at S.C. 125 (SV-325)	2.74	0.91	2.60	1.60	4.01	12	7
Fourmile Branch (SV-2039)	<MDA	NA	NA	<MDA	<MDA	12	0
Pen Branch (SV-2047)	<MDA	NA	NA	<MDA	<MDA	12	0
Steel Creek (SV-327)	<MDA	NA	NA	<MDA	<MDA	12	0
Steel Creek Boat Landing (SV-2018)	<MDA	NA	NA	<MDA	<MDA	12	0
Highway 301 Bridge (SV-118)	<MDA	NA	NA	<MDA	<MDA	12	0
Lower Three Runs Creek at Road B (SV-2053)	<MDA	NA	NA	<MDA	<MDA	12	0

2016 Ambient Monitoring Data-Beta

Sample Location	Average Concentration (pCi/L)	Standard Deviation	Median (pCi/L)	Minimum (pCi/L)	Maximum (pCi/L)	Number of Samples	Number of Detections
Jackson Boat Landing (SV-2010)	4.55	NA	NA	<MDA	4.55	12	1
Tims Branch (SV-324)	<MDA	NA	NA	<MDA	<MDA	12	0
Upper Three Runs Creek at S.C. 125 (SV-325)	<MDA	NA	NA	<MDA	<MDA	12	0
Fourmile Branch (SV-2039)	4.77	NA	NA	<MDA	4.77	12	1
Pen Branch (SV-2047)	<MDA	NA	NA	<MDA	<MDA	12	0
Steel Creek (SV-327)	<MDA	NA	NA	<MDA	<MDA	12	0
Steel Creek Boat Landing (SV-2018)	5.05	NA	NA	<MDA	5.05	12	1
Highway 301 Bridge (SV-118)	4.63	NA	NA	<MDA	4.63	12	1
Lower Three Runs Creek at Road B (SV-2053)	<MDA	NA	NA	<MDA	<MDA	12	0

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Chapter 5 Nonradiological Monitoring of Surface Water on SRS

5.1.0 PROJECT SUMMARY

The streams located on 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 DHEC ESOP is used to monitor the ambient water quality of streams on SRS.

DHEC assessed the surface water quality for nonradiological parameters in 2016 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 by DHEC's Bureau of Water (DHEC 2012b). As an indication of possible water quality issues, DHEC data is compared to the freshwater standard guidelines in DHEC's Water Classifications and Standards, Regulation 61-68 (DHEC 2014b). 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. 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.

Nine DHEC 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. A map of DHEC sample locations can be found in Section 5.4.0. Six of the DHEC sample locations are colocated with DOE-SR sample locations to provide data comparisons (Section 5.5.0, Table 1). 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. A list of water quality parameter analyses and sample frequency can be found in Section 5.5.0, Table 2.

5.2.0 RESULTS AND DISCUSSION

Nonradiological Monitoring of Surface Water Summary Statistics can be found in Section 5.6.0 and all Nonradiological Monitoring of Surface Water Data can be found in the 2016 DHEC Data File.

Many chemical and biological processes in surface waters can be affected by pH, a measurement that indicates the alkalinity or acidity of a substance (EPA 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, which results 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) (DHEC 2014b). All DHEC locations had yearly averages within the standard. See Section 5.5.0, Figure 1 for a comparison of DHEC and DOE-SR data for colocated samples (SRNS 2017).

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 Biochemical Oxygen Demand (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 Dissolved Oxygen (DO) means less oxygen to sustain higher forms of aquatic life (EPA 1997).

The South Carolina freshwater standard for DO is a daily average of no less than 5.0 mg/L with a minimum of 4.0 mg/L (DHEC 2014b). All individual samples and yearly averages met the DO standard in 2016. A DO comparison of DHEC and DOE-SR data for colocated samples can be found in Section 5.5.0, Figure 2 (SRNS 2017).

There are no numeric criteria in the South Carolina freshwater standards for a maximum BOD level; however, all 2016 DHEC samples were near or below the LLD of 2.0 mg/L. DOE-SR did not collect BOD samples in 2016, therefore, no comparison was made for BOD.

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 (EPA 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 (DHEC 2014b).

DHEC data showed that the stream temperatures during each sampling event were comparable to each other, including samples representative of natural conditions that were upstream of most SRS operations.

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 (EPA 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 mg/L. 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 (NAS 1974).

In 2016, most of the locations sampled were below the recommended minimum level for alkalinity. The low alkalinity, as related to pH, in SRS streams may be due to the presence of naturally low buffering compounds in the streams. DOE-SR did not sample for alkalinity in 2016, therefore, no comparison was made.

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 (DHEC 2014b). All DHEC-monitored streams were below the standard for turbidity in 2016. DOE-SR did not sample for turbidity in 2016, therefore, no comparison was made.

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Turbidity is directly affected by the water's TSS, which refers to the amount of material suspended in the water (EPA 1997). There is no freshwater quality standard for TSS. A TSS comparison of DHEC and DOE-SR data for colocated samples can be found in Section 5.5.0, Figure 3 (SRNS 2017).

The South Carolina freshwater *E. coli* standard is a daily maximum of 349 Most Probable Number per 100mL (MPN/100mL). All but one of the nine streams sampled had individual samples that exceeded 349 MPN/100mL. One location (SV-2055) had a yearly average above the standard. DOE-SR did not collect samples for *E. coli* in 2016, therefore, no comparison was made.

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 (EPA 1997). In 2016, DHEC 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.

DHEC 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 EPA 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 (EPA 2009). To provide a conservative approach, DHEC uses the maximum of 1 mg/L as an indication of possible water quality issues. All locations had samples below 1 mg/L.

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 2016, therefore, no comparison was made. A comparison of DHEC and DOE-SR data from colocated samples for total phosphorous and nitrate/nitrite, respectively can be found in Section 5.5.0, Figures 4 and 5 (SRNS 2017).

Most metals are considered to be pollutants, including some that are toxic or known carcinogens. In 2016, DHEC personnel collected samples for the following metals: cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, and zinc. 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. 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 has a recommended EPA limit in freshwater streams of 1 mg/L (EPA 2008). One of the DHEC and DOE-SR sample locations had results above the EPA recommended level. The yearly average at SV-324 was 2.6 mg/L and 3.38 mg/L respectively (SRNS 2017). The DHEC sampling location SV-324 and DOE-SR sampling location TB-5 are located on Tims Branch, which has several ground water seeps that contribute to its relatively low flow. It is likely that the elevated iron measured at this location is influenced by naturally occurring processes. A comparison of DHEC and DOE-SR iron data for colocated samples can be found in Section 5.5.0, Figure 6.

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All DHEC manganese sample results were within the levels seen in the Savannah River Basin (DHEC 2013b). However, there is no standard for this parameter. DHEC and DOE-SR detected manganese in all the colocated sample locations. See Section 5.5.0, Figure 7 for a manganese comparison of DHEC and DOE-SR data for colocated samples (SRNS 2017).

The freshwater quality standard for cadmium in South Carolina streams is not to exceed 0.0001 mg/L (DHEC 2014b). DHEC samples had cadmium levels above the standard at three locations at an average of 0.0003 mg/L. DOE-SR detected cadmium above the standard at two of the colocated sample locations in 2016 (SRNS 2017). The detection limit for DOE-SR is higher than the standard at 0.0005 mg/L; therefore, any detection of cadmium exceeds the standard.

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 (DHEC 2014b). There were no DHEC detections of chromium in 2016. DHEC detected copper above the standard in one sample at 0.018 mg/L. DOE-SR detected copper with three results above the standard at an average of 0.0036 mg/L (SRNS 2017). DHEC did not detect nickel in 2016. DOE-SR detected nickel in three of the colocated sample locations, but none of the averages exceeded the standard (SRNS 2017).

The freshwater quality standard for lead in South Carolina streams is not to exceed 0.00054 mg/L (DHEC 2014b). Due to laboratory limitations, DHEC and DOE-SR have LLDs higher than the standard. Therefore, any detection of lead is over the standard. There were two DHEC detections at SV-328 and SV-2061. DOE-SR had no lead detections in 2016 in the colocated samples (SRNS 2017).

The freshwater quality standard for mercury in South Carolina streams is not to exceed 0.00091 mg/L (DHEC 2014b). Mercury was not detected in any of the DHEC samples in 2016. DOE-SR detected mercury at two of the colocated sampling locations, but did not exceed the standard (SRNS 2017).

The freshwater quality standard for zinc in South Carolina streams is not to exceed 0.037 mg/L (DHEC 2014b). DHEC and DOE-SR had no samples over the standard in 2016. A zinc comparison of DHEC and DOE-SR yearly averages for colocated samples can be found in Section 5.5.0, Figure 8.

Most VOCs, PCBs, and pesticides are 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. There were no detections of VOC, PCB, or pesticide contaminants in 2016 in either the DHEC or DOE-SR samples in 2016 (SRNS 2017).

Small discrepancies in data between DOE-SR and DHEC 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 DHEC summary statistics due to the lack of numeric data.

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5.3.0 CONCLUSIONS AND RECOMMENDATIONS

The parameters identified that were above or below EPA or DHEC 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 SRS in 2016 compared favorably with the South Carolina Freshwaters Standard or other recommendations for the parameters and monitored locations. The 2016 DHEC results for most parameters were similar to DHEC's Bureau of Water data for the Savannah River watershed (DHEC 2013b). DHEC 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.

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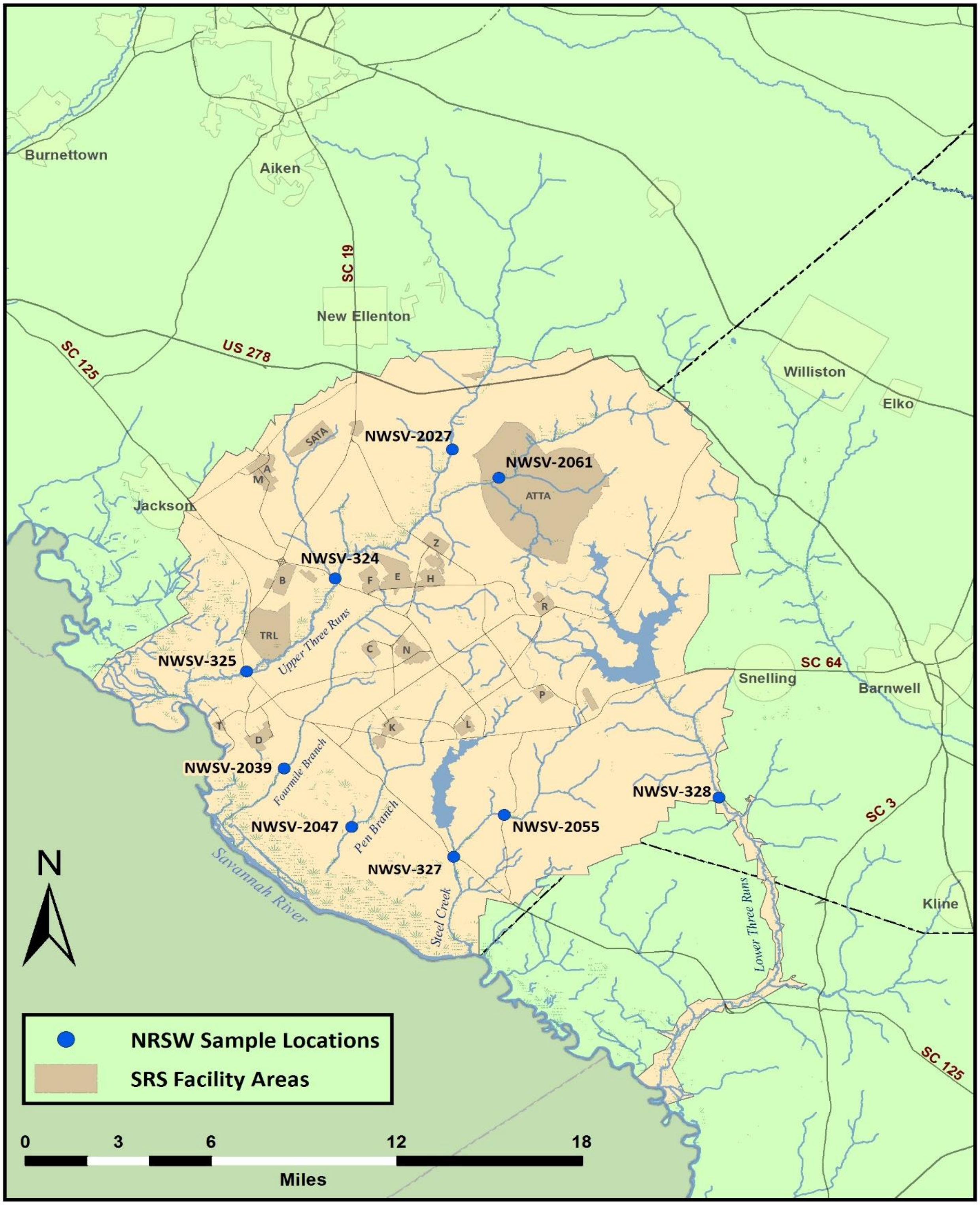
5.4.0 MAP

Nonradiological Surface Water Sampling Locations



2016 ESOP Non-Radiological Surface Water Monitoring www.scdhec.gov/srs

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5.5.0 TABLES AND FIGURES

Table 1. DHEC 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

*Colocated with DOE-SR sample locations.

Table 2. DHEC Water Quality Parameter Analyses

Laboratory	Frequency	Parameter
DHEC Lab Aiken, S.C.	Monthly	Turbidity, BOD, E. Coli, and TSS.
DHEC Lab Columbia, S.C.	Monthly	Alkalinity, Ammonia, Nutrients, Mercury, and Metals
Field	Semi-annually	VOCs, Pesticides, and PCBs.

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TABLES AND FIGURES

Figure 1. pH 2016 Yearly Average DHEC and DOE-SR Comparison (SRNS 2017)

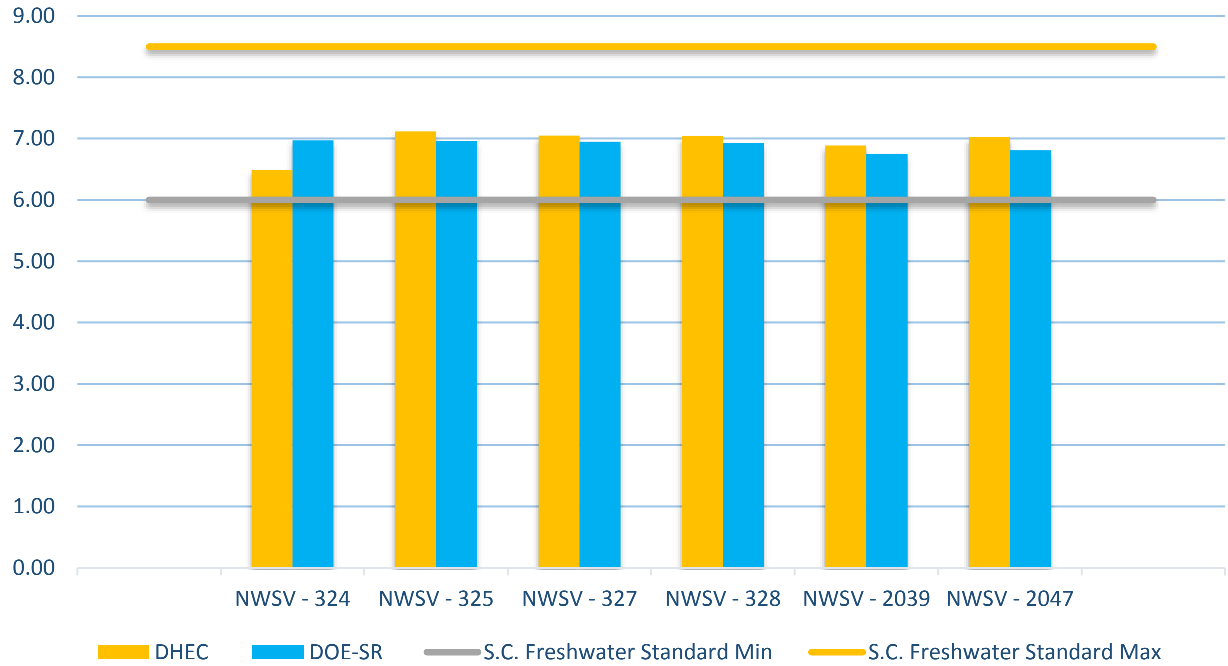
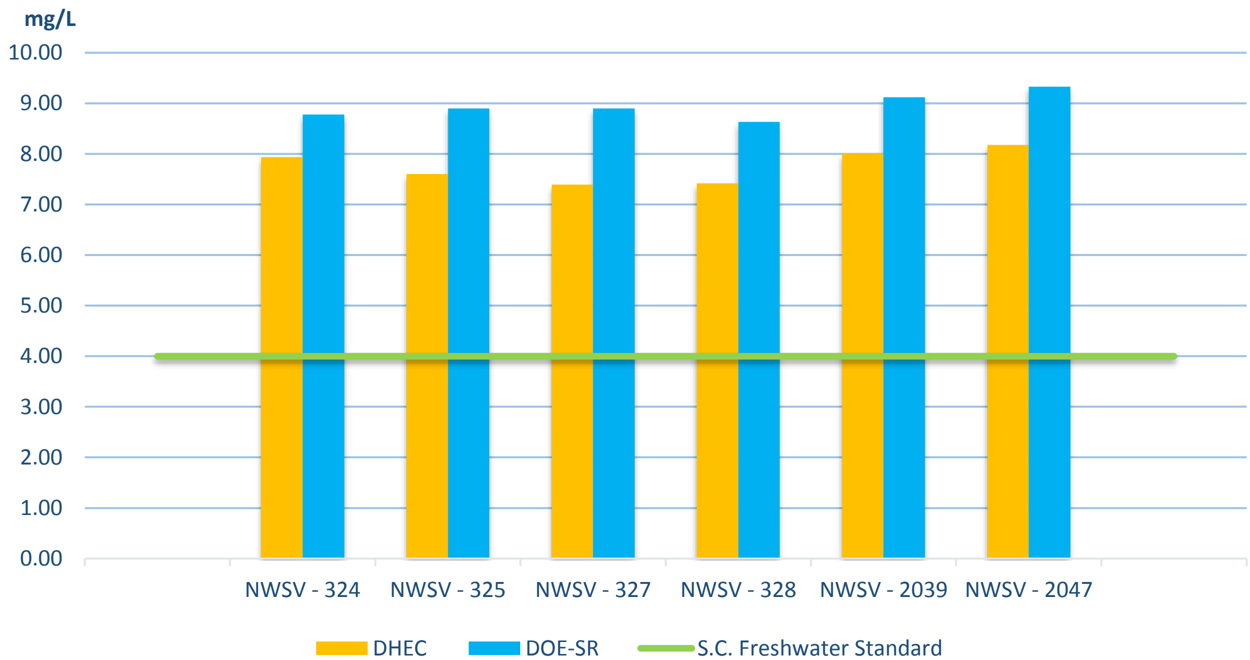


Figure 2. DO 2016 Yearly Average DHEC and DOE-SR Comparison (SRNS 2017)



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TABLES AND FIGURES

Figure 3. TSS 2016 Yearly Average DHEC and DOE-SR Comparison (SRNS 2017)

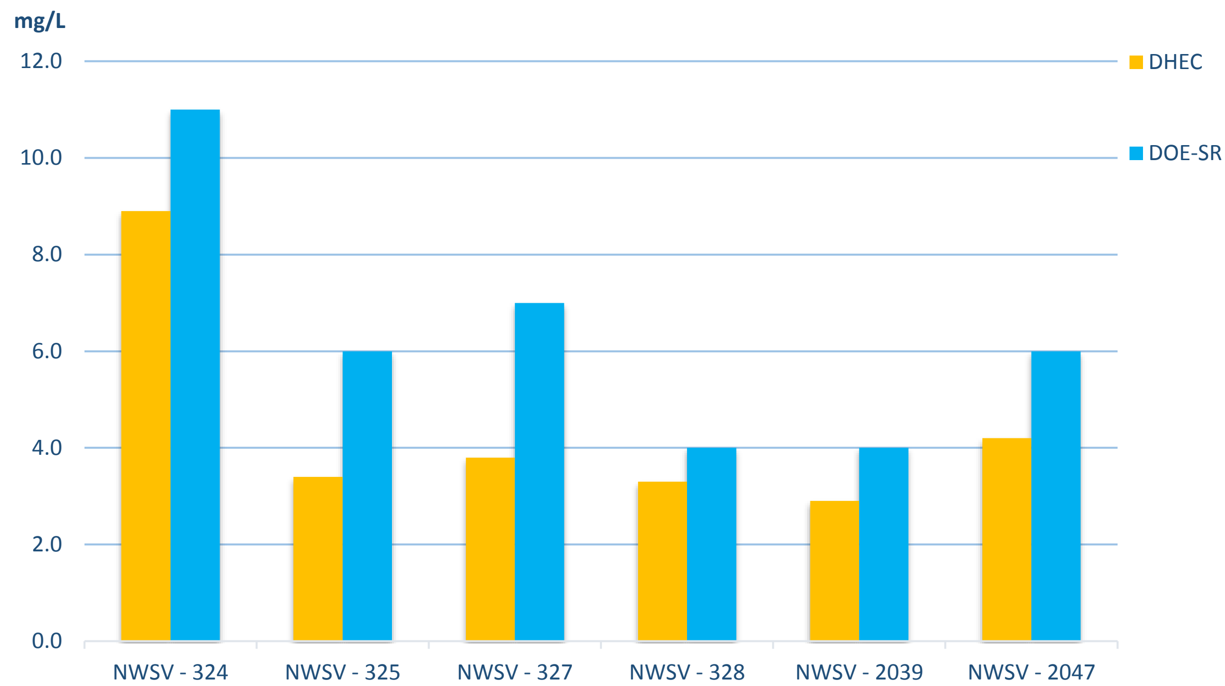
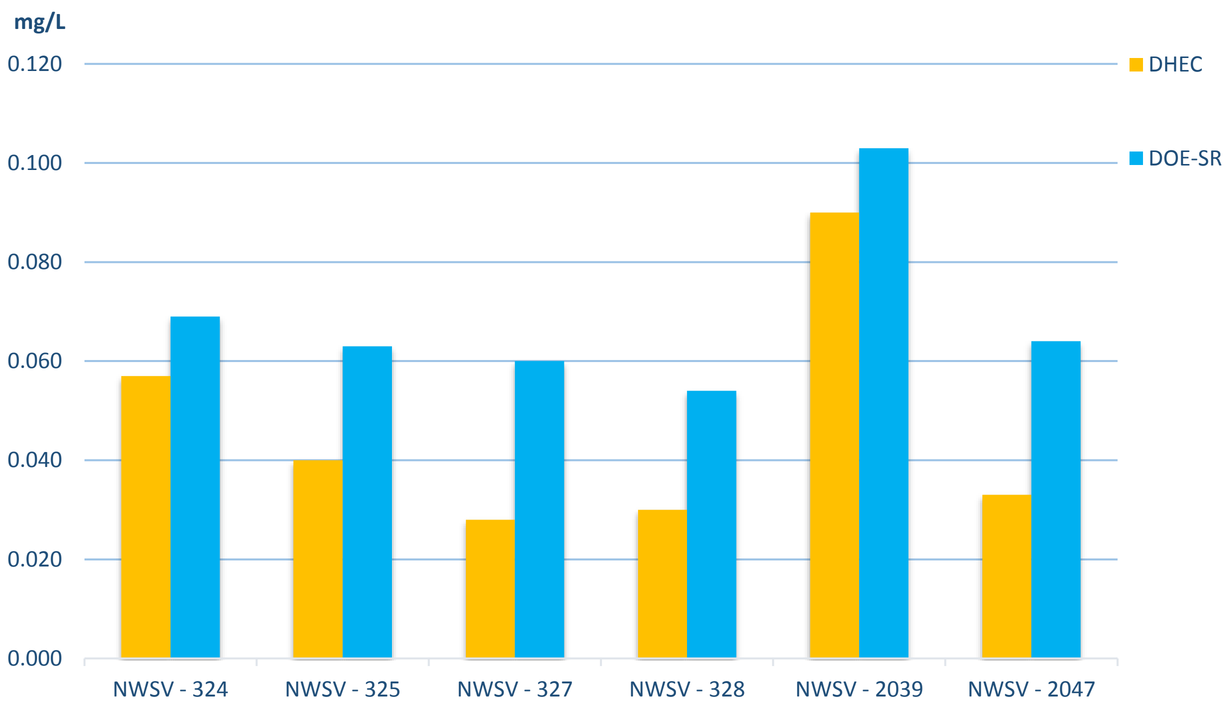


Figure 4. Total Phosphorous 2016 Yearly Average DHEC and DOE-SR Comparison (SRNS 2017)



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TABLES AND FIGURES

Figure 5. Nitrate/Nitrite 2016 Yearly Average DHEC and DOE-SR Comparison (SRNS 2017)

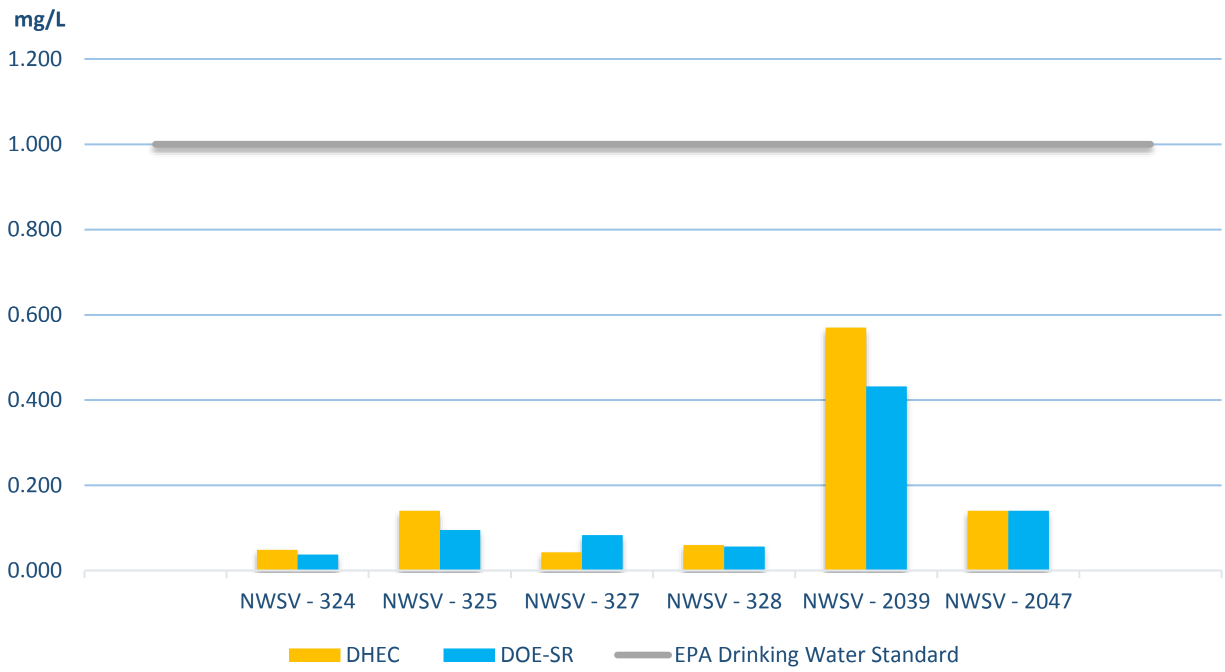
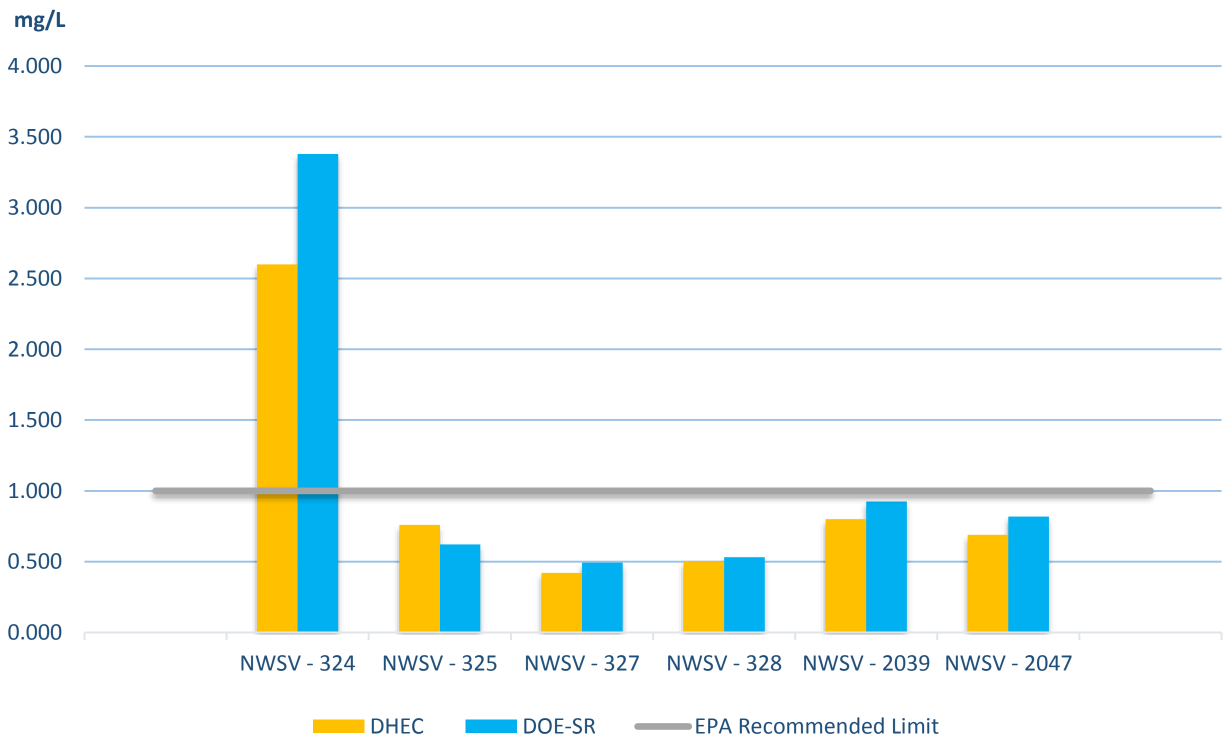


Figure 6. Iron 2016 Yearly Average DHEC and DOE-SR Comparison (SRNS 2017)



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TABLES AND FIGURES

Figure 7. Manganese 2016 Yearly Average DHEC and DOE-SR Comparison (SRNS 2017)

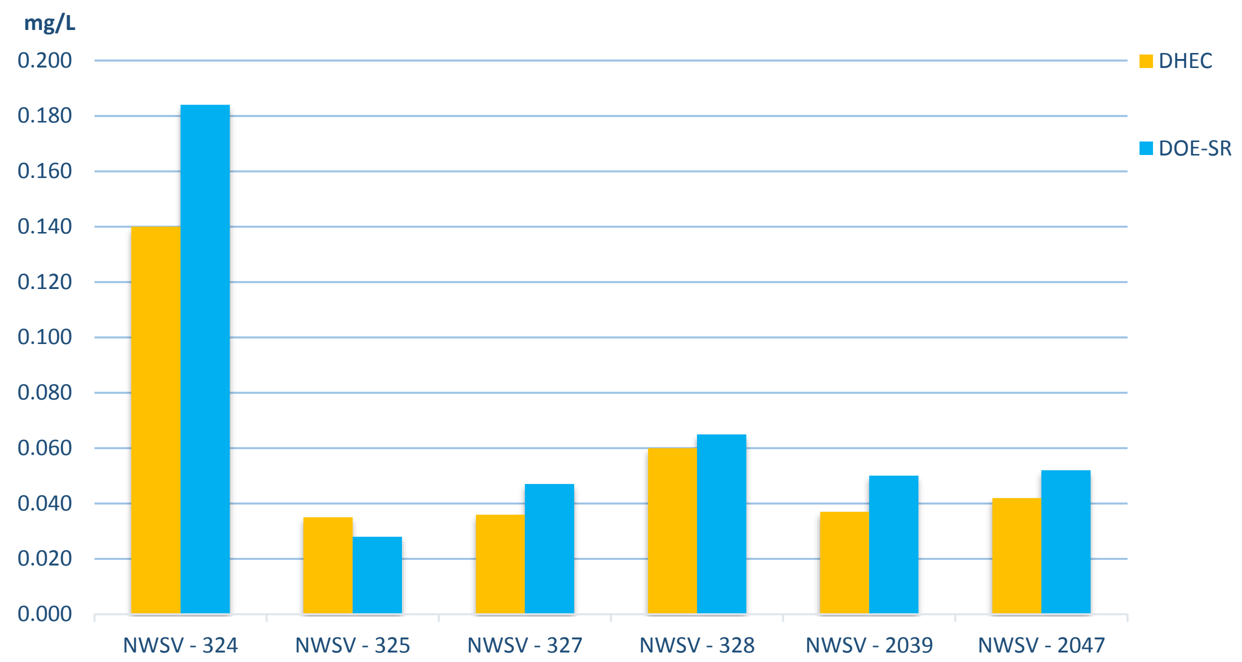

Figure 8. Zinc 2016 Yearly Average DHEC and DOE-SR Comparison (SRNS 2017)

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5.6.0 SUMMARY STATISTICS

NWSV-324 Tims Branch at Road C

Parameters		Average	Standard Deviation	Median	Minimum	Maximum	Number of Detects
Field	pH (SU)	6.49	0.73	6.49	5.45	7.80	12
	DO (mg/L)	7.94	2.46	8.34	4.13	11.34	12
	Water Temp (°C)	16.24	6.00	16.57	5.70	23.89	12
Laboratory	Alkalinity (mg/L)	4.1	1.3	4.1	2.4	6.0	12
	Turbidity (NTU)	7.3	5.5	4.8	2.6	22	12
	BOD (mg/L)	3.1	NA	3.1	3.1	3.1	1
	TSS (mg/L)	8.9	8.9	5.85	2.4	33	10
	E. Coli (cnt/100mL)	293	329	99	10	1046	12
	TKN (mg/L)	0.74	0.77	0.54	0.10	3.0	12
	Ammonia (mg/L)	0.07	0.014	0.06	0.051	0.10	8
	Nitrate/Nitrite (mg/L)	0.049	0.017	0.050	0.028	0.081	10
	Total Phosphorus (mg/L)	0.057	0.041	0.043	0.022	0.160	11
	Cadmium (mg/L)	<LLD	NA	NA	<LLD	<LLD	0
	Chromium (mg/L)	<LLD	NA	NA	<LLD	<LLD	0
	Copper (mg/L)	<LLD	NA	NA	<LLD	<LLD	0
	Iron (mg/L)	2.6	1.6	2.5	0.4	5.8	12
	Lead (mg/L)	<LLD	NA	NA	<LLD	<LLD	0
	Manganese (mg/L)	0.14	0.172	0.07	0.017	0.64	12
	Nickel (mg/L)	<LLD	NA	NA	<LLD	<LLD	0
	Zinc (mg/L)	0.01	NA	0.01	0.012	0.01	1
	Mercury (mg/L)	<LLD	NA	NA	<LLD	<LLD	0

NWSV-325 Upper Three Runs at Road A

Parameters		Average	Standard Deviation	Median	Minimum	Maximum	Number of Detects
Field	pH (SU)	7.12	0.83	6.93	5.83	8.58	12
	DO (mg/L)	7.60	2.33	8.06	4.11	11.17	12
	Water Temp (°C)	16.65	5.81	16.88	6.20	24.39	12
Laboratory	Alkalinity (mg/L)	3.3	0.74	3.7	2.1	4.2	11
	Turbidity (NTU)	3.3	1.4	3.0	1.8	7.2	12
	BOD (mg/L)	<LLD	NA	NA	<LLD	<LLD	0
	TSS (mg/L)	3.4	1.2	3.1	1.4	5.0	10
	E. Coli (cnt/100mL)	172	149	125	50	579	12
	TKN (mg/L)	0.42	0.21	0.47	0.13	0.73	12
	Ammonia (mg/L)	0.074	0.029	0.060	0.050	0.120	5
	Nitrate/Nitrite (mg/L)	0.14	0.032	0.15	0.061	0.18	12
	Total Phosphorus (mg/L)	0.040	0.011	0.038	0.023	0.060	10
	Cadmium (mg/L)	<LLD	NA	NA	<LLD	<LLD	0
	Chromium (mg/L)	<LLD	NA	NA	<LLD	<LLD	0
	Copper (mg/L)	<LLD	NA	NA	<LLD	<LLD	0
	Iron (mg/L)	0.76	0.96	0.51	0.34	3.80	12
	Lead (mg/L)	<LLD	NA	NA	<LLD	<LLD	0
	Manganese (mg/L)	0.035	0.055	0.017	0.011	0.200	11
	Nickel (mg/L)	<LLD	NA	NA	<LLD	<LLD	0
	Zinc (mg/L)	0.012	NA	0.012	0.010	0.014	3
	Mercury (mg/L)	<LLD	NA	NA	<LLD	<LLD	0

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SUMMARY STATISTICS

NWSV-327 Steel Creek at Road A

Parameters		Average	Standard Deviation	Median	Minimum	Maximum	Number of Detects
Field	pH (SU)	7.05	0.67	7.01	6.00	8.14	12
	DO (mg/L)	7.39	2.41	8.00	3.75	10.81	12
	Water Temp (°C)	18.84	7.16	18.34	8.03	29.41	12
Laboratory	Alkalinity (mg/L)	19	4.5	21	10	23	12
	Turbidity (NTU)	3.5	1.6	3.1	1.9	6.6	12
	BOD (mg/L)	2.4	NA	2.4	2.4	2.4	1
	TSS (mg/L)	3.8	1.6	3.8	1.00	6.1	10
	E. Coli (cnt/100mL)	291	672	112	24	2420	12
	TKN (mg/L)	0.41	0.18	0.365	0.19	0.73	12
	Ammonia (mg/L)	0.059	0.007	0.058	0.050	0.071	7
	Nitrate/Nitrite (mg/L)	0.043	0.018	0.047	0.020	0.069	9
	Total Phosphorus (mg/L)	0.028	N/A	0.024	0.022	0.037	3
	Cadmium (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	Chromium (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	Copper (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	Iron (mg/L)	0.42	0.17	0.41	0.21	0.68	12
	Lead (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	Manganese (mg/L)	0.036	0.019	0.036	0.014	0.084	12
	Nickel (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	Zinc (mg/L)	0.01	0.00	0.01	0.01	0.01	2
	Mercury (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0

NWSV-328 Lower Three Runs at Patterson Mill Road

Parameters		Average	Standard Deviation	Median	Minimum	Maximum	Number of Detects
Field	pH (SU)	7.04	0.67	6.89	6.06	8.23	12
	DO (mg/L)	7.42	2.44	7.40	4.15	11.48	12
	Water Temp (°C)	17.78	6.06	17.97	7.21	25.52	12
Laboratory	Alkalinity (mg/L)	30.33	5.16	29.50	22.00	41.00	12
	Turbidity (NTU)	2.49	0.88	2.35	1.5	4.2	12
	BOD (mg/L)	2.2	NA	2.20	2.2	2.2	1
	TSS (mg/L)	3.3	1.3	3.25	1.5	5.2	10
	E. Coli (cnt/100mL)	209.10	348.26	103.05	50.40	1299.70	12
	TKN (mg/L)	0.46	0.21	0.53	0.12	0.68	11
	Ammonia (mg/L)	0.05	0.00	0.05	0.05	0.05	4
	Nitrate/Nitrite (mg/L)	0.06	0.04	0.05	0.03	0.15	10
	Total Phosphorus (mg/L)	0.03	0.01	0.03	0.03	0.06	9
	Cadmium (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	Chromium (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	Copper (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	Iron (mg/L)	0.50	0.16	0.48	0.36	0.98	12
	Lead (mg/L)	0.002	NA	0.002	0.002	0.002	1
	Manganese (mg/L)	0.06	0.02	0.05	0.03	0.10	12
	Nickel (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	Zinc (mg/L)	0.02	N/A	0.01	0.01	0.03	5
	Mercury (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0

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SUMMARY STATISTICS

NWSV-2027 Upper Three Runs at Road 2-1

Parameters		Average	Standard Deviation	Median	Minimum	Maximum	Number of Detects
Field	pH (SU)	7.56	0.62	7.59	6.41	8.46	12
	DO (mg/L)	7.09	2.46	7.15	3.08	10.54	12
	Water Temp (°C)	17.20	4.16	17.55	9.32	22.51	12
Laboratory	Alkalinity (mg/L)	1.17	0.15	1.1	1.0	1.4	6
	Turbidity (NTU)	2.1	0.82	2.1	1.0	3.5	12
	BOD (mg/L)	3.20	N/A	3.2	3.2	3.2	1
	TSS (mg/L)	3.0	1.5	2.7	1.2	6.0	10
	E. Coli (cnt/100mL)	151	121	104	64	435	11
	TKN (mg/L)	0.32	0.19	0.25	0.12	0.70	11
	Ammonia (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	Nitrate/Nitrite (mg/L)	0.26	0.04	0.26	0.18	0.33	12
	Total Phosphorus (mg/L)	0.025	N/A	0.025	0.020	0.029	3
	Cadmium (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	Chromium (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	1
	Copper (mg/L)	0.02	N/A	0.02	0.02	0.018	1
	Iron (mg/L)	0.28	0.066	0.27	0.17	0.40	12
	Lead (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	Manganese (mg/L)	0.012	0.003	0.012	0.010	0.014	2
	Nickel (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	Zinc (mg/L)	0.01	0.001	0.01	0.01	0.01	2
	Mercury (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0

NWSV-2039 Fourmile Branch at Road A-13.2

Parameters		Average	Standard Deviation	Median	Minimum	Maximum	Number of Detects
Field	pH (SU)	6.89	0.68	6.78	5.71	7.83	12
	DO (mg/L)	8.01	2.54	8.70	4.20	12.02	12
	Water Temp (°C)	16.47	6.23	16.64	4.74	24.25	12
Laboratory	Alkalinity (mg/L)	11.43	2.7	12	6.8	15	12
	Turbidity (NTU)	3.8	0.9	3.8	2.3	5.3	12
	BOD (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	1
	TSS (mg/L)	2.9	1.1	2.7	1.50	5.2	10
	E. Coli (cnt/100mL)	96	71	81	28	270	12
	TKN (mg/L)	0.43	0.20	0.52	0.12	0.70	12
	Ammonia (mg/L)	0.057	0.007	0.054	0.051	0.065	3
	Nitrate/Nitrite (mg/L)	0.57	0.20	0.52	0.28	0.93	12
	Total Phosphorus (mg/L)	0.09	0.030	0.087	0.041	0.14	12
	Cadmium (mg/L)	0.0002	NA	0.0002	0.0002	0.0002	1
	Chromium (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	1
	Copper (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	Iron (mg/L)	0.80	0.11	0.80	0.61	0.96	12
	Lead (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	Manganese (mg/L)	0.037	0.008	0.036	0.024	0.050	12
	Nickel (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	Zinc (mg/L)	0.015	0.006	0.012	0.011	0.027	6
	Mercury (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0

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SUMMARY STATISTICS

NWSV-2047 Pen Branch at Road A-13.2

Parameters		Average	Standard Deviation	Median	Minimum	Maximum	Number of Detects
Field	pH (SU)	7.03	0.79	6.76	5.94	8.47	12
	DO (mg/L)	8.18	2.52	9.20	4.44	11.73	12
	Water Temp (°C)	16.34	6.10	16.37	5.68	24.25	12
Laboratory	Alkalinity (mg/L)	19	5.8	21	8.4	25	12
	Turbidity (NTU)	4.7	1.9	4.0	3.4	10.0	12
	BOD (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	TSS (mg/L)	4.2	3.6	3.2	1.50	14.0	10
	E. Coli (cnt/100mL)	233	353	98	39	1203	12
	TKN (mg/L)	0.47	0.19	0.49	0.20	0.77	12
	Ammonia (mg/L)	0.073	0.022	0.065	0.053	0.110	5
	Nitrate/Nitrite (mg/L)	0.14	0.061	0.13	0.080	0.30	12
	Total Phosphorus (mg/L)	0.033	0.0109	0.031	0.020	0.060	11
	Cadmium (mg/L)	0.0004	NA	0.0004	0.0004	0.0004	1
	Chromium (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	Copper (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	Iron (mg/L)	0.69	0.13	0.66	0.51	0.90	12
	Lead (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	Manganese (mg/L)	0.042	0.016	0.035	0.021	0.074	12
	Nickel (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	Zinc (mg/L)	0.012	0.002	0.010	0.010	0.014	5
	Mercury (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0

NWSV-2055 Meyers Branch at Road 9

Parameters		Average	Standard Deviation	Median	Minimum	Maximum	Number of Detects
Field	pH (SU)	7.05	0.67	6.92	6.24	8.41	12
	DO (mg/L)	7.95	2.31	8.52	4.23	11.29	12
	Water Temp (°C)	16.69	5.41	16.91	6.93	23.58	12
Laboratory	Alkalinity (mg/L)	12.89	3.8	15	6	17	12
	Turbidity (NTU)	3.1	1.4	2.8	1.9	7.4	12
	BOD (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	1
	TSS (mg/L)	4.0	1.7	3.6	2.1	7.5	10
	E. Coli (cnt/100mL)	485	626	335	82	2420	12
	TKN (mg/L)	0.46	0.17	0.49	0.18	0.68	12
	Ammonia (mg/L)	0.081	0.036	0.062	0.055	0.14	6
	Nitrate/Nitrite (mg/L)	0.106	0.027	0.110	0.046	0.15	12
	Total Phosphorus (mg/L)	0.026	N/A	0.024	0.021	0.034	3
	Cadmium (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	Chromium (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	Copper (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	Iron (mg/L)	0.50	0.11	0.50	0.37	0.73	12
	Lead (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	Manganese (mg/L)	0.039	0.0118	0.036	0.026	0.065	12
	Nickel (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	Zinc (mg/L)	0.011	0.0005	0.011	0.011	0.012	4
	Mercury (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0

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SUMMARY STATISTICS

NWSV-2061 Upper Three Runs at Road 2-1

Parameters		Average	Standard Deviation	Median	Minimum	Maximum	Number of Detects
Field	pH (SU)	7.29	0.75	7.13	6.32	8.84	12
	DO (mg/L)	7.76	2.48	8.02	3.76	11.26	12
	Water Temp (°C)	17.66	6.00	18.01	6.71	25.66	12
Laboratory	Alkalinity (mg/L)	4.7	1.1	5.1	2.7	6.0	12
	Turbidity (NTU)	2.8	1.1	2.4	1.5	4.9	12
	BOD (mg/L)	2.1	NA	2.1	2.1	2.1	1
	TSS (mg/L)	3.7	1.7	3.2	1.9	7.6	10
	E. Coli (cnt/100mL)	182	118	172	58	461	12
	TKN (mg/L)	0.37	0.12	0.40	0.20	0.55	12
	Ammonia (mg/L)	0.088	0.045	0.088	0.056	0.120	2
	Nitrate/Nitrite (mg/L)	0.056	0.029	0.050	0.026	0.13	10
	Total Phosphorus (mg/L)	0.058	0.024	0.056	0.026	0.100	12
	Cadmium (mg/L)	0.0003	NA	0.0003	0.0003	0.0003	1
	Chromium (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	Copper (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	Iron (mg/L)	0.44	0.08	0.47	0.27	0.53	12
	Lead (mg/L)	0.0021	NA	0.0021	0.0021	0.0021	1
	Manganese (mg/L)	0.019	0.0053	0.019	0.011	0.029	12
	Nickel (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0
	Zinc (mg/L)	0.011	NA	0.011	0.011	0.011	1
	Mercury (mg/L)	<LLD	N/A	N/A	<LLD	<LLD	0

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Chapter 6 Monitoring of Sediments on and Adjacent to SRS

6.1.0 PROJECT SUMMARY

The accumulation of radiological and nonradiological contaminants in sediment can have direct impacts on aquatic organisms that can result in human exposure. Water bodies can be impacted through direct discharge, atmospheric fallout, or 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 transportation of sediments is a dynamic process. 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 (EPA 1987).

SRS streams receive surface water runoff and water from permitted discharges (DOE 1995). 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 Savannah River.

DHEC personnel evaluate 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. Radionuclide detections in sediment are typically the result of accumulation over many years and do not represent yearly depositions. Sediment samples on SRS are routinely split with DOE-SR to compare results.

A complete list of all radiological and nonradiological analytes can be found in Section 6.5.0, Tables 3 and 4. DHEC sediment sampling locations are illustrated in Section 6.4.0, Map. Split samples were collected from six stream locations on SRS, and three SRS stormwater basins. A complete list of sample locations is listed in Section 6.5.0, Table 1a, 1b, and 2.

6.2.0 RESULTS AND DISCUSSION

DHEC sediment monitoring summary statistics can be found in Section 6.6.0 and sediment monitoring data can be found in the 2016 DHEC Data File.

6.2.1 Radiological Results

Cesium-137 releases from Z-Area have the potential to contaminate tributaries of McQueen Branch, which flows into Upper Three Runs. The impact for possible contamination warrants long-term monitoring by DHEC along SRS streams and the publicly accessible Savannah River.

The creek mouths of SRS are a conduit for the dispersal of radionuclides into publicly accessible water. Cesium-137 activity was found by DHEC in the sediment within several creek mouths at the Savannah River. Actinium-228, potassium-40, lead-212, lead-214, radium-226, and thorium-234 are NORM decay products that account for the remaining gamma detections. All other gamma-emitting radionuclides had no detections above their respective MDA.

DHEC had sporadic gross alpha and gross non-volatile beta activity detections in 2016.

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Cesium-137 is the most abundant anthropogenic radionuclide found in the sediment samples. Cesium-137 levels in 2016 data from samples collected outside of SRS boundaries are all within the expected range and consistent with previous DHEC background data and may be attributed, in part, to fallout from past nuclear events in the 1950s and 1960s.

Figure 1 in Section 6.5.0 illustrates DHEC average Cs-137 activity in sediment samples from SRS stormwater basins, SRS streams, SRS creek mouths, publicly accessible boat landings, and background sampling locations. DHEC Cs-137 data from the SRS creek mouths were trended for 2012-2016 (Section 6.5.0, Figure 2).

Figure 3 in Section 6.5.0 illustrates the Cs-137 levels in the Savannah River creek mouths for DHEC and DOE-SR samples from 2016. The highest level of Cs-137 from all 2016 DHEC and DOE-SR collocated sediment samples occurred at Steel Creek at Hwy 125. DHEC had the highest Cs-137 in the Steel Creek mouth and boat landing samples. DOE-SR did not sample the Steel Creek mouth or boat landing. Cesium-137 contamination in this area is well documented and not unexpected.

6.2.2 Nonradiological Results

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 SRS. Re-distribution of sediment from flooding can carry contaminants to downstream locations. Geological factors in the Savannah River basin contribute to the levels of metals through erosion and sedimentation. All 2016 samples were below the Ecological Screening Value (ESV) for barium, beryllium, copper, manganese, and nickel.

SRS sediments should continue to be monitored due to current releases of contaminants 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 erosion and sedimentation. Monitoring of on-site sediments is of great importance since over-land precipitation and streams transport contaminated sediment with radionuclides outside the SRS boundary.

Comparisons were made to the ESV for sediment which does not represent remediation goals or cleanup levels, but is used to identify constituents of potential concern (WSRC 2005).
The DHEC cadmium MDL is higher than the ESV of 0.36 milligram per kilogram (mg/kg), therefore any detections are above the ESV. Cadmium was detected by DHEC in six of the public boat landings, two of the on-site streams, two of the stormwater basins, and two of the background samples. DOE-SR detected cadmium above the ESV in one stormwater basin and three creek mouth samples.

Chromium was detected by DHEC above the ESV of 28 mg/kg at the Steel Creek boat landing and two of the stormwater basins. DOE-SR detected chromium above the ESV in two stormwater basin samples.

DHEC detected lead above the ESV of 11 mg/kg in two of the stormwater basins and all three of the background samples. DOE-SR detected lead above the ESV in two stormwater basin and one creek mouth samples.

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DOE-SR detected manganese above the ESV of 220 mg/kg in all creek mouth samples. DHEC did not analyze creek mouth samples for metals in 2016.

Mercury was detected above the ESV of 0.1 mg/kg in the Lower Three Runs Creek sample. DOE-SR did not detect mercury above the ESV.

Zinc was detected by DHEC above the ESV of 46 mg/kg in four of the public boat landing, two of the stormwater basins, and two of the background samples. DOE-SR detected zinc above the ESV in two stormwater basin, one on-site stream, and two creek mouth samples.

6.3.0 CONCLUSIONS AND RECOMMENDATIONS

The continuation of sediment sampling and analysis, along with trending of data, is necessary to closely monitor contamination of SRS sediments.

DHEC 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 DHEC 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 constituents of concern and results will be compared in the DHEC Data Report. Cooperation between DOE-SR and DHEC provides credibility and confidence in the information being provided to the public.

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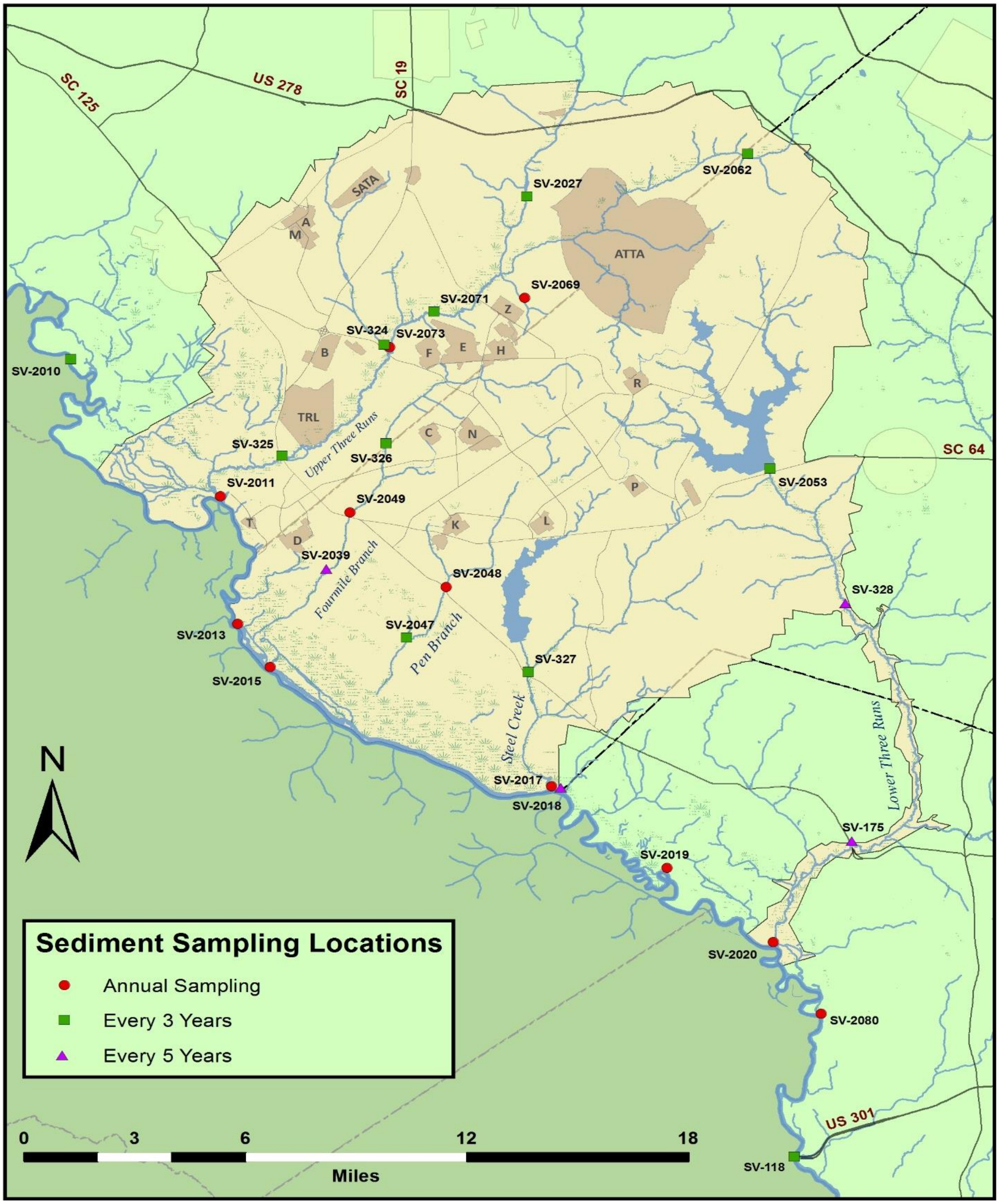
6.4.0 MAP

SRS Sediment Sampling Locations



2016 ESOP Sediment Monitoring www.scdhec.gov/srs

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6.5.0 TABLES AND FIGURES

2016 DHEC Sediment Sample Locations

Table 1a. Non-Publicly Accessible Sediment Sample Locations on SRS

Sample Location ID	Location Description
SRS Creek Mouth Samples	
SV-2011	Upper Three Runs mouth @ RM 157.2
SV-2013	Beaver Dam Creek mouth @ RM 152.1
SV-2015	Fourmile Branch creek mouth @ RM 150.6
SV-2017	Steel Creek mouth @ RM 141.5
SV-2020	Lower Three Runs mouth @ RM 129.1
Non-Publicly Accessible Stream Samples	
SV-327	Steel Creek @Road 125
SV-328	Lower Three Runs @ Patterson Mill Road
SV-2048	Pen Branch @ Road 125
SV-2049	Four Mile Creek @ Road 125
SV-2053	Par Pond @ Road B
SV-2069	McQueen Branch @ Monroe Owens Road.
SV-2073	Upper Three Runs @ Road C
SRS Stormwater Basin Samples	
SME-001	E-001 E Area stormwater basin
SME-002	E-002 E Area stormwater basin
SME-003	E-003 E Area stormwater basin

Table 1b. Publicly Accessible Sediment Sample Locations at the Savannah River Boat Landings

Sample Location ID	Location Description
Upstream of SRS	
SMFF16	Fury’s Ferry Landing
SMSC16	Steven’s Creek Landing
SMRVP16	North Augusta Riverview Park Boat Landing
SMJBL16	Jackson Boat Landing
Downstream of SRS	
SV-118	Burton’s Ferry Landing, Screven County, G.A.
SV-2018	Steel Creek Landing
SMSCL16	Steel Creek Landing, Barnwell County
SMLHL16	Little Hell Landing
SMJL16	Johnson’s Landing
SMBFL16	Burton’s Ferry Landing
SMCB16	Cohen’s Bluff Landing

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TABLES AND FIGURES

Table 2. Background Sediment Samples

Sample Location ID	County
SMSR16	Salkehatchie River, Colleton County
SMED16	Edisto River, Dorchester County
SMEGF16	Mountain Creek, Edgefield County

Table 3. Gamma Analytes

Radioisotope	Abbreviation
Actinium-228	Ac-228
Americium-241	Am-241
Antimony-125	Sb-125
Beryllium-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
Plutonium-238	Pu-238
Plutonium-239/240	Pu-239/240
Manganese-54	Mn-54
Sodium-22	Na-22
Lead-212	Pb-212
Lead-214	Pb-214
Radium-226	Ra-226
Ruthenium-103	Ru-103
Thorium-234	Th-234
Yttrium-88	Y-88
Zinc-65	Zn-65
Zirconium-95	Zr-95

Table 4. Metal Analytes

Radioisotope	Abbreviation	ESV (mg/kg)
Barium	Ba	330
Beryllium	Be	10
Cadmium	Cd	0.36
Chromium	Cr	28
Copper	Cu	28
Lead	Pb	11
Manganese	Mn	220
Mercury	Hg	0.1
Nickel	Ni	38
Zinc	Zn	46

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TABLES AND FIGURES

Figure 1. 2016 Comparisons of Cs-137 Average Activity Among Sample Location Type

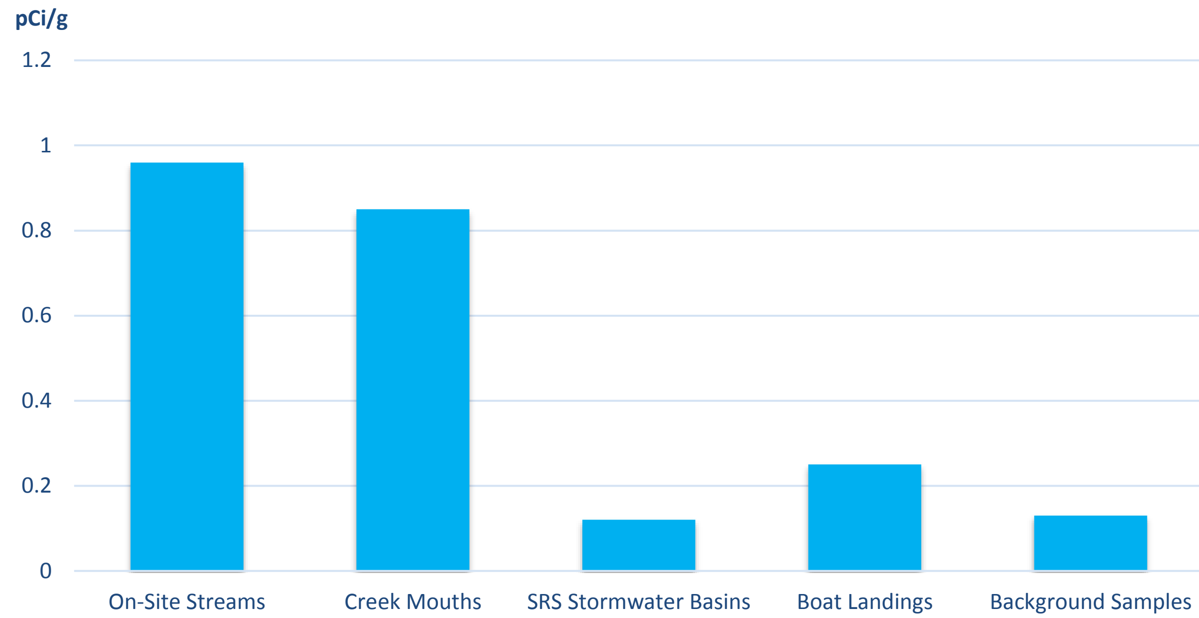
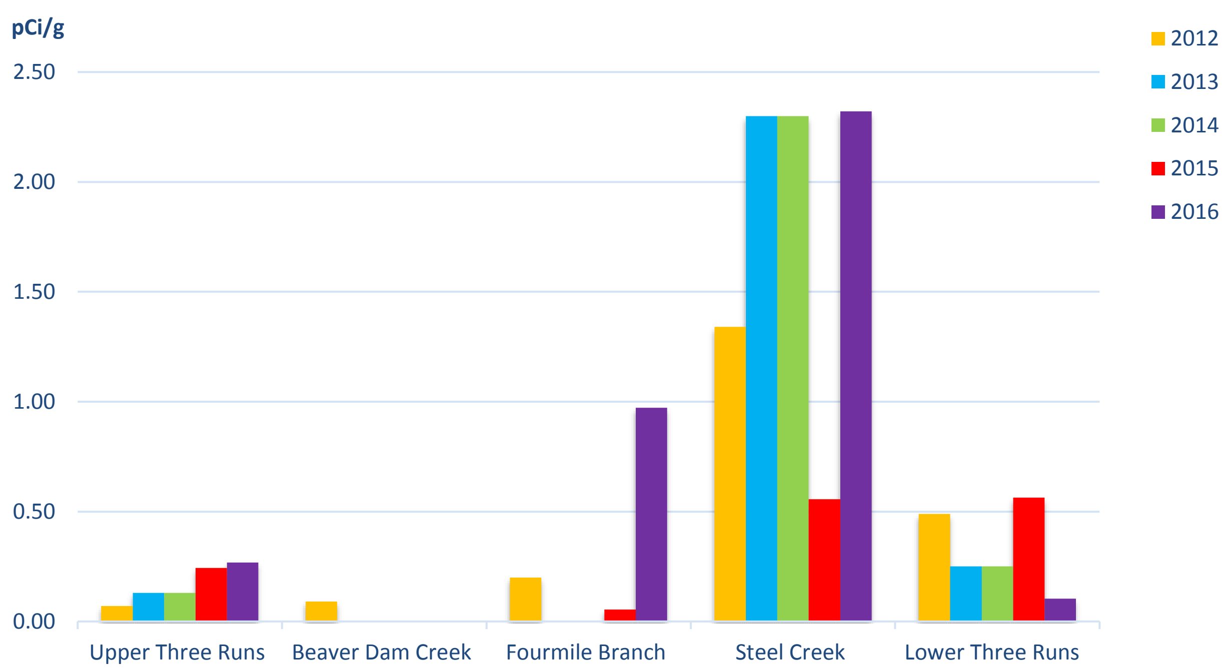


Figure 2. 2012-2016 Trending Data for Cs-137 in SRS Creek Mouth Samples (DHEC 2014a, 2015-2017)



Note: No bar denotes no detection for that year.

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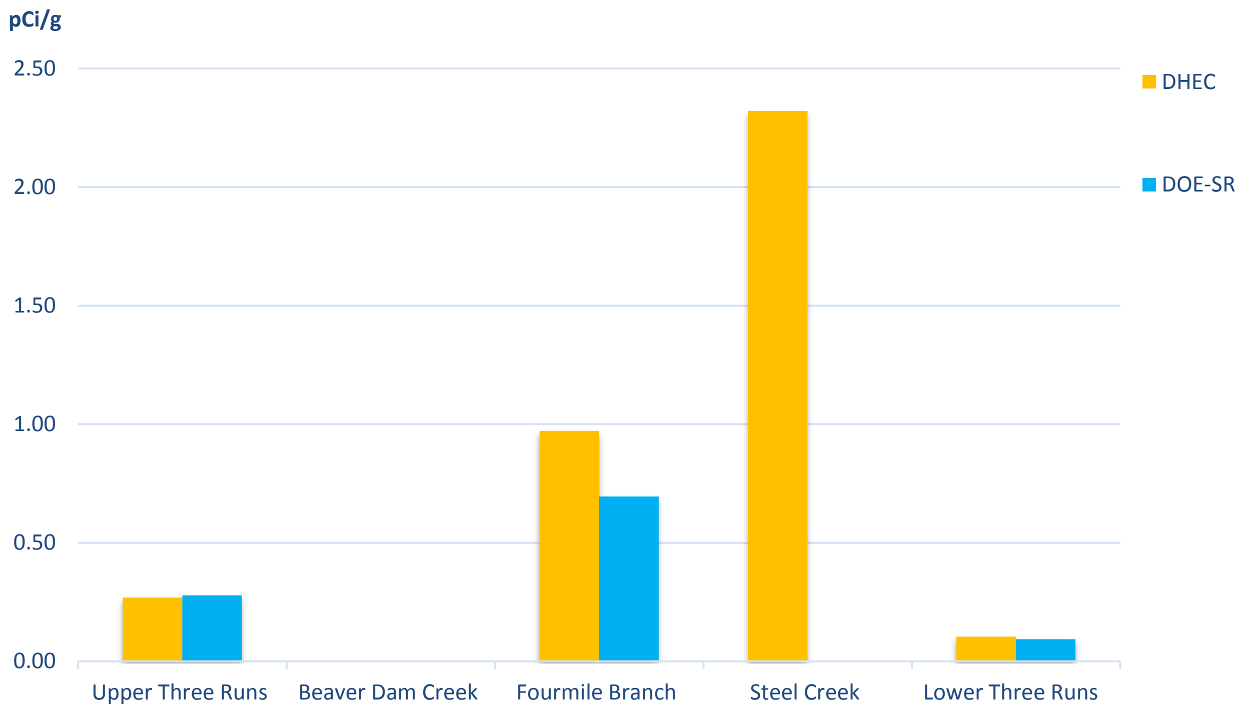
TABLES AND FIGURES

Figure 3. 2016 Cesium-137 in Savannah River Creek Mouths–DHEC Comparison to DOE-SR Data (SRNS 2017)



Notes:

1. Beaver Dam Creek had no detection from DHEC or DOE-SR.
2. DOE-SR did not sample Steel Creek Boat Landing in 2016.

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6.6.0 SUMMARY STATISTICS

2016 Radiological

On-Site Streams

Analyte	Average Concentration (pCi/g)	Standard Deviation	Median (pCi/g)	Minimum (pCi/g)	Maximum (pCi/g)	Number of Detections	Number of Samples
Cs-137	0.96	0.86	0.66	0.24	2.24	6	6
Gross Alpha	32.70	25.17	32.70	14.90	50.50	2	6
Gross Beta	24.3	NA	24.3	<LLD	24.3	1	6

Creek Mouths

Analyte	Average Concentration (pCi/g)	Standard Deviation	Median (pCi/g)	Minimum (pCi/g)	Maximum (pCi/g)	Number of Detections	Number of Samples
Cs-137	0.92	1.01	0.62	0.10	2.32	4	5
Gross Alpha	27.1	NA	27.1	<LLD	27.1	1	5
Gross Beta	18.84	4.78	17.10	15.30	26.80	5	5

Stormwater Basins

Analyte	Average Concentration (pCi/g)	Standard Deviation	Median (pCi/g)	Minimum (pCi/g)	Maximum (pCi/g)	Number of Detections	Number of Samples
Cs-137	0.12	0.13	0.12	0.02	0.21	2	3
Gross Alpha	16.4	NA	16.4	<LLD	16.4	1	3
Gross Beta	ND	NA	NA	<LLD	<LLD	0	3

Boat Landings

Analyte	Average Concentration (pCi/g)	Standard Deviation	Median (pCi/g)	Minimum (pCi/g)	Maximum (pCi/g)	Number of Detections	Number of Samples
Cs-137	0.31	0.26	0.22	0.03	0.64	6	11
Gross Alpha	16.1	NA	16.1	<LLD	16.1	1	11
Gross Beta	16.46	4.88	13.00	12.70	25.10	7	11

Background Samples

Analyte	Average Concentration (pCi/g)	Standard Deviation	Median (pCi/g)	Minimum (pCi/g)	Maximum (pCi/g)	Number of Detections	Number of Samples
Cs-137	0.13	0.08	0.10	0.07	0.21	3	3
Gross Alpha	ND	NA	NA	<LLD	<LLD	0	3
Gross Beta	ND	NA	NA	<LLD	<LLD	0	3

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SUMMARY STATISTICS

2016 Nonradiological (Metals)

On-Site Streams

Analyte	Average Concentration (mg/kg)	Standard Deviation	Median (mg/kg)	Minimum (mg/kg)	Maximum (mg/kg)	Number of Detections	Number of Samples
Barium	37	39	21	8	110	6	7
Beryllium	1.07	0.33	1.07	0.83	1.30	2	7
Cadmium	1.10	0.14	1.10	1.00	1.20	2	7
Chromium	7.8	5.2	8.3	1.4	15.0	7	7
Copper	4.5	4.6	3.0	1.1	11.0	4	7
Lead	9.30	2.40	9.30	7.60	11.00	2	7
Manganese	117	55	120	43	220	7	7
Nickel	5.0	3.6	4.0	2.0	9.8	4	7
Zinc	15	12	10	4	33	7	7

Boat Landings

Analyte	Average Concentration (mg/kg)	Standard Deviation	Median (mg/kg)	Minimum (mg/kg)	Maximum (mg/kg)	Number of Detections	Number of Samples
Barium	102.34	88.77	88.50	8.70	290	8	9
Beryllium	0.56	0.14	0.56	0.46	0.66	2	9
Cadmium	2.1	0.7	1.9	1.3	3.3	6	9
Chromium	17.5	12.2	17.0	1.8	37.0	9	9
Copper	11.0	5.8	8.7	6.4	22.0	6	9
Lead	9.4	0.6	9.4	9.0	9.8	2	9
Manganese	ND	NA	NA	<LLD	<LLD	0	9
Nickel	8	4	9	3	13	7	9
Zinc	44.7	28.1	41.0	5.2	84.0	9	9

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SUMMARY STATISTICS

Stormwater Basins

Analyte	Average Concentration (mg/kg)	Standard Deviation	Median (mg/kg)	Minimum (mg/kg)	Maximum (mg/kg)	Number of Detections	Number of Samples
Barium	77.67	55.90	61	32	140	3	3
Beryllium	0.87	0.41	1.00	0.41	1.20	3	3
Cadmium	4.4	0.2	4.4	4.2	4.5	2	3
Chromium	29	21	35	6	46	3	3
Copper	12.2	9.8	14	1.7	21	3	3
Lead	23	1	23	22	24	2	3
Manganese	101	77	130	14	160	3	3
Nickel	11.1	8.0	13	2.3	18	3	3
Zinc	98	95	82	12	200	3	3

Background Samples

Analyte	Average Concentration (mg/kg)	Standard Deviation	Median (mg/kg)	Minimum (mg/kg)	Maximum (mg/kg)	Number of Detections	Number of Samples
Barium	52	17	44	41	71	3	3
Beryllium	0.42	0.16	0.42	0.31	0.53	2	3
Cadmium	1.9	0.9	1.9	1.2	2.5	2	3
Chromium	16.47	10.07	12	9.4	28	3	3
Copper	4.9	1.9	5.7	2.8	6.3	3	3
Lead	26	21	14	13	50	3	3
Manganese	ND	NA	NA	<LLD	<LLD	0	3
Nickel	4.93	1.59	4.5	3.6	6.7	3	3
Zinc	43	30	30	22	78	3	3

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Chapter 7 Surface Soil Monitoring Adjacent to SRS

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7.1.0 PROJECT SUMMARY

DHEC independently evaluates surface soils adjacent to SRS from ground surface to a 12-inch depth for gross alpha, gross non-volatile beta, and select gamma-emitting radionuclides, as well as specific metals of concern. Soil samples are 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.

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 SRS perimeter (within 50-miles from an SRS center point) and South Carolina background contaminant levels in soils. SRS perimeter and South Carolina background averages were used to determine if DHEC data is 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.

DHEC collected samples in 2016 from three background sites. Nineteen samples were collected from SRS perimeter locations (Section 7.5.0, Table 1). SRS perimeter sampling locations are depicted on the Map in Section 7.4.0. A list of all background sampling locations is in Section 7.5.0, Table 2.

7.2.0 RESULTS AND DISCUSSION

Soil Monitoring Summary Statistics for radionuclides and metals can be found in Section 7.6.0 and all Soil Monitoring Data can be found in the 2016 DHEC Data File.

7.2.1 Radiological Parameter Results

A list of all radiological analytes can be found in Section 7.5.0, Table 5. Most samples had detectable amounts of Cs-137, an anthropogenic radionuclide, that may be due to past releases by SRS and atmospheric fallout from past nuclear weapons testing (EPA 2014). An assessment of Cs-137 activity in 2016 is comparable to levels detected by DHEC in the past. There were no surface soil samples collected in 2016 that were above the EPA Preliminary Remediation Goals (PRGs) (Section 7.5.0, Table 3). The conservative soil ingestion PRGs correspond to a risk for a chronic total exposure pathway residential scenario and a one in one million increased cancer risk.

DHEC had Cs-137 detections in 17 of 19 SRS perimeter samples and two of the three background samples above the LLD in 2016.

Cesium-137 was the only gamma-emitting radionuclide that DHEC and DOE-SR shared in analytical results. DHEC data from 2016 background samples show a slight increase in the average level of Cs-137 from the 2015 data. DOE-SR reports in 2016 that Cs-137 concentrations are consistent with historical results. Trending data for Cs-137 is in Section 7.5.0, Figures 1 and 2.

The results found by both DHEC 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). In previous years, increases of Cs-137 activity in the perimeter samples 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, DHEC only collected samples within 50-miles of the SRS center point to determine the yearly average.

The only other gamma-emitting radionuclides detected in DHEC surface soil samples were potassium-40, lead-212, lead-214, radium-226, actinium-228, and thallium-234. These are NORM decay products.

In 2016, there were no gross alpha and only one gross non-volatile beta detection in a background location.

7.2.2 Nonradiological Parameter Results

A complete list of all DHEC nonradiological analytes can be found in Section 7.5.0, Table 6. DOE-SR did not analyze for metals; therefore, no comparisons could be made. DHEC saw no exceedances of the EPA Regional Screening Levels (RSLs) in any of the surface soil samples in 2016. The EPA RSLs can be found in Section 7.5.0, Table 4 (EPA 2014).

Barium has been a constituent of the H-Area Hazardous Waste Management Facility (WSRC 1993). Barium was detected in 10 of the 19 SRS perimeter samples and all three background samples.

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 not detected in the SRS perimeter or background samples in 2016 above the detection limit.

Cadmium enters the atmosphere through fuel and coal combustion (Till et al. 2001). One of the perimeter and two of the background surface soil samples yielded detections.

Chromium solutions were used at 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 separations 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 a considerable distance in the air and contain trace elements of chromium (Alloway 1995). Chromium was detected in all SRS perimeter and background samples.

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 15 SRS perimeter samples and one background.

Atmospheric emissions of lead from SRS occurred through coal and fuel combustion (Till et al. 2001). Lead can deposit in soil and, due to its immobility, can 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 16 SRS perimeter and two background samples.

Manganese has been released in the separations areas processes and discharged to liquid waste tanks (Till et al. 2001). It is also a byproduct of coal burning. Manganese was detected in all SRS perimeter and background samples.

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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 five SRS perimeter and two background samples.

Zinc was released in relatively small amounts to the separations areas seepage basins as well as the M-Area seepage basin (Till et al. 2001). Zinc was detected in all SRS perimeter and background samples.

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. There were no mercury detections in surface soil samples collected in 2016.

7.3.0 CONCLUSIONS AND RECOMMENDATIONS

Soil samples from DHEC and DOE-SR programs varied by location and in number. When interpreting data, it should be taken into consideration that samples were collected from a variety of soil types and locations.

DHEC 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 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 DHEC provides credibility and confidence in the information being provided to the public.

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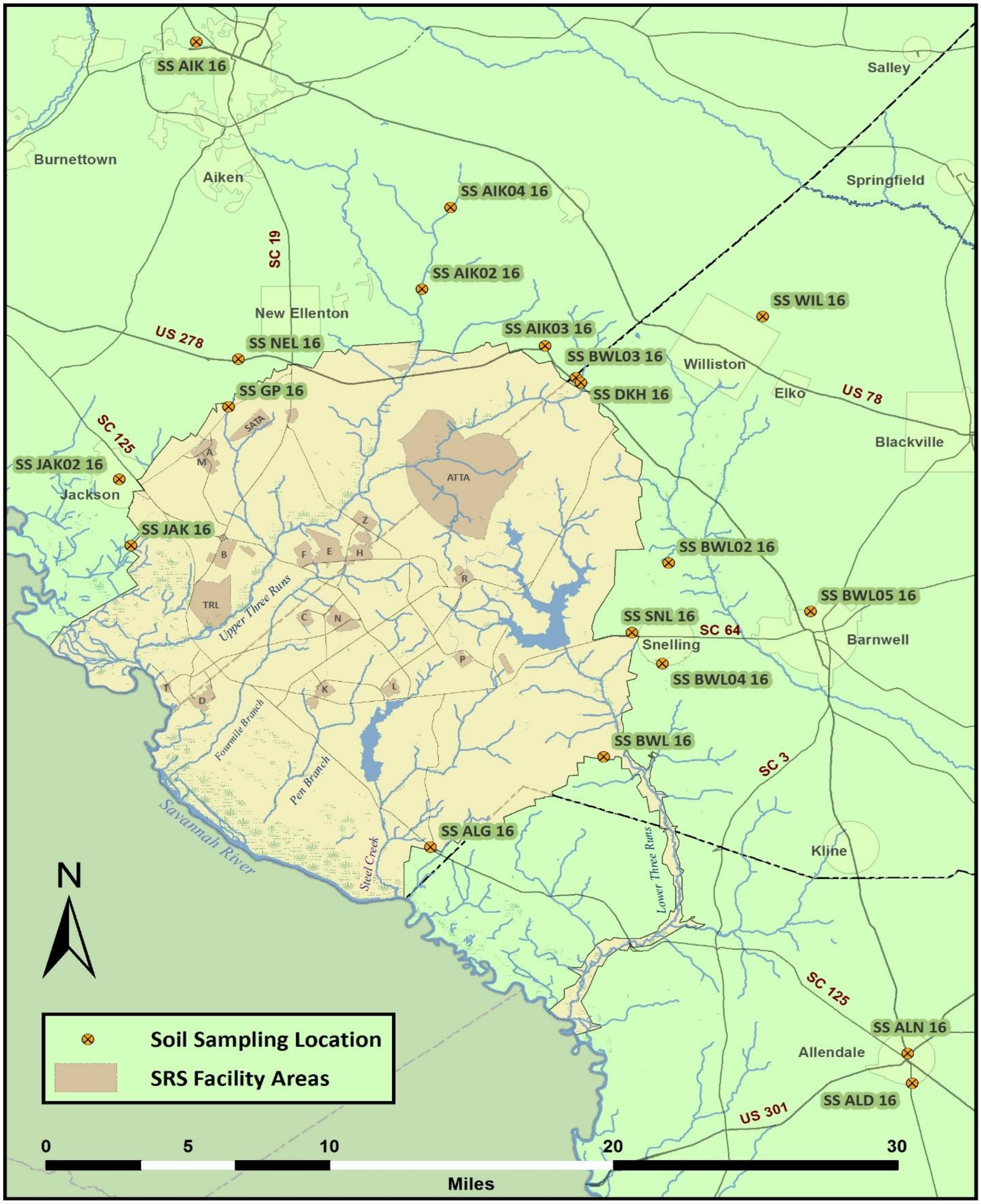
7.4.0 MAP

SRS Perimeter Surface Soil Monitoring



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7.5.0 TABLES AND FIGURES

Table 1. Perimeter Soil Samples Collected in 2016

Sample ID	Location	County
SSALG16	Allendale Gate	Allendale
SSSNL16	Snelling Gate	Barnwell
SSDKH16	Darkhorse	Barnwell
SSALN16	Allendale	Allendale
SSGP16	Green Pond	Aiken
SSJAK16	Jackson	Aiken
SSAIK16	Aiken	Aiken
SSJAK0216	Jackson	Aiken
SSNEL16	New Ellenton	Aiken
SSBWL16	Colocated at VG site BWL-004	Barnwell
SSAIK0216	Boggy Gut Road	Aiken
SSBWL0216	Colocated at VG site BWL-002	Barnwell
SSBWL0316	Colocated at VG site BWL-001	Barnwell
SSAIK0316	Colocated at VG site AIK 0903	Barnwell
SSALD16	Colocated at VG site ALD-251	Allendale
SSBWL0416	Colocated at VG site BWL-003	Barnwell
SSAIK0416	Upper Three Runs at Barnwell Rd	Aiken
SSBWL0516	Barnwell Lake Edgar Brown	Barnwell
SSWIL16	Williston Plum Location EVBWL-02	Barnwell

Table 2. Background Soil Samples Collected in 2016

Sample ID	County
SSCOL16	Colleton
SSDOR16	Dorchester
SSEGF16	Edgefield

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TABLES AND FIGURES

Table 3. Soil Ingestion Preliminary Remediation Goals of Select Anthropogenic Radionuclides

Radionuclide	Abbreviation	PRG
Americium-241	Am-241	4.9 pCi/g
Cesium-137	Cs-137	28 pCi/g
Cobalt-60	Co-60	83 pCi/g
Iodine-131	I-131	6000 pCi/g
Plutonium-238	Pu-238	3.9 pCi/g
Plutonium-239/240	Pu-239/240	3.9 pCi/g

Table 4. Regional Screening Levels of Metals sampled by DHEC

Analyte	Abbreviation	RSL
Barium	Ba	15,000 mg/kg
Beryllium	Be	160 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

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TABLES AND FIGURES

Table 5. Radiological Analytes

Radioisotope	Abbreviation
Actinium-228	Ac-228
Americium-241	Am-241
Beryllium-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
Plutonium-238	Pu-238
Plutonium-239/240	Pu-239/240
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 6. Nonradiological Analytes

Analyte	Abbreviation
Barium	Ba
Beryllium	Be
Cadmium	Cd
Chromium	Cr
Copper	Cu
Mercury	Hg
Manganese	Mn
Nickel	Ni
Lead	Pb
Zinc	Zn

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TABLES AND FIGURES

Figure 1. 2012-2016 DHEC and DOE-SR Trending Averages for Cesium-137 (SRNS 2013-2017, DHEC 2014a, 2015-2017)

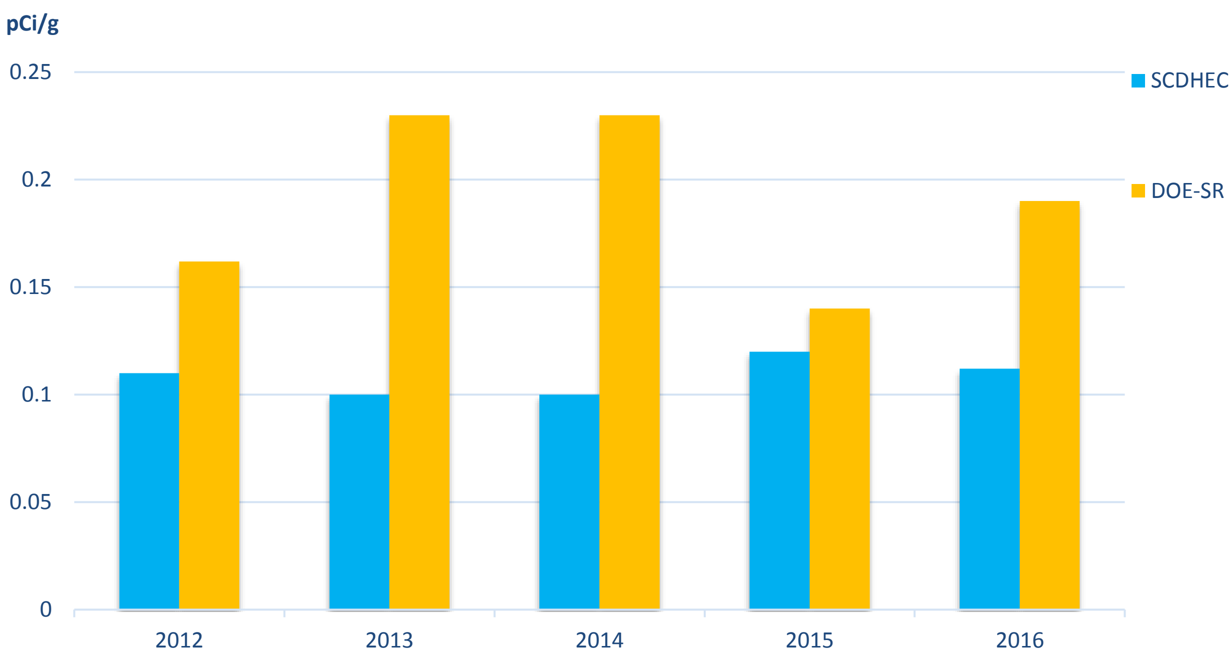
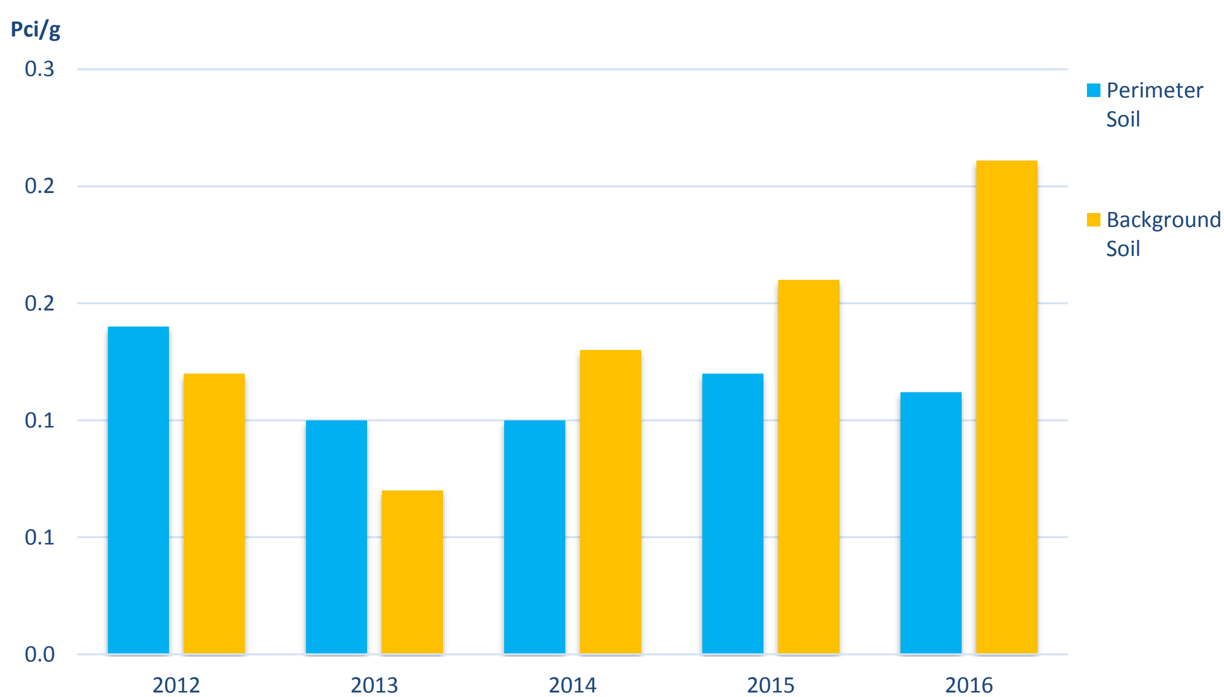


Figure 2. 2012-2016 Perimeter and Background Trending Averages for Cesium-137 (DHEC 2014a, 2015-2017)



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7.6.0 SUMMARY STATISTICS

2016 Radiological Statistics

SRS Perimeter Samples

Analyte	Average Concentration (pCi/g)	Standard Deviation	Median (pCi/g)	Minimum (pCi/g)	Maximum (pCi/g)	Number of Detections	Number of Samples
Cs-137	0.112	0.039	0.113	0.042	0.172	17	19
Gross Beta	13.1	NA	13.1	<LLD	13.1	1	19

Background Samples

Analyte	Average Concentration (pCi/g)	Standard Deviation	Median (pCi/g)	Minimum (pCi/g)	Maximum (pCi/g)	Number of Detections	Number of Samples
Cs-137	0.211	0.154	0.211	0.102	0.320	2	3

2016 Nonradiological (Metals) Statistics

SRS Perimeter Samples

Analyte	Average Concentration (mg/kg)	Standard Deviation	Median (mg/kg)	Minimum (mg/kg)	Maximum (mg/kg)	Number of Detections	Number of Samples
Barium	25	12	23	12	55	19	19
Cadmium	1.20	NA	NA	<LLD	1.20	1	19
Chromium	3.99	2.35	3.10	1.70	9.70	19	19
Copper	2.17	1.50	1.60	1.00	5.60	15	19
Lead	7.44	1.76	7.15	5.20	12.00	16	19
Manganese	65.76	53.99	57.00	7.60	170.00	19	19
Nickel	3.92	0.64	3.90	3.20	4.70	5	19
Zinc	6.41	4.13	5.20	2.80	17.00	19	19

Background Samples

Analyte	Average Concentration (mg/kg)	Standard Deviation	Median (mg/kg)	Minimum (mg/kg)	Maximum (mg/kg)	Number of Detections	Number of Samples
Barium	39.67	30.92	31.00	14.00	74.00	3	3
Cadmium	1.40	0.28	1.40	1.20	1.60	2	3
Chromium	21.37	19.05	14.00	7.10	43.00	3	3
Copper	6.70	NA	NA	<LLD	6.70	1	3
Lead	13.40	6.51	13.40	8.80	18.00	2	3
Manganese	205.67	289.54	39.00	38.00	540.00	3	3
Nickel	5.70	5.09	5.70	2.10	9.30	2	3
Zinc	25.00	3.46	23.00	23.00	29.00	3	3

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Chapter 8 Radiological Monitoring of Terrestrial Vegetation Adjacent to SRS

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8.1.0 PROJECT SUMMARY

DOE-SR contracts for the collection and analysis of terrestrial vegetation, primarily Bermuda grass, to determine concentrations of radionuclides (SRNS 2017). The samples are obtained from 10 locations at the SRS perimeter, one onsite location at the burial grounds, and three locations 25 miles from the center of SRS. DHEC 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 laurel cherry (*Prunus caroliniana*).

In 2016, DHEC conducted independent vegetation monitoring at 17 perimeter, three background locations, and three 25-mile locations. These 25-mile samples allow comparisons to be made between tritium levels at the SRS perimeter and in the general SRS area. DHEC and DOE-SR perimeter stations sampled in 2016 are shown in Section 8.4.0, Map.

8.2.0 RESULTS AND DISCUSSION

Terrestrial Vegetation Data

Terrestrial Vegetation Monitoring Summary Statistics can be found in Section 8.6.0 and all Terrestrial Vegetation Monitoring Data can be found in the 2016 DHEC Data File.

Tritium was detected in vegetation from 10 of the 11 perimeter sites sampled in 2016. There were tritium detections at all three of the 25-mile stations in 2016.

Additional samples collected as background samples in St. George, South Carolina, Walterboro, South Carolina, and at the Old Sheldon Church ruins in Beaufort County yielded no detections.

Tritium analysis results from DHEC and DOE-SR sampling are presented in Section 8.5.0, Table 2 However, differences between the two programs in sampling dates, the vegetation sampled, and analysis methods should be considered during comparison. Provided there are detections, data comparison of associated locations from the two programs is conducted by converting from picocuries per gram (pCi/g) to pCi/L.

DHEC and DOE-SR had three colocated sampling locations (Patterson Mill Road, Allendale Gate, and Talatha Gate) that had no detections for tritium in 2016 (SRNS 2017).

DOE-SR and DHEC sampled vegetation at nine comparable locations, including colocations, in 2016. At these locations, DOE-SR reported one detection of 230 pCi/L while DHEC had seven at an average of 1745 pCi/L. Most of the tritium activity detected by DHEC was from samples collected in the later part of the year; DOE-SR only sampled in the spring.

Gamma

In 2016, DHEC detected actinium-228, beryllium-7, potassium-40, lead-212, and lead-214. Because all these isotopes are NORM, the results will not be discussed in this section, but are presented in the 2016 DHEC Data File. A list of radionuclides in the gamma spectroscopy analysis are in Section 8.5.0, Table 1.

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EPA has established an MCL of four millirem (mrem) per year for total beta particle and photon radioactivity from man-made radionuclides in drinking water. The average concentration of cesium-137 which is assumed to yield four mrem per year is 200 pCi/L (EPA 2002a).

DOE-SR detected Cs-137 at seven of nine sampling stations that had a comparable DHEC location or colocation. DHEC had detections at three of nine comparable locations in 2016. Gamma analysis results for Cs-137 from DHEC and DOE-SR sampling in 2016 are presented in Section 8.5.0, Table 2. Figure 1 in Section 8.5.0 illustrates the DHEC vegetation sample results from 2012 to 2016.

The man-made isotopes Co-60 and Am-241 were not detected in the DHEC 2016 samples.

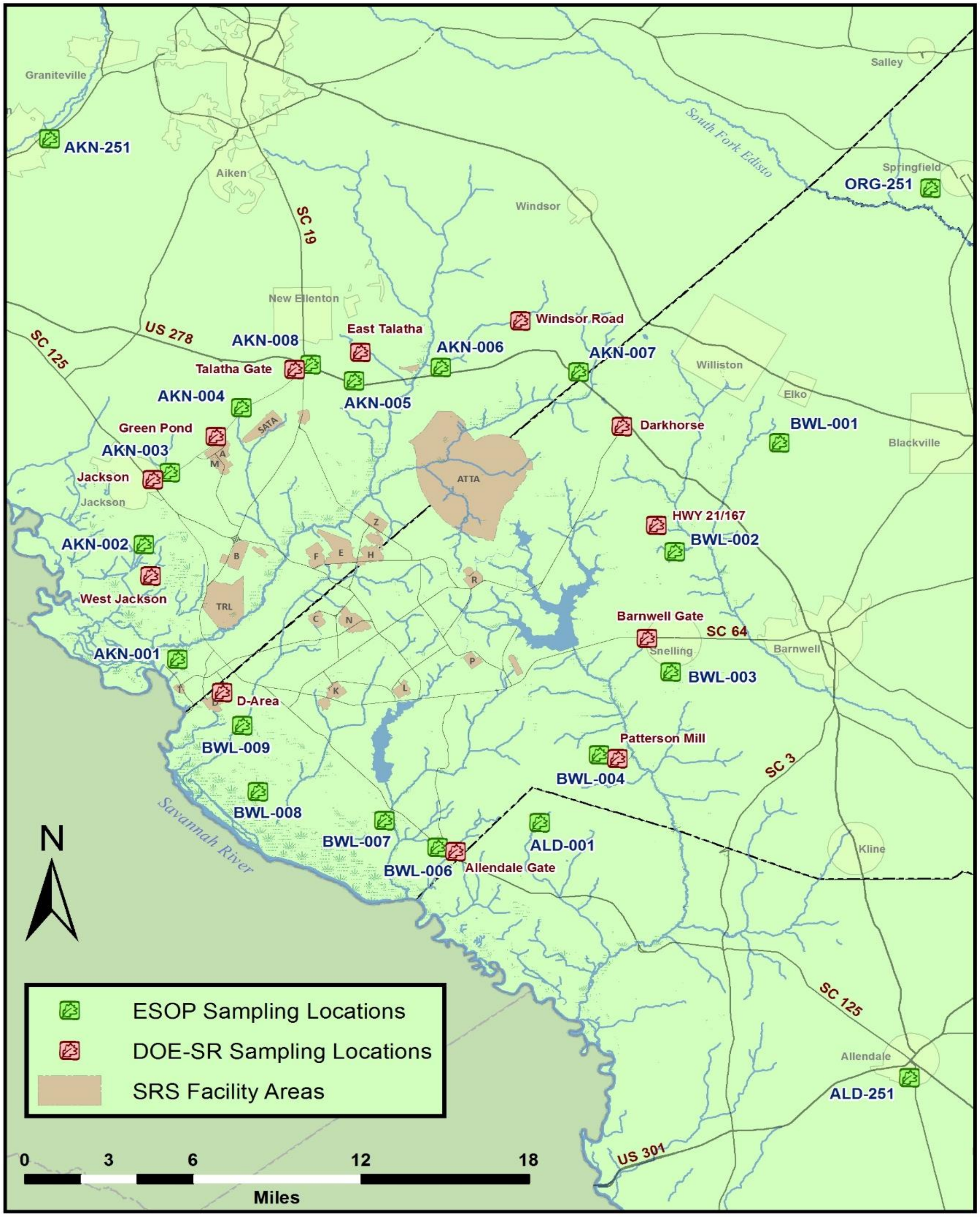
8.3.0 CONCLUSIONS AND RECOMMENDATIONS

DHEC and DOE-SR collect a different suite of terrestrial vegetation (e.g., DHEC collects leaves from trees, whereas DOE-SR conducts annual grass collections). Both sample sets are complimentary and allow indirect comparisons to be made.

Differences in analysis, sampling methods, and the dates samples were obtained may account for any discrepancies between the data.

8.4.0 MAP

Terrestrial Vegetation Sampling Locations



2016 ESOP Terrestrial Vegetation Monitoring www.scdhec.gov/srs

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8.5.0 TABLES AND FIGURES

Table 1. Radiological Analytes for Gamma Spectroscopy Analysis

Radioisotope	Abbreviation
Actinium-228	Ac-228
Americium-241	Am-241
Beryllium-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

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TABLES AND FIGURES

Table 2. 2016 Cesium-137 Data Comparison for DHEC and DOE-SR Sampling Locations

DOE-SR Data			DHEC Data		
Station	**Result (pCi/g)**	**Standard Deviation**	**Station**	**Results Average (pCi/g)**	**Standard Deviation**
D-Area	<MDC	NA	**BWL-009[a]**	NS	NA
Jackson	0.23	0.03	**AKN-003[a]**	<MDA	NA
Green Pond	0.06	0.02	**AKN-004[a]**	NS	NA
Talatha Gate	0.12	0.03	**AKN-008[b]**	0.07[c]	NA
East Talatha	0.17	0.03	**AKN-005[a]**	0.09	0.05
Darkhorse	0.10	0.02	**BWL-001[a]**	NS	NA
Barnwell Gate	<MDC	NA	**BWL-003[a]**	NS	NA
Patterson Mill Road	0.09	0.03	**BWL-004[b]**	0.13[c]	NA
Allendale Gate	0.55	0.06	**BWL-006[b]**	<MDA	NA
Average	0.17		**Average**	0.09	
Standard Deviation	0.03		**Standard Deviation**	0.04	
Median	0.11		**Median**	0.09	

Notes:
1. <MDC denotes less than the DOE-SR Minimum Detectable Concentration
2. <MDA denotes less than the DHEC Minimum Detectable Activity
3. NS is No Sample
4. NA is Not Applicable
5. [a] Comparable DHEC Location
6. [b] Colocation
7. [c] DHEC Average based on one detection

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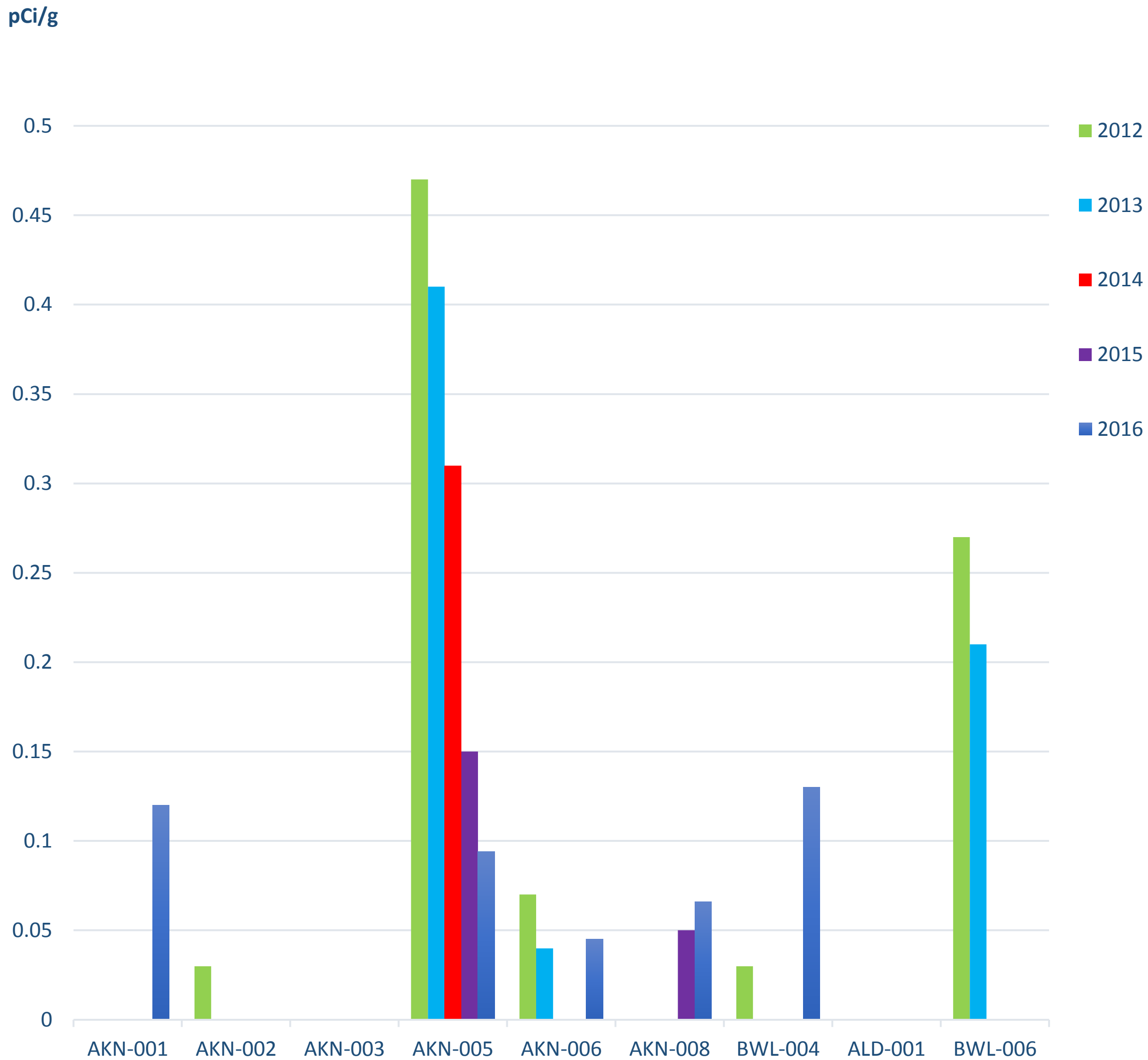
TABLES AND FIGURES

Figure 1. 2012-2016 Cs-137 in Vegetation at SRS Perimeter (DHEC 2014a, 2015-2017)



Notes:
1. Missing bars indicate an average that was less than the minimum detectable activity
2. Some bars may be based on a single detection

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8.6.0 SUMMARY STATISTICS

2016 SRS Perimeter Locations-Tritium

Sample Location	Average (pCi/L)	Standard Deviation	Median (pCi/L)	Minimum (pCi/L)	Maximum (pCi/L)	Number of Samples	Number of Detections
AKN-001	ND	NA	NA	<LLD	<LLD	2	0
AKN-002	ND	NA	NA	<LLD	<LLD	2	0
AKN-003	2755	2284	2755	1140	4370	2	2
AKN-004	388	NA	388	<LLD	388	2	1
AKN-005	ND	NA	NA	<LLD	<LLD	2	0
AKN-006	430	NA	430	<LLD	430	1	1
AKN-007	1200	NA	1200	<LLD	1200	2	1
AKN-008	ND	NA	NA	<LLD	<LLD	2	0
BWL-001	359	NA	359	<LLD	359	2	1
BWL-002	577	NA	577	<LLD	577	2	1
BWL-003	2328	2223	2328	756	3900	2	2
BWL-004	ND	NA	NA	<LLD	<LLD	2	0
ALD-001	335	NA	335	<LLD	335	2	1
BWL-006	ND	NA	NA	<LLD	<LLD	2	0
BWL-007	ND	NA	NA	<LLD	<LLD	2	0
BWL-008	1173	703	1173	676	1670	2	2
BWL-009	1300	NA	1300	>LLD	1300	2	1
Total	1315	1322	756	335	4370	33	13

2016 25-Mile Radius Locations-Tritium

Sample Location	Average (pCi/L)	Standard Deviation	Median (pCi/L)	Minimum (pCi/L)	Maximum (pCi/L)	Number of Samples	Number of Detections
AKN-251	1234	914	1234	588	1880	2	2
ALD-251	652	606	652	223	1080	2	2
ORG-251	1445	1068	1445	689	2200	2	2

Notes:
1. pCi/L is picocuries per liter
2. LLD is Lower Limit of Detection
3. ND is Not Detected
4. NA is Not Applicable

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SUMMARY STATISTICS

2016 SRS Perimeter-Cesium-137

Sample Location	Average (pCi/g) fresh	Standard Deviation	Median (pCi/g)	Minimum (pCi/g)	Maximum (pCi/g)	Number of Samples	Number of Detections
AKN-001	0.120	NA	0.120	<MDA	0.120	2	1
AKN-002	ND	NA	NA	<MDA	<MDA	2	0
AKN-003	ND	NA	NA	<MDA	<MDA	2	0
AKN-005	0.094	0.047	0.094	0.061	0.127	2	2
AKN-006	0.045	NA	0.045	<MDA	0.045	1	1
AKN-008	0.066	NA	0.066	<MDA	0.066	2	1
BWL-004	0.130	NA	0.130	<MDA	0.130	2	1
ALD-001	ND	NA	NA	<MDA	<MDA	2	0
BWL-006	ND	NA	NA	<MDA	<MDA	2	0
Total	0.091	0.038	0.093	0.045	0.130	17	6

Notes:
1. pCi/g is picocuries per gram
2. MDA is Minimum Detectable Activity
3. ND is Not Detected
4. NA is Not Applicable
5. Averages may be based on one detection and exclude non-detections

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Chapter 9 Radiological Monitoring of Edible Vegetation Adjacent to SRS

9.1.0 PROJECT SUMMARY

The Radiological Monitoring of Edible Vegetation Project monitors edible food in perimeter and background locations around SRS. DHEC defined a study area comprised of grids radiating out to 25 miles from the SRS center point, 25 miles to 50 miles, and background locations greater than 50 miles from the SRS centerpoint (Map in Section 9.4.0). DOE-SR, as compared to DHEC, 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. Comparisons are based on tables and data sections of this report with the DOE-SR Environmental Report 2016 (SRNS 2017). Direct comparisons between DOE-SR and DHEC could not be made due to variation in sampling and analysis methodologies.

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 contributed some domestically grown crops. Wild edible vegetation such as muscadines and plums was also collected. References to vegetation in this report pertain to the edible parts of plants.

DHEC background sampling helps to separate atomic test fallout contamination levels and other sources (e.g. ongoing permitted releases at other nuclear facilities) from SRS source potential contamination. However, fallout dispersion patterns and concentrations are weather related and not uniform, and no assignment of specific source can be made.

9.2.0 RESULTS AND DISCUSSION

Edible Vegetation Monitoring Summary Statistics can be found in Section 9.6.0 and all Edible Vegetation Monitoring Data can be found in the 2016 DHEC Data File.

Section 9.5.0, Tables 1-3 show the radionuclides of concern, the guideline levels, the intervention levels and their conversion to pCi/g for data comparison. The International Atomic Energy Agency (IAEA 2004) has established guideline levels for radionuclides in foods for general consumption, emphasizing the cumulative radioactivity guideline levels (Section 9.5.0, Table 2).

The U.S. Food and Drug Administration (FDA) also has guidance levels for specific radionuclides called Derived Intervention Levels (DILs). The FDA 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 9.5.0, Table 3) (FDA 2005).

DHEC had tritium detections in two of the nine greens/vegetables samples, five of the 23 fruits/ nuts samples, and two of the nine fungi samples. DOE-SR only had one detection for tritium in greens collected in the southwest quadrant within 10 miles of the SRS perimeter (SRNS 2017).

DHEC had the highest tritium detection from a fungi sample in Aiken County at 3,010 pCi/L. The observed levels of tritium in edible vegetation were below the IAEA Radionuclides Guidelines for Food of 270,000 pCi/L.

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In 2016, DOE-SR edible vegetation exhibited radiological detections of strontium-89/90, uranium-234, uranium-235, neptunium-237, uranium-238, americium-241, technetium-99 (SRNS 2017). All DOE-SR food sample radionuclide detections were less than the IAEA guideline levels and the FDA DILs. All the detected gamma radionuclides, except Cs-137, originated from naturally occurring radioactive material. NORM radionuclides were the source of most detections in edible vegetation and are not discussed further as radionuclides of concern unless detection levels exceed the South Carolina background.

DHEC only had Cs-137 detections in fungi samples in 2016. There were five Cs-137 detections out of nine samples, with the highest detection being a from a background location in Columbia, S.C. at 0.63 pCi/g, which is well below the guideline levels. DOE-SR had detections in ten of the 20 samples collected in 2016 at an average of 0.017 pCi/g.

9.3.0 CONCLUSIONS AND RECOMMENDATIONS

DHEC and DOE-SR have different edible vegetation sampling schemes. DOE-SR samples primarily domestic plants collected from annual contributors in quadrants at zero to 10 miles from the perimeter of the SRS border and one quadrant at 25 miles; whereas, DHEC accepts domestic plants as donations from citizens and collects perennial wild edible vegetation and fungi found within 50 miles of the SRS center point and background locations.

In the future, DHEC will explore opportunities to split samples with DOE-SR and attempt to establish colocated sampling locations for better comparisons between the two. DHEC will consider analyzing samples for Sr-89/90 to compare to the DOE-SR data. In addition, DHEC will continue to collect wild fungi due to its inherent ability to bioconcentrate Cs-137. DOE-SR might consider sampling some wild vegetation for comparisons with DHEC.

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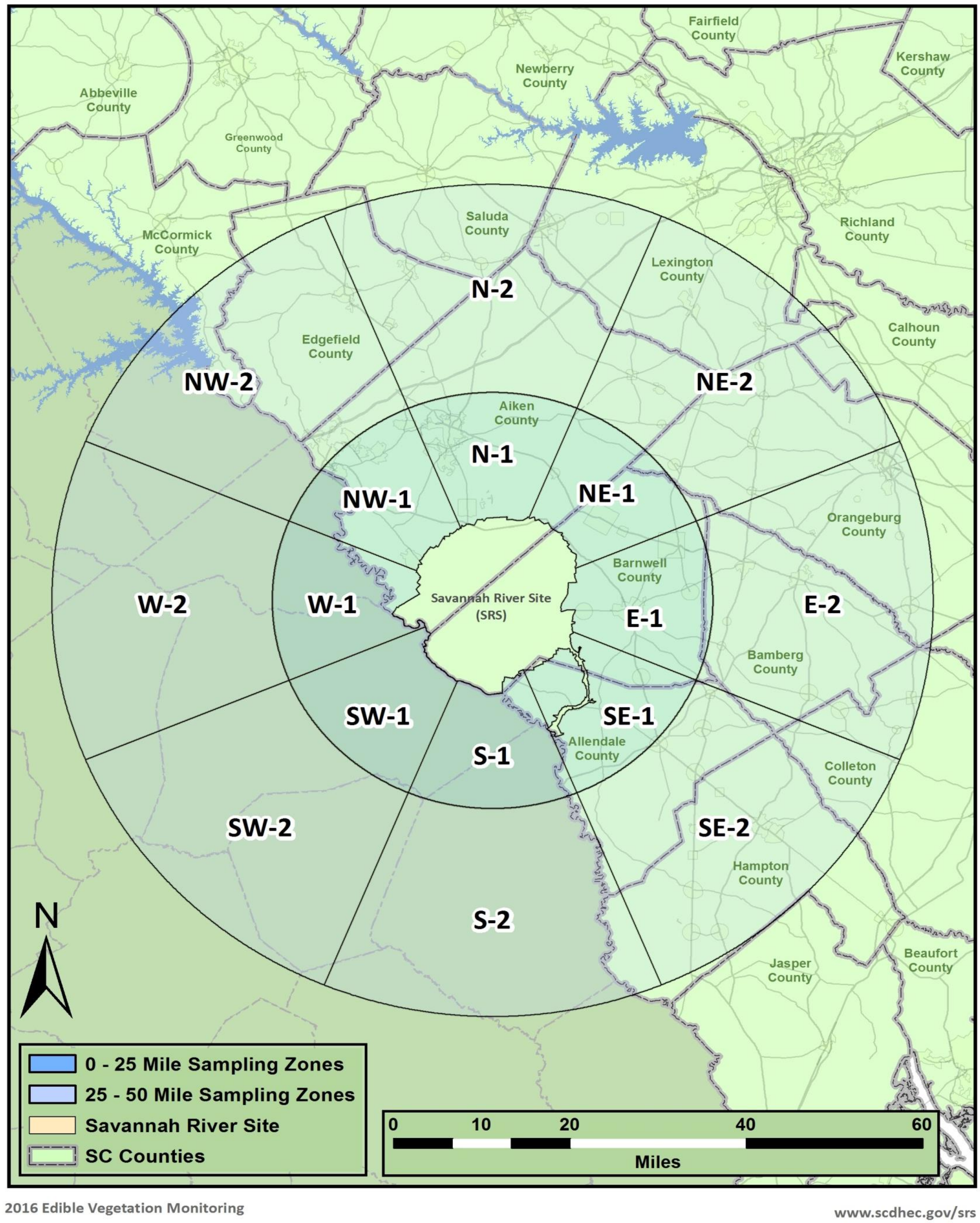
9.4.0 MAP

DHEC Edible Vegetation Monitoring



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9.5.0 TABLES AND FIGURES

Table 1. Radiological Laboratory Suite

Radioisotope	Abbreviation
Actinium-228	Ac-228
Americium-241	Am-241
Beryllium-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

TABLES AND FIGURES

Table 2. IAEA Guideline Levels for Radionuclides in Food

Radionuclides	Bq/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
tritium, C-14, Tc-99	10000	270

Table 3. FDA Derived Intervention Levels for Radionuclides in Food

FDA Derived Intervention Levels for Each Radionuclide Group for Food in Domestic Commerce and Food Offered for Import		
	Guidance Levels	
Radionuclide Group	Bq/kg	pCi/g
Sr-90	160	4.32
I-131	170	4.59
Cs-134, Cs-137	1200	32.4
Pu-238, Pu-239, Am-241	2	0.054

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9.6.0 SUMMARY STATISTICS

2016 Tritium Detections in Edible Vegetation by Grid

Grid	Average (pCi/L)	Standard Deviation (pCi/L)	Median	Minimum	Maximum	Number of Detections	Number of Samples
W-1	ND	NA	ND	<LLD	<LLD	0	1
NW-1	555	NA	555	<LLD	555	1	5
NW-2	1200	NA	1200	<LLD	1200	1	3
N-1	220	NA	220	<LLD	220	1	6
N-2	ND	NA	ND	<LLD	<LLD	0	5
NE-1	1158	1135	1158	<LLD	1960	2	5
NE-2	3010	NA	3010	<LLD	3010	1	6
E-1	291	NA	291	<LLD	291	1	8
E-2	315	NA	315	315	315	1	1
SE-1	266	NA	266	<LLD	266	1	6
S-1	ND	NA	ND	<LLD	<LLD	0	1
Background	ND	NA	ND	<LLD	<LLD	0	2
Total	982	1019	455	<LLD	3010	8	45

2016 Tritium Detections in Edible Vegetation by Type

Type	Average (pCi/L)	Standard Deviation (pCi/L)	Median	Minimum	Maximum	Number of Detections	Number of Samples
Greens/Vegetables	311	63	311	<LLD	355	2	9
Fruits/Nuts	797	764	315	<LLD	1960	5	23
Fungi	1783	1763	1783	<LLD	3010	2	9

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Chapter 10 Radiological Monitoring of Dairy Milk

10.1.0 PROJECT SUMMARY

Operations at SRS have resulted in the potential for radiological constituents to be released to the surrounding environment. Milk from dairies around SRS is routinely analyzed for levels of radioactivity that could impact human health.

Consumption of milk products containing radioactive materials can be a human exposure pathway. When an atmospheric release occurs, radionuclides can be deposited on pastures and ingested by grazing dairy animals. The animals may release a portion of the radionuclides into their milk that could be consumed by humans (Till et al. 2001). Radionuclides could also enter milk through the irrigation of a pasture using groundwater containing radioactive materials and through uptake by plants from soil containing radioactive materials.

DHEC collected milk at five dairy locations within South Carolina (Section 10.4.0, Map). Four of these locations are within a 50-mile radius of the SRS center point and one is a background location beyond the 50-mile radius. This project provides analytical data for trending and comparison to published DOE-SR data.

DHEC personnel collected unpasteurized milk samples on a quarterly basis in 2016. All milk samples from each quarter were analyzed for tritium, total strontium (Sr-89/90), and gamma-emitting radionuclides. While a select group of gamma-emitting radionuclides (iodine-131 (I-131), Cs-137, and cobalt-60 (Co-60)) are analytes of concern in dairy milk for this project, all other detections such as potassium-40 (K-40) are considered NORM. Naturally occurring radionuclides are the source of most public exposure; however, they are not discussed in this report unless detections are significantly greater than those of the background location detections. DHEC analyzes samples for Sr-89/90 instead of only Sr-90. This is done to provide a more conservative result, and it is assumed the total strontium detected is in the form of Sr-90.

10.2.0 RESULTS AND DISCUSSION

Milk Monitoring Summary Statistics can be found in Section 10.6.0 and all Milk Monitoring Data can be found in the 2016 DHEC Data File.

None of the 20 DHEC milk samples collected during 2016 exhibited tritium activity above the LLD. DOE-SR detected tritium in one sample from a South Carolina dairy and one from a Georgia dairy out of the 32 samples collected for 2016.

DHEC analyzed for gamma-emitting radionuclides (K-40, I-131, Cs-137, and Co-60) in 20 milk samples collected in 2016. All analytical results for these radionuclides were below the sample MDA except for natural occurring K-40. These results are consistent with past gamma results and no summary statistics were calculated for these radionuclides due to a lack of numerical data. DOE-SR had one detection of Cs-137 from a Georgia dairy. Radionuclide contributions to milk may come from SRS, other nearby nuclear facilities, or legacy contamination from the cold war period (Till et al. 2001).

Three of the 20 DHEC milk samples collected in 2016 exhibited strontium activity above the MDA. The highest detection came from a perimeter location in Edgefield. Section 10.5.0, Figure 1 shows the trend for DHEC strontium detections for the last five years. All strontium averages have been below the EPA established MCL of 8 pCi/L for Sr-90 since testing initiated in 1998 (EPA 2002b). DOE-SR detected Sr-89/90 in three of 32 samples collected in 2016. One detection

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was from a South Carolina dairy and two were from Georgia dairies. The average activity for all detections was 1.67 pCi/L. The highest detection was 4.47 pCi/L (SRNS 2017).

10.3.0 CONCLUSIONS AND RECOMMENDATIONS

A large portion of the radiological activity observed in milk samples can be attributed to fallout from past nuclear testing (Kathren 1984). Also, radionuclides within soil and plants can potentially be redistributed as a result of farming practices and prescribed burns. DHEC will continue to monitor tritium, gamma-emitting radionuclides, and strontium in milk to ensure the safety of milk consumption by the public.

DHEC will continue to seek opportunities to add additional dairies to the sampling program for better coverage of the study area.

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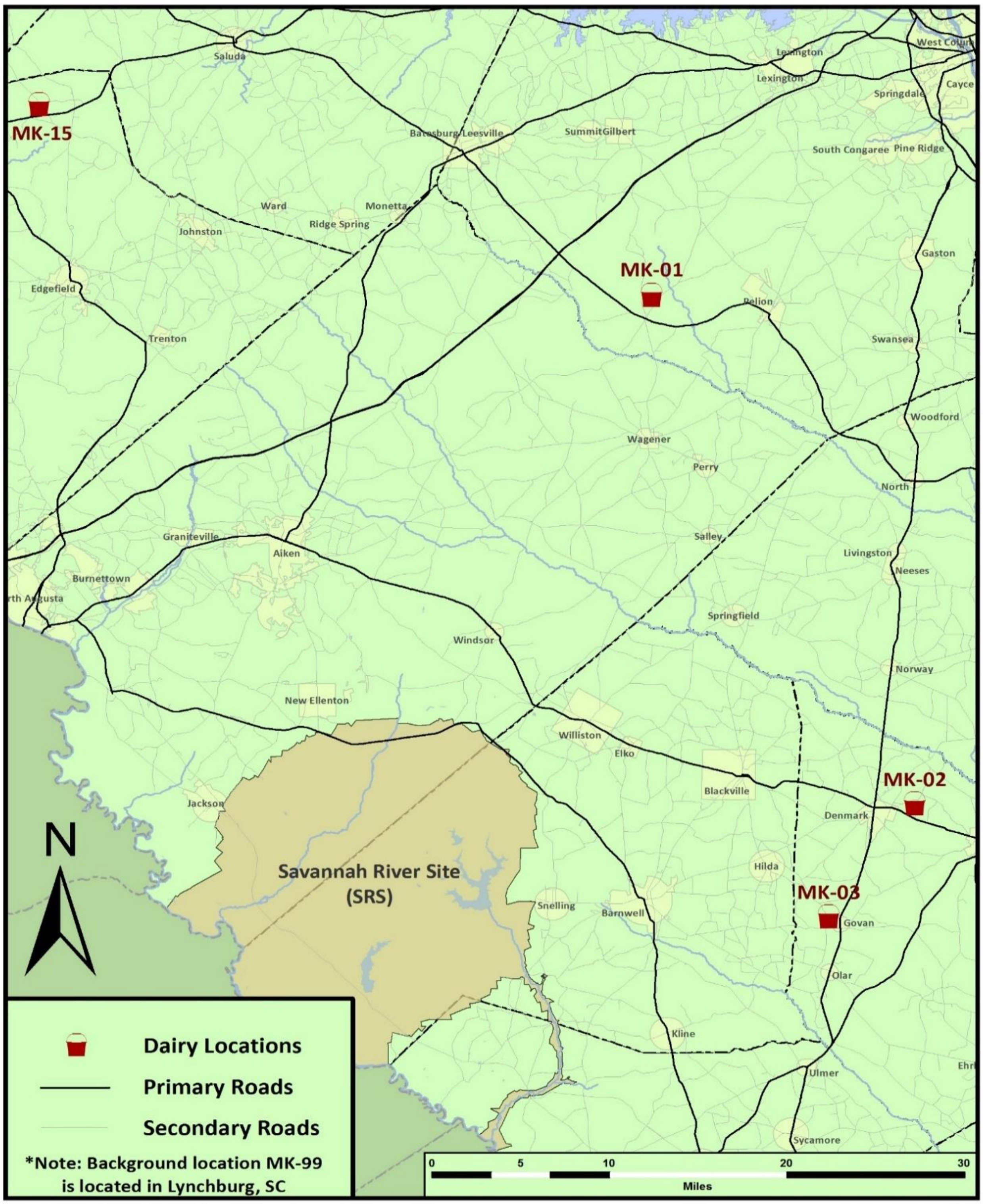
10.4.0 MAP

Radiological Dairy Milk Monitoring Sampling Locations



2016 ESOP Dairy Milk Monitoring

www.scdhec.gov/srs

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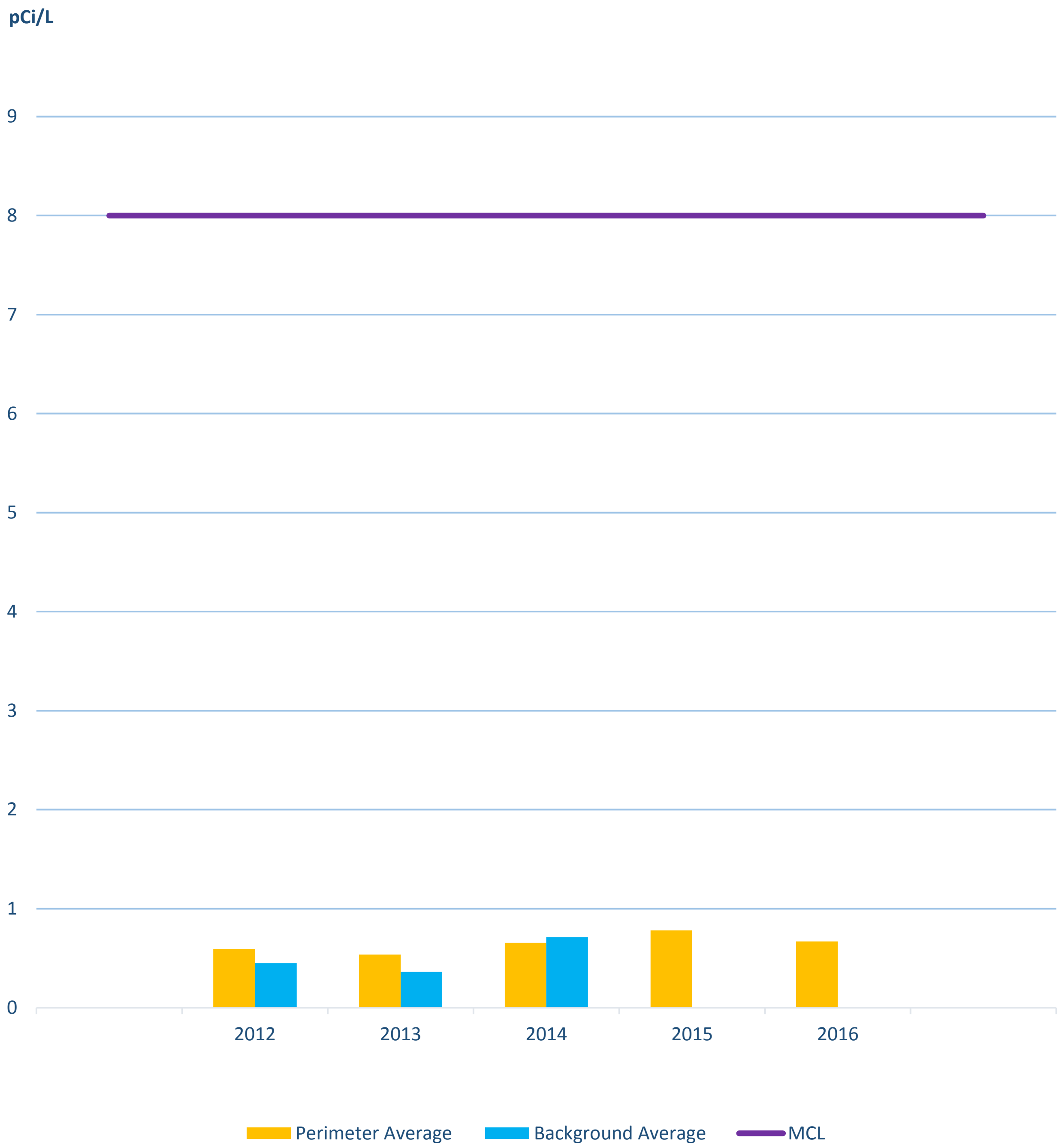
10.5.0 FIGURES

Figure 1. DHEC Average Strontium-89/90 Data Trends for 2011-2016 (DHEC 2014a, 2015-2017)



Notes:
1. No bar indicates <MDA

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10.6.0 SUMMARY STATISTICS

2016 Strontium-89/90 All Sample Detections

Sample Location	Average (pCi/L)	Standard Deviation	Median (pCi/L)	Minimum (pCi/L)	Maximum (pCi/L)	Number of Samples	Number of Detections
MK-01	ND	NA	ND	<LLD	<LLD	4	0
MK-02	0.662	NA	0.662	<LLD	0.662	4	1
MK-03	ND	NA	ND	<LLD	<LLD	4	0
MK-15	0.667	0.140	0.667	<LLD	0.776	4	2
MK-99	ND	NA	ND	<LLD	<LLD	4	0

Yearly Total	0.667
Standard Deviation	0.099
Median	0.662

2016 Strontium 89/90 Comparison of Perimeter and Background Locations

Strontium-89/90 (pCi/L)	Perimeter Locations (<50 Miles)			Background Locations (>50 Miles)			Perimeter minus Background
	Average	Standard Deviation	Median	Average	Standard Deviation	Median	Average
	0.672	0.99	0.662	<LLD	NA	<LLD	0.672

Notes:
1. ND is Not Detected
2. NA is Not Applicable

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Chapter 11 Radiological Monitoring of Fish Associated with SRS

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11.1.0 PROJECT SUMMARY

DHEC ESOP conducts non-regulatory, independent monitoring and surveillance of fish to determine the magnitude, extent, and trend levels for radionuclides and selected metals.

In 2016, DHEC collected largemouth bass (*Micropterus salmoides)* and channel catfish (*Ictalurus punctatus*) from four stations where creeks from SRS meet the Savannah River: Upper Three Runs Creek (SV-2011), Fourmile Branch (SV-2015), Steel Creek (SV-2017), and Lower Three Runs Creek (SV-2020). Samples were also collected from the background station on the Combahee River between Beaufort and Colleton counties (MD-119), one Savannah River station upstream of SRS, New Savannah Bluff Lock and Dam (NSBLD SV-2028), and two stations downstream of SRS (Highway 301 SV-118, and Highway 17 saltwater SV-2091). Stations sampled in 2016 are shown in Section 11.4.0, Map. These stations are accessible to the public.

Five largemouth bass and five channel catfish were collected from all Savannah River stations and the Combahee River background site. Five red drum and five mullet were collected from the saltwater station. Edible portions of the fish were analyzed for mercury and other selected metals, gamma-emitting isotopes and tritium. Non-edible portions were analyzed for Sr-89/90.

11.2.0 RESULTS AND DISCUSSION

Fish Monitoring Summary Statistics can be found in Section 11.6.0 and all Fish Monitoring Data can be found in the 2016 DHEC Data File.

11.2.1 Radiological Data Comparison

DHEC bass and catfish data collected in 2016 were compared to DOE-SR reported data (SRNS 2017). Data comparisons are in Section 11.5.0, Tables 1-8. One difference between the two programs is that DHEC analyzes one composite from each species for each station, whereas the DOE-SR program analyzes three composites per station. Therefore, a single composite for a DHEC station was compared to the average of the three DOE-SR composites reported.

Trending graphs for 2016 and 2012-2016 activity levels of tritium, Cs-137, and Sr-89/90 are reported in Section 11.5.0, Figures 1-3.

DHEC largemouth bass samples from three stations and DOE-SR bass samples from four stations exhibited tritium activity. DHEC catfish from four stations and DOE-SR catfish from three stations exhibited tritium activity (Section 11.5.0, Figure 1). The DHEC saltwater sampling station (SV-2091) produced detections in the red drum sample. The DHEC background station (MD119) did not have tritium activity.

Tritium levels tend to be highest at the stations adjacent to SRS (creek mouth stations) and decrease with distance downstream. Tritium has been detected upstream of SRS only occasionally at low levels.

DHEC largemouth bass samples from four stations and DOE-SR bass samples from six stations exhibited Cs-137 activity. None of the DHEC catfish composites from the Savannah River stations exhibited a detectable level of Cs-137 in 2016. DOE-SR detected Cs-137 in all but one catfish sample. The DHEC saltwater and the background stations did not exhibit Cs-137 activity in any samples (Section 11.5.0, Figure 2).

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Strontium-89/90 was detected at all six stations for DHEC and all six stations for DOE-SR in bass and catfish (Section 11.5.0, Figure 3) (SRNS 2017).

11.2.2 Non-radiological Data Comparison

DHEC and DOE-SR analyze fish for antimony, arsenic, cadmium, manganese, mercury, chromium, copper, lead, nickel, and zinc. DOE-SR collected seatrout and panfish, which DHEC did not collect. Therefore, no comparison is made for those fish.

DOE-SR had no detections in 2016 for antimony or lead. DOE-SR had one detection of arsenic in mullet and three in red drum. DOE-SR and DHEC did not detect arsenic in freshwater fish. Cadmium was detected in one DOE-SR red drum sample, two catfish samples, and three catfish samples. DOE-SR detected chromium in two mullet, three red drum, 28 bass, and 29 catfish. DOE-SR detected copper in all seven mullet samples, six red drum, all 14 bass, and 13 catfish. DOE-SR detected nickel in three red drum, four bass, and three catfish samples. DOE-SR had zinc detections in seven mullet, six red drum, and all 42 bass and 42 catfish samples. DHEC detected copper and zinc in all 16 composites analyzed. DHEC detected manganese in two bass and one catfish composites and DOE-SR had four mullet, six red drum, 28 bass and 42 catfish detections.

Mercury was detected in all six DHEC bass and catfish composite samples from all six Savannah River stations (Section 11.5.0, Figure 4). DOE-SR detected mercury in all 42 bass and 42 catfish samples. DHEC composites from the background station on the Combahee River exhibited detectable mercury in bass and catfish. DOE-SR detected mercury in one mullet. Mercury was also detected by DHEC in red drum from the Hwy 17 saltwater location.

11.3.0 CONCLUSIONS AND RECOMMENDATIONS

A review of DHEC data indicates 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 radionuclides, their extent, and trends. This data will allow DHEC to better advise, inform, and protect those people at risk. 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.

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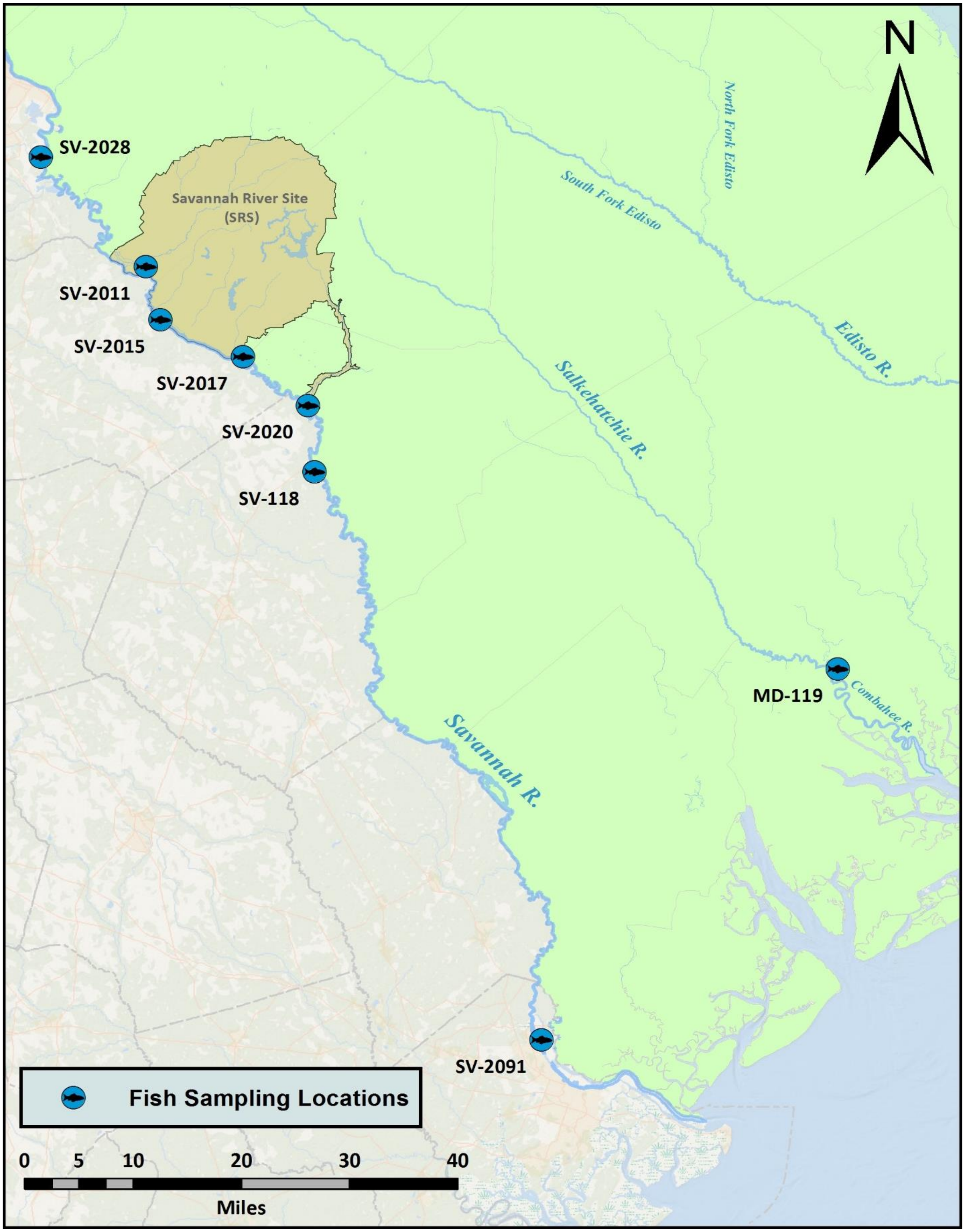
11.4.0 MAP

Fish Monitoring Sampling Locations



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11.5.0 TABLES AND FIGURES

2016 DHEC and DOE-SR Data Comparison

Table 1. Tritium in Edible Bass

Location	Agency	Number of Samples	Result (pCi/L)
NSBLD	DHEC	1	<LLD
	DOE-SR	3	<MDC
Upper Three Runs	DHEC	1	<LLD
	DOE-SR	3	<MDC
Fourmile Branch	DHEC	1	<LLD
	DOE-SR	3	330
Steel Creek	DHEC	1	323
	DOE-SR	3	190
Lower Three Runs	DHEC	1	459
	DOE-SR	3	140
Hwy. 301	DHEC	1	224
	DOE-SR	3	100

Table 2. Tritium in Edible Catfish

Location	Agency	Number of Samples	Result (pCi/L)
NSBLD	DHEC	1	<LLD
	DOE-SR	3	<MDC
Upper Three Runs	DHEC	1	<LLD
	DOE-SR	3	0.11
Fourmile Branch	DHEC	1	269
	DOE-SR	3	<MDC
Steel Creek	DHEC	1	192
	DOE-SR	3	0.16
Lower Three Runs	DHEC	1	315
	DOE-SR	3	0.08
Hwy. 301	DHEC	1	232
	DOE-SR	3	<MDC

Table 3. Cesium-137 in Edible Bass

Location	Agency	Number of Samples	Result (pCi/g)
NSBLD	DHEC	1	<MDA
	DOE-SR	3	0.05
Upper Three Runs	DHEC	1	0.08
	DOE-SR	3	0.12
Fourmile Branch	DHEC	1	0.11
	DOE-SR	3	0.16
Steel Creek	DHEC	1	0.24
	DOE-SR	3	0.12
Lower Three Runs	DHEC	1	0.06
	DOE-SR	3	0.14
Hwy. 301	DHEC	1	<MDA
	DOE-SR	3	0.04

Note: DOE-SR data are averages

Table 4. Cesium-137 in Edible Catfish

Location	Agency	Number of Samples	Result (pCi/g)
NSBLD	DHEC	1	<MDA
	DOE-SR	3	0.03
Upper Three Runs	DHEC	1	<MDA
	DOE-SR	3	0.03
Fourmile Branch	DHEC	1	<MDA
	DOE-SR	3	0.05
Steel Creek	DHEC	1	<MDA
	DOE-SR	3	0.07
Lower Three Runs	DHEC	1	<MDA
	DOE-SR	3	0.11
Hwy. 301	DHEC	1	<MDA
	DOE-SR	3	0.02

Note: DOE-SR data are averages

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TABLES AND FIGURES

2016 DHEC and DOE-SR Data Comparison

Table 5. Strontium-89/90 in Non-Edible Bass

Location	Agency	Number of Samples	Result (pCi/g)
NSBLD	DHEC	1	0.07
	DOE-SR	3	0.76
Upper Three Runs	DHEC	1	0.06
	DOE-SR	3	0.73
Fourmile Branch	DHEC	1	0.02
	DOE-SR	3	2.28
Steel Creek	DHEC	1	0.05
	DOE-SR	3	0.64
Lower Three Runs	DHEC	1	0.03
	DOE-SR	3	0.63
Hwy. 301	DHEC	1	0.06
	DOE-SR	3	0.67

Table 6. Strontium-89/90 in Non-Edible Catfish

Location	Agency	Number of Samples	Result (pCi/g)
NSBLD	DHEC	1	0.04
	DOE-SR	3	0.74
Upper Three Runs	DHEC	1	0.08
	DOE-SR	3	0.74
Fourmile Branch	DHEC	1	0.04
	DOE-SR	3	1.01
Steel Creek	DHEC	1	0.02
	DOE-SR	3	0.62
Lower Three Runs	DHEC	1	0.04
	DOE-SR	3	0.88
Hwy. 301	DHEC	1	0.03
	DOE-SR	3	0.62

Table 7. Mercury in Edible Bass

Location	Agency	Number of Samples	Result (mg/kg)
NSBLD	DHEC	1	0.17
	DOE-SR	7	0.47
Upper Three Runs	DHEC	1	0.67
	DOE-SR	7	0.52
Fourmile Branch	DHEC	1	0.69
	DOE-SR	7	0.55
Steel Creek	DHEC	1	0.92
	DOE-SR	7	0.33
Lower Three Runs	DHEC	1	0.64
	DOE-SR	7	0.64
Hwy. 301	DHEC	1	0.64
	DOE-SR	7	0.67

Note: DOE-SR data are averages

Table 8. Mercury in Edible Catfish (mg/kg)

Location	Agency	Number of Samples	Result (mg/kg)
NSBLD	DHEC	1	0.42
	DOE-SR	7	0.12
Upper Three Runs	DHEC	1	0.13
	DOE-SR	7	0.14
Fourmile Branch	DHEC	1	0.30
	DOE-SR	7	0.22
Steel Creek	DHEC	1	0.27
	DOE-SR	7	0.26
Lower Three Runs	DHEC	1	0.20
	DOE-SR	7	0.20
Hwy. 301	DHEC	1	0.16
	DOE-SR	7	0.21

Note: DOE-SR data are averages

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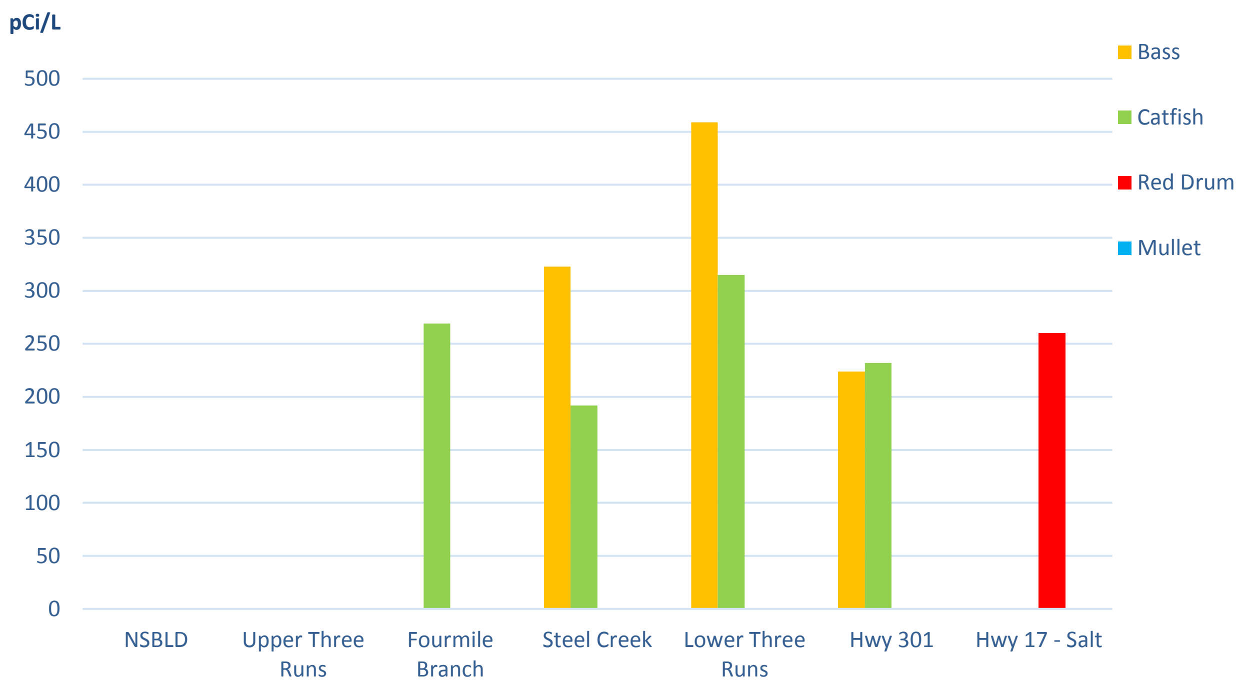
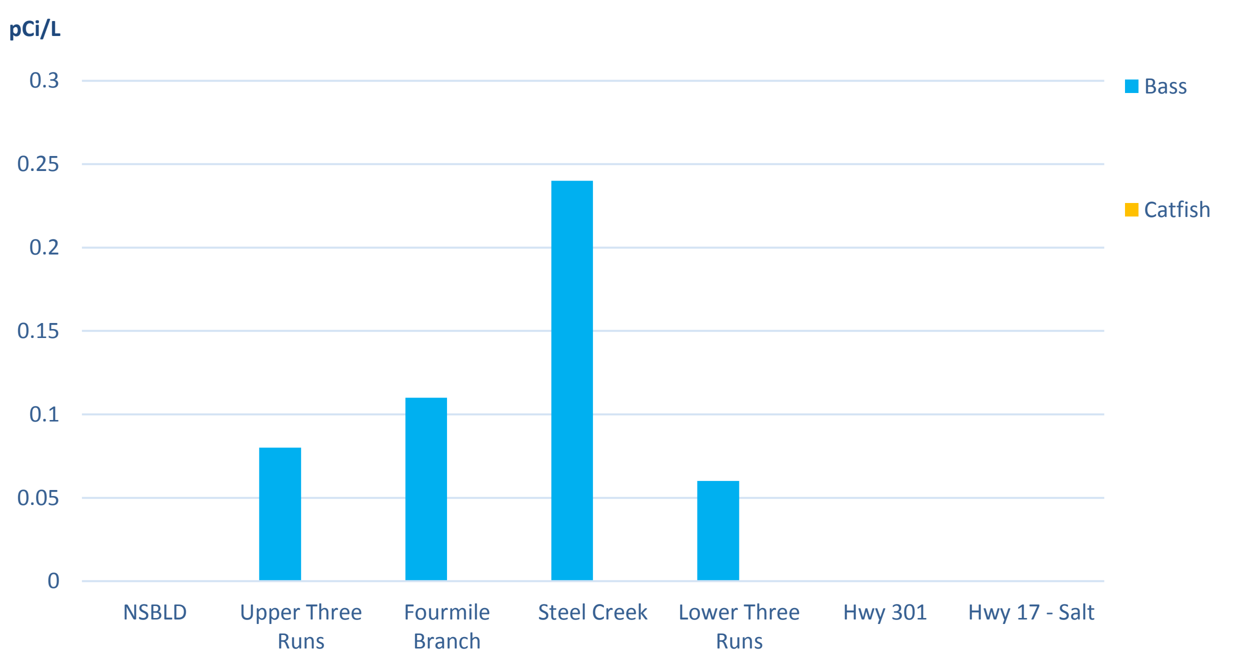
TABLES AND FIGURES

Figure 1. 2016 Tritium in Fish Composites



Note: Missing bars indicate <LLD

Figure 2. 2016 Cesium-137 in Fish Composites



Note: Missing bars indicate <LLD

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TABLES AND FIGURES

Figure 3. 2016 Strontium-89/90 in Fish Bone Composites

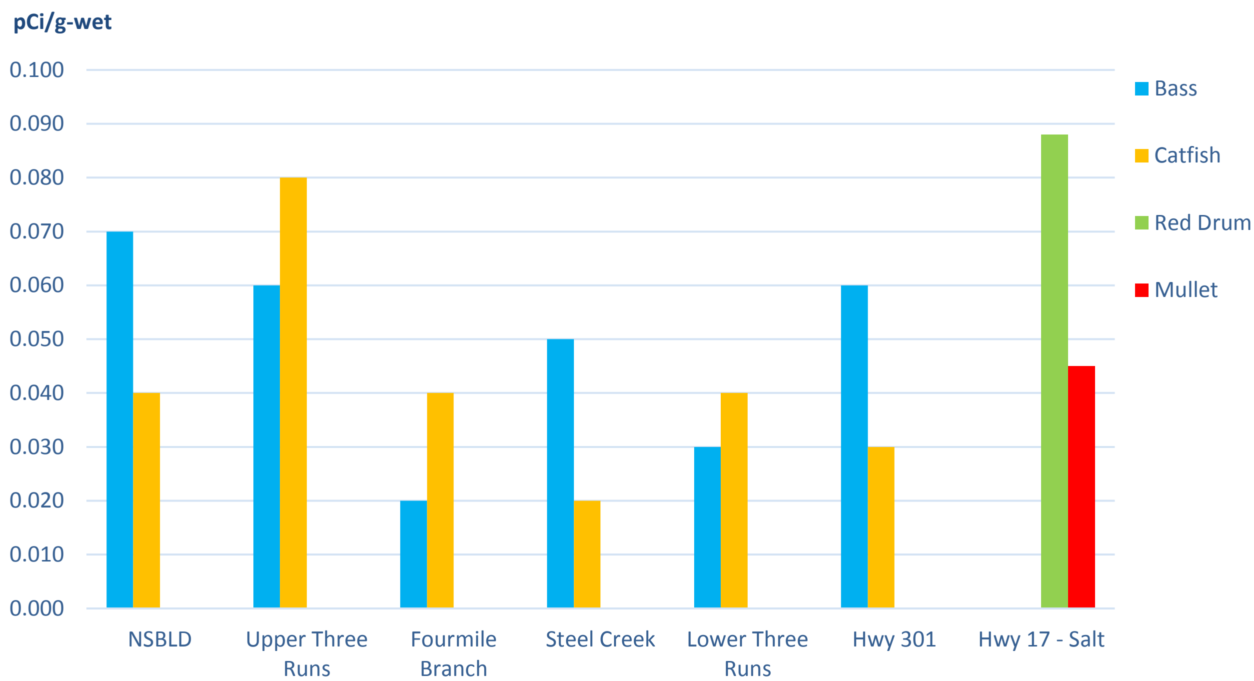
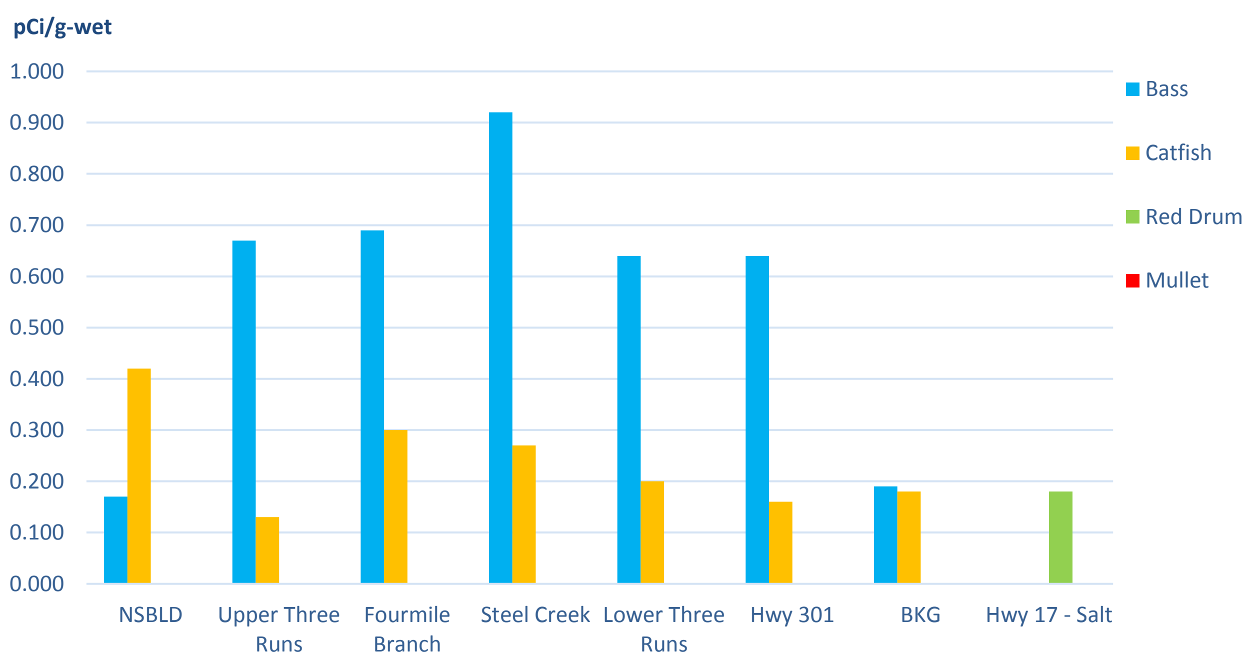


Figure 4. 2016 Mercury in Fish



Note: Missing bars indicate <LLD

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SUMMARY STATISTICS

2016 Tritium Levels in Savannah River Fish (pCi/L)

Edible	Average	Standard Deviation	Median	Maximum	Minimum	Number of Samples	Number of Detects
Bass	335.33	117.98	323.00	224	459	6	3
Catfish	252.00	52.47	250.50	192	315	6	4

2016 Cesium-137 Levels in Savannah River Fish (pCi/g–wet)

Edible	Average	Standard Deviation	Median	Maximum	Minimum	Number of Samples	Number of Detects
Bass	0.12	0.08	0.09	0.06	0.24	6	4
Catfish	ND	NA	NA	<MDA	<MDA	6	0

2016 Strontium-89/90 Levels in Savannah River Fish (pCi/g–wet)

Non-Edible	Average	Standard Deviation	Median	Maximum	Minimum	Number of Samples	Number of Detects
Bass	0.05	0.02	0.05	0.07	0.02	6	6
Catfish	0.04	0.02	0.04	0.08	0.02	6	6

2016 Mercury Levels in Savannah River Fish (mg/kg)

Edible	Average	Standard Deviation	Median	Maximum	Minimum	Number of Samples	Number of Detects
Bass	0.56	0.27	0.64	0.92	0.17	6	6
Catfish	0.25	0.11	0.24	0.42	0.13	6	6

Notes:
1. ND is Not Detected
2. NA is Not Applicable
3. Tritium results represent the activity level in water distilled from the fish tissue
4. Cs-137 results represent the activity level in fish tissue
5. Sr-89/90 results represent the activity level in an aliquot of fish bone

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Chapter 12 Game Animal Monitoring Adjacent to SRS

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12.1.0 PROJECT SUMMARY

DHEC conducts game animal monitoring activities around SRS. The game animal project addresses concerns of potentially contaminated white-tailed deer and feral hogs migrating off SRS, and can provide valuable information concerning potential exposure to Cs-137 from consuming game animals harvested around SRS. 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).

White-tailed deer and feral hogs have access to several contaminated areas on and off SRS and are a vector for the redistribution of contaminants (primarily Cs-137). A five-mile study area was established based on a typical white-tailed deer upper limit home range to ensure that potentially contaminated deer residing at or near the SRS boundary would be included in the sample set. 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 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.

12.2.0 RESULTS AND DISCUSSION

Game Monitoring Summary Statistics can be found in Section 12.6.0 and all Game Monitoring Data can be found in the 2016 DHEC Data File.

DHEC analyzed muscle tissue collected in 2016 for Cs-137 from 29 deer collected from area hunters via hunting clubs, plantations, and Crackerneck Wildlife Management Area within a five-mile study area adjacent to SRS (Section 12.4.0, Map). Additionally, eight deer tissue samples were collected and analyzed from a background location 85 miles southeast of SRS in Beaufort County, South Carolina. There were no hogs collected in 2016. Sample size, location, and collection dates were dependent on the participating hunters.

Cesium-137 and the naturally occurring isotope K-40 were the only isotopes detected in game samples collected in 2016. Naturally occurring isotopes will not be discussed in this report. Cesium-137 concentrations from deer collected in the SRS perimeter study area in 2016 are shown in Section 12.5.0, Figure 1. Figure 2 in Section 12.5.0 illustrates the average concentration of Cs-137 found in deer over the last five years.

DOE-SR does not collect game animal samples within the DHEC study area, and off-site hunter doses are based on DOE-SR models. DHEC 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).

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12.3.0 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). Although a portion of Cs-137 was deposited on SRS from site operations, levels found in the study area and background location are likely results of above ground nuclear weapons testing (Haselow 1991).

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). A hunter consuming deer from SRS, the study area, or background locations would most likely ingest a portion of the activity associated with these animals. Refer to the 2016 DHEC Critical Pathway Dose report for a better understanding of the contamination found in game versus other food sources.

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

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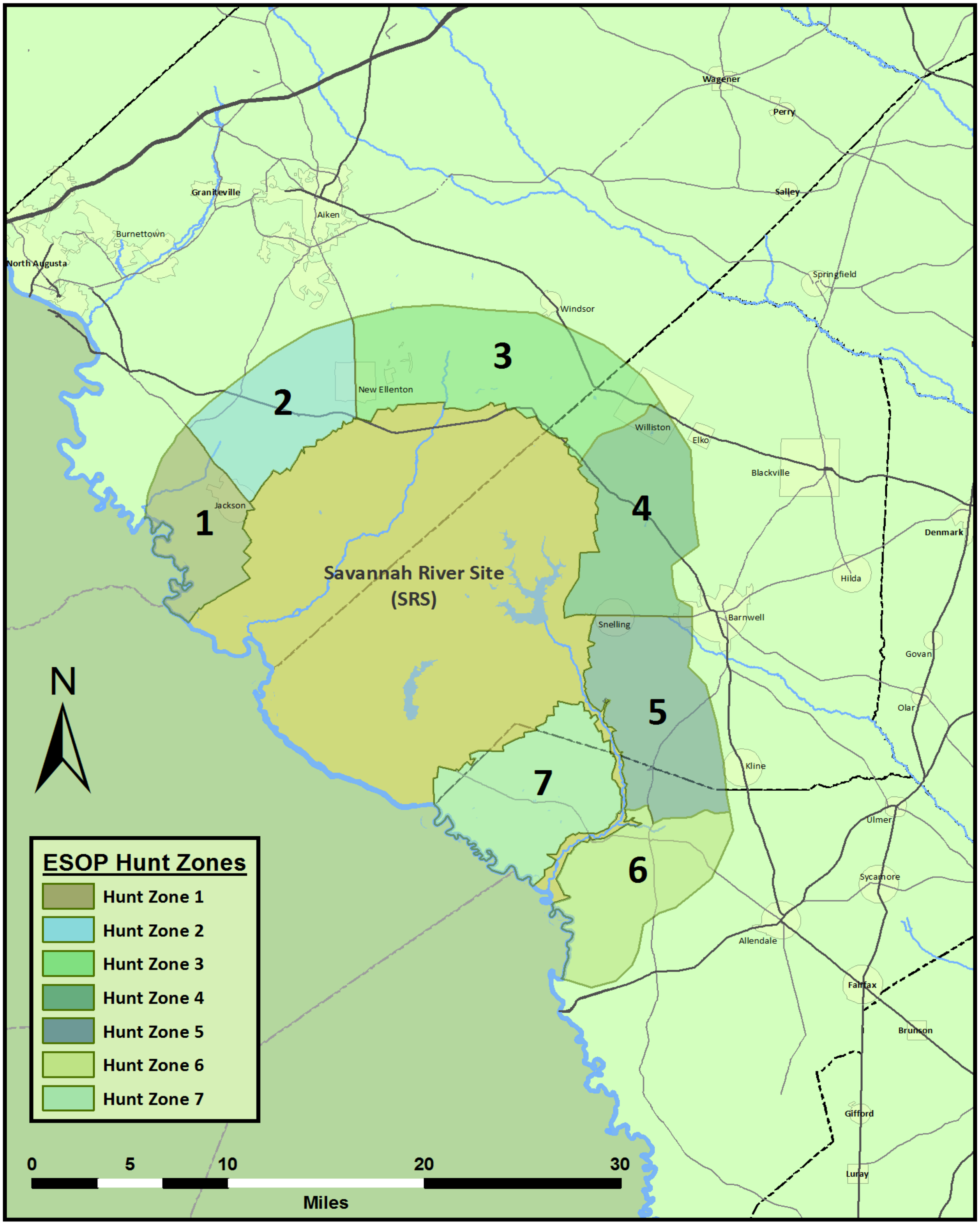
12.4.0 MAP

Radiological Monitoring of Game Adjacent to SRS



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12.5.0 TABLES AND FIGURES

Figure 1. 2016 DHEC Hunt Zone Average Cs-137 Concentration in Deer

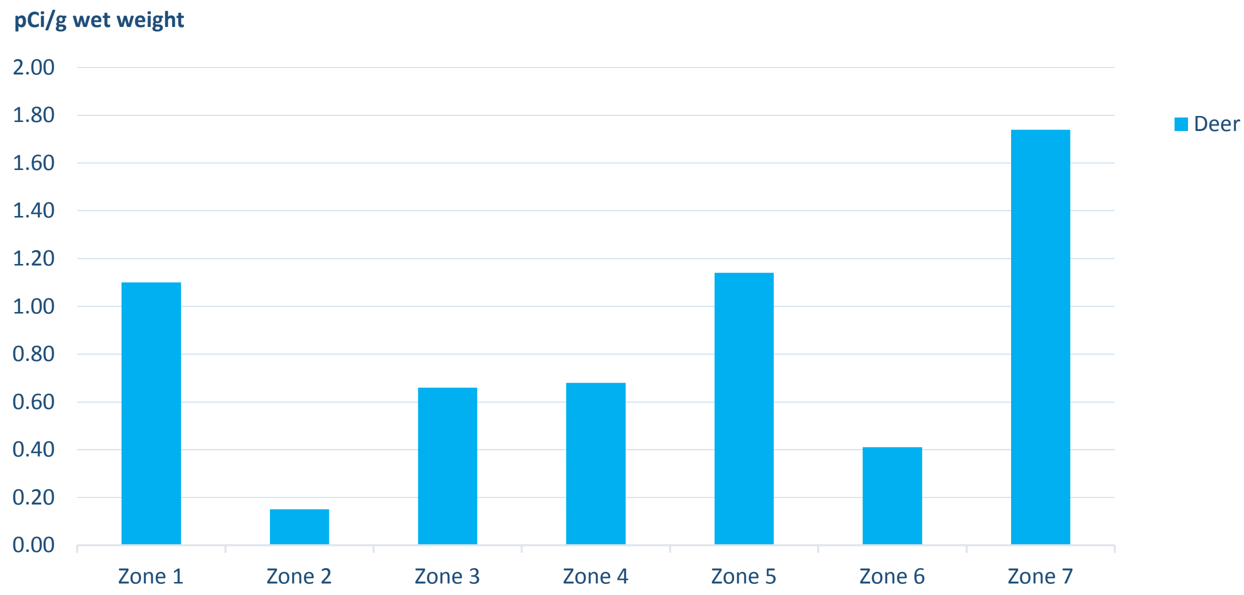
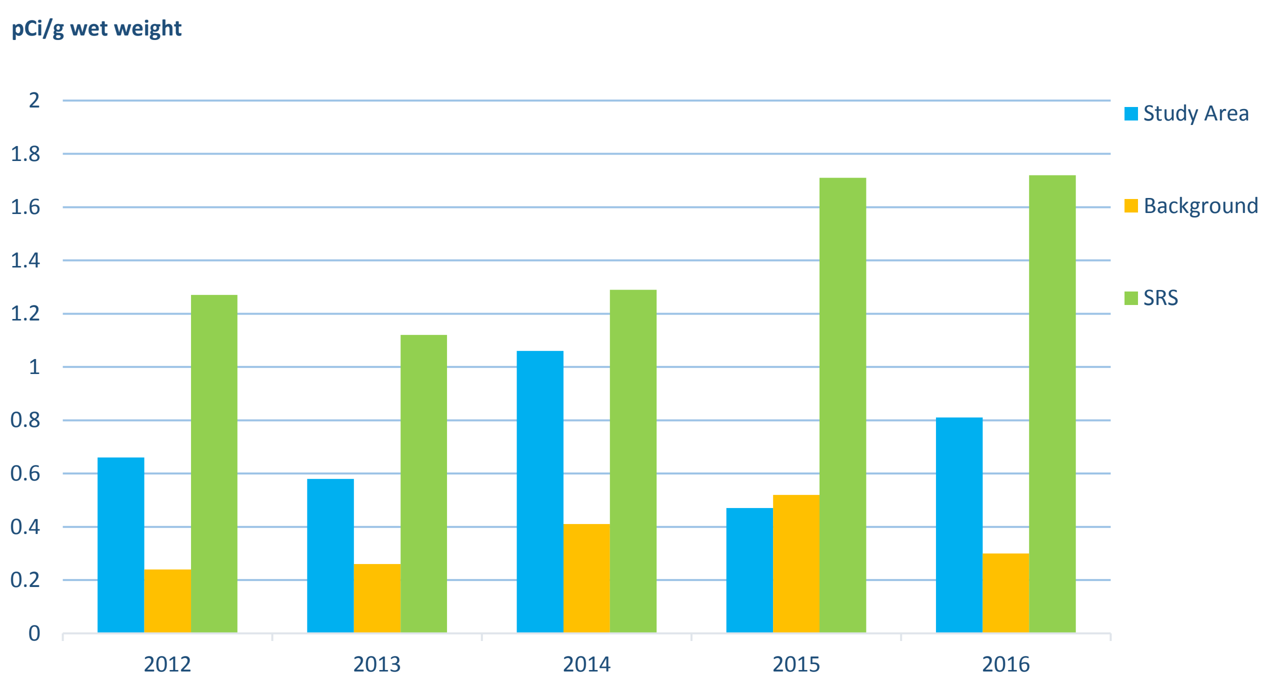


Figure 2. 2012-2016 Average Cs-137 Concentration in Deer (DHEC 2014a, 2015-2017)



Notes:
1. 2011 Background location was Bamberg County
2. 2012-2016 background location was Pinkney Island National Wildlife Refuge
3. SRS data is from on-site deer only and DHEC data is from SRS 5-mile perimeter only

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12.6.0 SUMMARY STATISTICS

2016 Cs-137 Concentration (pCi/g wet weight) in Deer

	Number of Samples	Average	Standard Deviation	Median	Minimum	Maximum
Study Area Deer	29	0.81	0.64	0.53	0.09	2.15
Background Deer	8	0.30	0.21	0.27	0.08	0.75

2016 Cs-137 Concentration (pCi/g wet weight) in Deer DHEC Hunt Zones

Hunt Zone	Number of Samples	Average	Standard Deviation	Median	Minimum	Maximum
Zone 1 Deer	4	1.10	0.64	1.21	0.29	1.67
Zone 2 Deer	4	0.15	0.09	0.12	0.09	0.29
Zone 3 Deer	5	0.66	0.40	0.65	0.19	1.17
Zone 4 Deer	4	0.68	0.69	0.38	0.25	1.71
Zone 5 Deer	5	1.14	0.63	1.33	0.43	1.86
Zone 6 Deer	4	0.41	0.29	0.37	0.12	0.79
Zone 7 Deer	3	1.74	0.43	1.78	1.29	2.15

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Chapter 13 Critical Pathway Dose Report

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13.1.0 PROJECT SUMMARY

DHEC 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 centerpoint. This study area was chosen for comparison to 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.

DHEC and DOE-SR programs were evaluated based on media potential exposure in mrem (Section 13.2.0). The figures in Section 13.4.0 illustrate the trends and central tendencies in the critical pathway potential dose exposures. The critical pathway dose is calculated on average exposed individual (AEI) and maximum exposed individual (MEI) bases which are summarized in Section 13.4.0, Table 1.

13.2.0 RESULTS AND DISCUSSION

All 2016 Dose Data can be found in Section 13.5.0.

The DHEC MEI is a hypothetical 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 2016 data and dose results are discussed under the following headings in this section: 2016 AEI and MEI Dose, Critical Pathways 2016 Summary, and DOE-SR and DHEC 2016 Comparisons. Total AEI Dose covers the 2007-2016 period, whereas other headings discuss only 2016 data. Not all media were collected for all years during this summary period (2007-2016).

The critical pathways were analyzed both on a mrem basis and percentage of dose basis (Section 13.4.0, Table 4). Percentages denote relative importance, whereas mrem denotes potential exposure levels. The dose critique attempts to point out the limits of this dose estimate and why any DOE-SR and DHEC estimates may or may not be similar.

13.2.1 2016 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 13.4.0 summarizes all DHEC detections by media on an AEI and MEI detection basis. Background readings are not subtracted before dose calculations are performed.

The AEI dose is a conservative estimate based on consumption rates, represented by the consumption rate column in the data tables, and average dose per media (Section 13.5.0). In 2016, the calculated AEI dose was 3.232 mrem (Section 13.4.0, Table 1), with 3.197 mrem from food dose. If fungi are not consumed, the AEI dose falls to 1.121 mrem. The AEI dose skews high, as only detections are used in the dose calculations. For a typical person in the study area, the dose they receive should be considerably lower than the AEI dose.

In 2016 the total calculated MEI dose was 6.488 mrem, of which 6.200 mrem was attributable to food consumption. If wild game is not consumed, the MEI dose falls to 3.412 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.

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If the individual did not store the media at the location, date, and time of DHEC 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 extreme).

Only speciated doses for specific radionuclides were included in the estimated doses for 2016. 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 NORM, was considered as part of a different critical pathway with contributions through the inhalation, ingestion, and direct exposure routes.

The MEI dose can be received by only one individual, since that individual had to consume the specific dose basis media. 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 Pu-239 and all beta as Sr-90 may double the calculated dose without evidence for that assumption in speciated data. Unspeciated dose assignments were discontinued in 2008 and replaced by calculating an MEI dose potential from the single highest detection per radionuclide per media.

13.2.2 Critical Pathways 2016 Summary

Atmospheric Pathway 2016 Summary

The DHEC 2016 atmospheric pathway contributed dose to the individual through the inhalation of tritium in air, the ingestion of food (predominantly from fungi and deer) and the consumption of rainwater as drinking water. Section 13.4.0, Table 2 illustrates the dominance of the atmospheric pathway, which accounted for 3.187 mrem, at 98.61 percent, of dose to the AEI and 6.007 mrem, at 92.59 percent, of dose to the MEI.

Liquid Pathway 2016 Summary

The DHEC 2016 liquid pathway estimated AEI dose to the individual was through the ingestion of fish, drinking water (both treated and untreated) from the Savannah River, swimming ingestion, and direct exposure routes and pathways (Section 13.4.0, Table 1). The liquid pathway contributions to dose exposure were second to those contributed by the atmospheric pathway. In 2016, the liquid pathway contribution to the AEI was 0.045 mrem, accounting for 1.39 percent of dose. The contribution to the MEI dose was 0.481 mrem, at 7.41 percent. The primary contributor to dose in the liquid pathway was Cs-137 in fish.

Food Subpathway 2016 Summary

The food subpathway was covered under the atmospheric and liquid pathways except for these few additional observations. The annual 2016 DHEC AEI food subpathway dose order from highest to lowest for averages was fungi, deer, fish, edible vegetation, and milk. The 2016 MEI food pathway order was deer, fungi, fish, edible vegetation, and milk. Most of this dose was due to Cs-137 in fungi for the AEI, at 2.10 mrem, and Cs-137 in deer for the MEI, at 3.076 mrem. The food pathway contained all detected radionuclides, including Cs-137, Sr-89/90, and tritium, that contributed to dose exposure.

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Isotopic Contribution Summary

Most of the AEI dose exposure in 2016 was due to Cs-137: 3.182 mrem (98.45 percent) of the 3.232 mrem total. The primary contributor to the Cs-137 AEI dose was wild fungi. Tritium was the second highest dose contributor in 2016 at 0.049 mrem. Cesium-137 and tritium were both found in the atmospheric and the liquid pathways.

Cs-137 was also the primary contributor to the MEI, at 6.169 mrem (95.08 percent) of the 6.488 mrem total, with tritium second, at 0.316 mrem. Wild game (deer) was the single largest dose contributor to the MEI, all of which was due to Cs-137.

13.2.3 2007-2016 Total AEI Dose

Section 13.4.0, Table 4 summarizes dose associated with all media on an AEI basis from 2007-2016. The critical pathway basis of comparison for DHEC detected dose comes from accumulated releases of radionuclides that were deposited outside of SRS during 2007-2016 and within 50-miles of the SRS center-point.

Section 13.4.0, Table 4 illustrates the dominance of the atmospheric pathway accumulated dose, at 84.57 percent, over the liquid pathway, at 15.43 percent. The food subpathway was the dominant route, accounting for 97.64 percent of accumulated exposure. In total, the AEI received a 3.031 mrem average dose per year during that 10-year period.

Section 13.4.0, Figures 1-3 and Table 4 illustrate the various pathways of cumulative dose exposure. The total AEI basis critical pathway dose, 3.232 mrem, is less than the 7.00 mrem dose an individual typically receives from living in a brick house for one year (Wahl 2011). Section 13.4.0, Figures 1-3 illustrate the media exposure trends via line graphs.

The predominant source of AEI exposure from 2007-2016 was wild game (deer and hog). In total it accounted for 18.292 mrem, which amounts to 60.36 percent of the total accumulated AEI exposure (30.306 mrem) during that time period. Following wild game were fungi (5.570 mrem; 18.38 percent), fish (4.112 mrem; 13.57 percent), and edible vegetation (1.396 mrem; 4.61 percent). Furthermore, wild game accounted for 71.37 percent of the accumulated dose from the atmospheric pathway and 61.81 percent of the food subpathway.

The predominant routes of accumulated exposure from 2007-2016 for water sources were nonpotable drinking water from the Savannah River (0.317 mrem) and nonpotable drinking water from rainwater (0.117 mrem). The primary routes for minor sources of accumulated dose were accidental ingestion from swimming (0.043 mrem) and direct exposure from wading (0.021 mrem).

13.2.4 DOE-SR and DHEC 2016 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 2017). 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 DHEC dose estimates as follows, although it must be noted that there are differences between DOE-SR and DHEC sampling and dose estimation protocols:

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1. The DOE-SR all-pathway dose and the sum of the DHEC fish, wading, swimming, public system drinking water from the Savannah River, vegetation, and milk doses 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.
2. The sum of the DOE-SR all-pathway, sportsman, Savannah River swamp hunter, and Savannah River swamp fisherman doses and the DHEC MEI serve as a means of comparison of the dose a survivalist type of individual who consumes fish from the Savannah River and wild game could receive in a year.

The DOE-SR all-pathway and the DHEC Public Scenario basis were the most relevant dose estimates that represent the potential dose exposure for the public in 2016 (Section 13.4.0, Table 3). The DOE-SR representative person all-pathway dose for 2016 was 0.19 mrem, an increase from 0.18 mrem in 2015. The sum of the DHEC AEI fish, wading, swimming, public system drinking water from the Savannah River, vegetation, and milk doses was 0.328 mrem in 2016. The DHEC public scenario dose estimate for 2016 is 0.328 percent of the DOE all-pathway dose standard of 100 mrem/year (SRNS 2017).

The sum of the DOE-SR all-pathway, Savannah River swamp hunter, and Savannah River swamp fisherman doses was 10.26 mrem in 2016, of which the single largest contributor was the DOE-SR swamp hunter dose, at 9.26 mrem. It must be noted that the DOE-SR dose summations are done for comparison to DHEC results. The DHEC MEI dose estimate for 2016, derived from offsite measurements only, was 6.488 mrem.

13.2.5 Dose Critique

Sampling results in most DHEC media revealed that the environmental data detections are asymmetric and skewed to the left (most detections are low and near the origin). The median of the population probably tends to be larger than the true mean. Most sampling resulted in less than MDA determinations and were not included in the DHEC summary statistics, which used detections only. The use of detections only in calculations was protective, and biases the measures of central tendency higher.

The NORM averages and maximums were not included in the dose estimates since this dose was considered part of the background dose for the study area. The yearly dose averages were based on DHEC detections only and are inflated since most sample results were less than MDA. 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 DHEC 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 provided an excessively high dose estimate and was 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 achievable by the MEI due to the unlikely exposure to all maximums at a constant rate

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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 DHEC 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 DHEC 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 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 for dose calculation. For example, the omission of less than MDA assignments from calculations would raise any calculated number to a higher value. Alternatively, less than MDA represents an undetermined low number that may be zero or any number up to the given MDA value for that analysis.

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. DOE-SR modeled radionuclide releases were not directly comparable to DHEC yearly-detected dose in some media due to bioaccumulation.

13.3.0 CONCLUSIONS AND RECOMMENDATIONS

The 2016 results indicated that monitoring of bioaccumulation of radionuclides and the associated dose should continue in addition to the primary inhalation, ingestion, and direct exposure routes from the typical atmospheric and liquid pathways. 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. DHEC will continue to monitor SRS and adjacent areas for the primary radionuclide contributors to dose potentially associated with DOE-SR operations.

13.4.0 TABLES AND FIGURES

TABLES AND FIGURES

Table 1. DHEC Dose Estimates (mrem) for all Media: AEI and MEI

Pathway	Route	Source of Exposure	AEI	MEI
Atmospheric	Inhalation	Surface Soil Resuspension	0.000	0.000
Atmospheric	Inhalation	Inhalation of tritium in Air	0.002	0.005
Air Inhalation Total			**0.002**	**0.005**
Liquid	Ingestion	Fish	0.022	0.290
Atmospheric	Ingestion	Cow Milk	0.001	0.002
Atmospheric	Ingestion	Wild Game (Hog)	NS	
Atmospheric	Ingestion	Wild Game (Deer)	1.060	3.076
Atmospheric	Ingestion	Vegetation (Leafy and Fruit)	0.004	0.011
Atmospheric	Ingestion	Fungi	2.110	2.821
Atmospheric	Ingestion	Soil Ingestion with Food	0.000	0.000
Food Ingestion Total			**3.197**	**6.200**
Liquid	Ingestion	Public System Drinking Water-Savannah River	0.006	0.019
Liquid	Ingestion	Public System Drinking Water-Groundwater	ND	
Liquid	Ingestion	Private Wells	ND	
Atmospheric	Ingestion	Nonpotable Drinking Water-Rainwater	0.010	0.091
Liquid	Ingestion	Nonpotable Drinking Water-Surface Water	0.017	0.166
Liquid	Ingestion	Ingestion from Swimming	0.000	0.006
Drinking Water Total			**0.033**	**0.282**
Liquid	Direct	Direct Exposure from Swimming	0.000	0.000
Liquid	Direct	Direct Exposure from Wading	0.000	0.000
Atmospheric	Direct	Direct Exposure from Farm Soil	0.000	0.001
Direct Exposure Total			**0.000**	**0.001**
Overall Total Dose			**3.232**	**6.488**

Notes:
1. NS is Not Sampled in 2016
2. ND is Not Detected in 2016

Table 2. DHEC Dose Estimates (mrem) for the Atmospheric and Liquid Pathways: AEI and MEI

Critical Pathway Summary	AEI	MEI
The Atmospheric Pathway Totals	3.187	6.007
The Liquid Pathway Totals	0.045	0.481
Combined Dose	**3.232**	**6.488**

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Table 3. DHEC/DOE-SR Dose Comparisons

Pathway	Comparison Basis	DOE-SR[1]	DHEC[2]
All-Pathway	DHEC All Pathway Approximation[3]	0.19	0.328
Sportsman	Onsite Hunter	13.5	NS
	Onsite Turkey	ND	NS
	Fish (On and Offsite)[4]	0.81	0.290
	Offsite Hunter (Deer and Soil)	9.26	3.076
	Hunter Soil Exposure[5]	2.90	0.001
Mushroom Consumer	Edible Fungi	NS	2.821

Notes:
1. DOE-SR data from Table 6-5a and Table 6-6 (SRNS 2017)
2. DHEC maximums or single highest detection basis for all media per route of exposure (Table 1.)
3. Sum of DHEC fish, wading exposure, swimming ingestion, Savannah River derived drinking water (treated only), vegetation, and milk (all MEI)
4. DOE-SR fish dose is the offsite fisherman dose. DHEC and DOE-SR fish dose includes fisherman soil exposure dose.
5. Soil sources were from Creek Plantation (DOE-SR) and direct exposure from farm soil (DHEC).

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Table 4. 2007-2016 DHEC AEI Exposure: Total AEI Dose (mrem) and Percentage (DHEC 2009-2011,2012a,2013a, 2014a, 2015-2017)

Pathway	AEI Media Categories	2016[1]	2007-2016[2]	2007-2016 % AEI[3]
Atmospheric	Surface Soil Resuspension Inhalation	0.000	0.009	0.03
Atmospheric	Tritium Inhalation	0.002	0.014	0.05
Liquid	Fish	0.022	4.112	13.57
Atmospheric	Cow Milk	0.001	0.222	0.73
Atmospheric	Wild Game (Deer and Hog)	1.060[4]	18.292	60.36
Atmospheric	Vegetation (Leafy and Fruit)	0.004	1.396	4.61
Atmospheric	Fungi	2.110	5.570	18.38
Atmospheric	Soil Ingestion with Food	0.000	0.000	0.00
Liquid	Public System Water from the Savannah River	0.006	0.110	0.36
Liquid	Public System Water from Groundwater	ND[5]	0.034	0.11
Liquid	Private Wells	ND[5]	0.040	0.31
Atmospheric	Nonpotable Drinking Water-Rainwater	0.010	0.117	0.39
Liquid	Nonpotable Drinking Water-Surface Water	0.017	0.317	1.05
Liquid	Ingestion from Swimming	0.000	0.043	0.14
Liquid	Direct Exposure from Swimming	0.000	0.000	0.00
Liquid	Direct Exposure from Wading	0.000	0.021	0.07
Atmospheric	Direct Exposure from Farm Soil	0.000	0.009	0.03
Totals		3.232	30.306	100%[6]

Notes:
1. The 2016 column is dose in mrem during 2016.
2. The 2007-2016 column is total dose in mrem over the 2007-2016 ten-year period.
3. The AEI % basis column is the percentage of the 2007-2016 total dose due to a given media.
4. Deer only in 2016.
5. There were no detections in 2016.
6. Total percentage is slightly higher than 100 percent due to rounding error.

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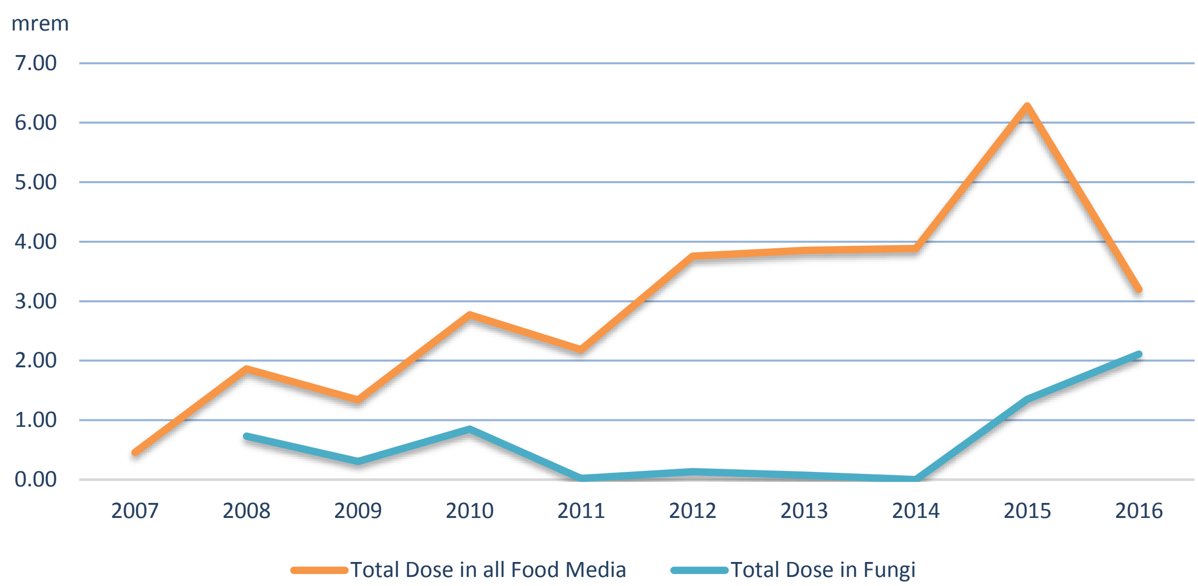
Figure 1. 2007-2016 DHEC AEI Food Dose (DHEC 2009-2017)



Notes:
1. This graph shows the total food AEI dose trend and the trend for the primary contributor to that dose in mrem.
2. Fungi was not sampled in 2007.

Figure 2. 2007-2016 DHEC AEI Water Dose (DHEC 2009-2017)

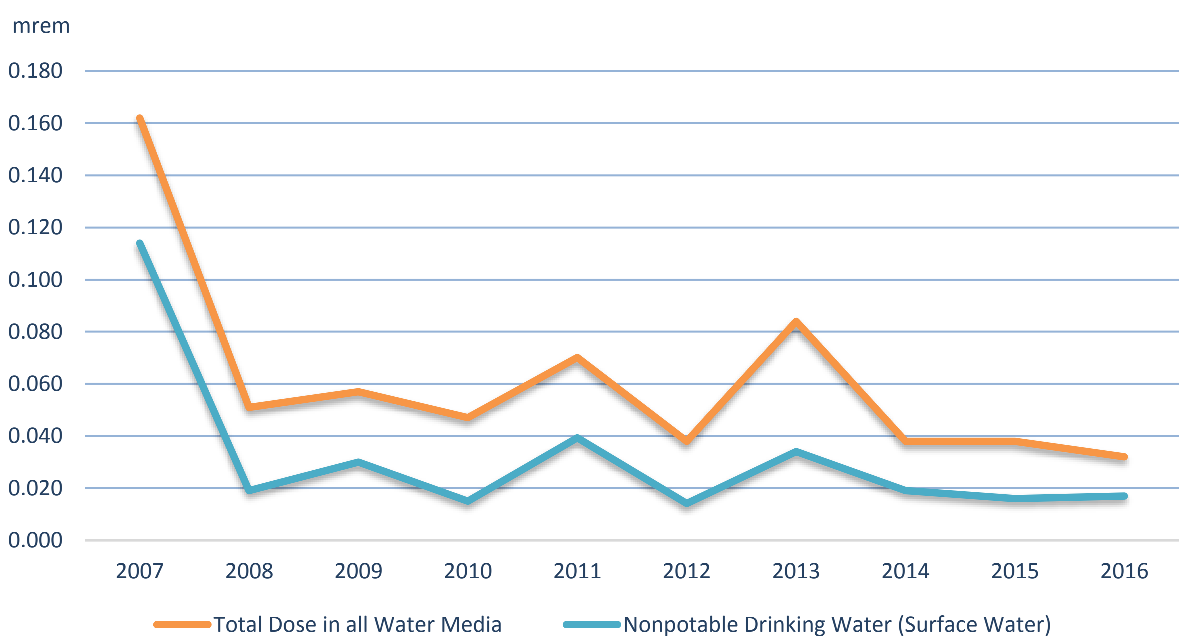


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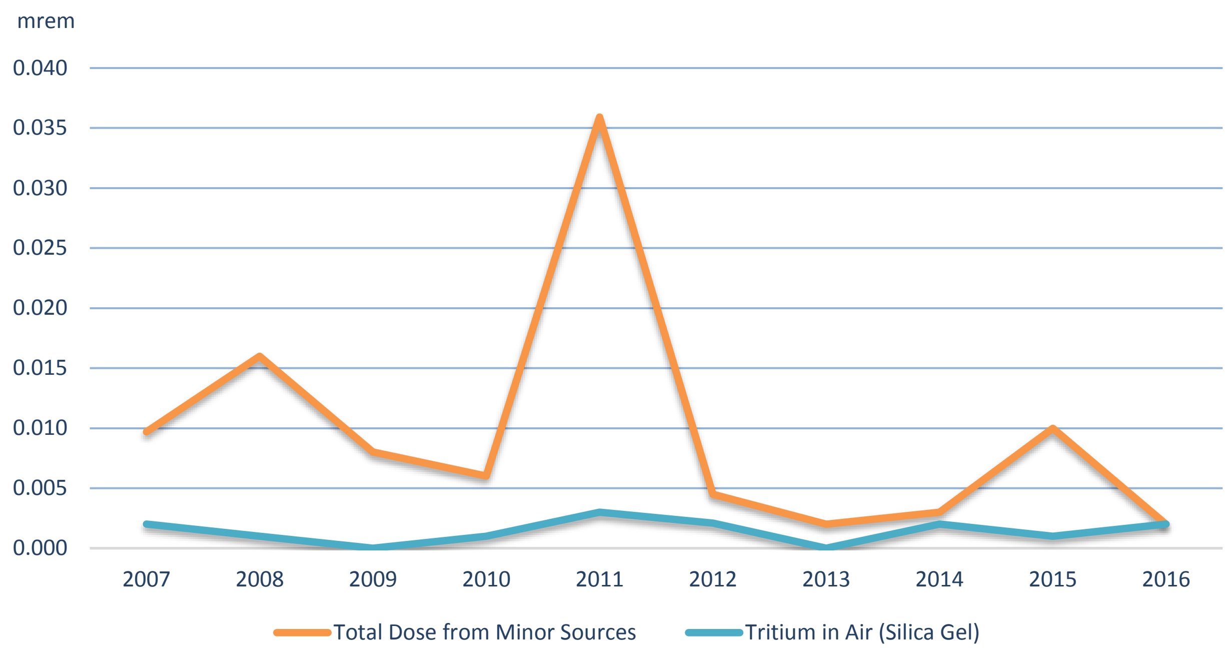
Figure 3. 2007-2016 DHEC AEI Dose from Minor Sources (DHEC 2009-2017)



Note: This graph shows the total minor sources AEI dose trend and the trend for the primary contributor to that dose in mrem.

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13.5.0 2016 DOSE DATA

Notes:
1. ND is No Detects
2. NA is Not Applicable
3. NS is Not Sampled

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2016 DOSE DATA

AEI Fish Dose

Potential Dose from Fish Ingestion (AEI)						
Media	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**	**Total Dose**	**mrem**
		pCi/g	kg/yr	mrem		
Bass	tritium	0.335	3.7	0.000		
	Cs-137	0.120	3.7	0.022		
Bass Dose Average				**0.011**	**Bass**	**0.022**
Catfish	tritium	0.252	3.7	0.000		
	Cs-137	ND	NA	NA		
Catfish Dose Average				**0.000**	**Catfish**	**0.000**
Flounder	tritium	ND	NA	NA		
	Cs-137	ND	NA	NA		
Flounder Dose Average				**NA**	**Flounder**	**NA**
Redfish	tritium	0.260	3.7	0.000		
	Cs-137	ND	NA	NA		
Red Drum Dose Average				**0.000**	**Red Drum**	**0.000**
All Fish Types Combined Dose Average (Detections Only)				**0.004**	**All Fish**	**0.022**

MEI Fish Dose

Potential Dose from Fish Ingestion (MEI)						
Media	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**	**Total Dose**	**mrem**
		pCi/g	kg/yr	mrem		
Bass	tritium	0.459	24.0	0.001		
	Cs-137	0.240	24.0	0.288		
Bass Dose Average				**0.144**	**Bass**	**0.289**
Catfish	tritium	0.315	24.0	0.000		
	Cs-137	ND	NA	NA		
Catfish Dose Average				**0.000**	**Catfish**	**0.000**
Flounder	tritium	ND	NA	NA		
	Cs-137	ND	NA	NA		
Flounder Dose Average				**NA**	**Flounder**	**NA**
Redfish	tritium	0.260	24.0	0.000		
	Cs-137	ND	NA	NA		
Red Drum Dose Average				**0.000**	**Red Drum**	**0.000**
All Fish Types Combined Dose Average (Detections Only)				**0.048**	**All Fish**	**0.290**

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2016 DOSE DATA

AEI Milk Dose

Potential Dose from Milk (AEI)						
Media	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**	**Total Dose**	**mrem**
		pCi/L	kg/yr	mrem		
Milk	tritium	ND	NA	NA		
	Sr-89/90	0.670	69.0	0.001		
	I-131	ND	NA	NA		
Milk Dose Average				**0.001**	**Milk**	**0.001**

MEI Milk Dose

Potential Dose from Milk (MEI)						
Media	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**	**Total Dose**	**mrem**
		pCi/L	kg/yr	mrem		
Milk	tritium	ND	NA	NA		
	Sr-89/90	0.776	260.0	0.002		
	I-131	ND	NA	NA		
Milk Dose Average				**0.002**	**Milk**	**0.002**

AEI Wild Game Dose

Potential Dose from Wild Game (AEI)				
Media	**Radionuclide**	**Dose**	**Total Dose**	**mrem**
Deer	Cs-137	1.060		
Hog	Cs-137	Not Sampled in 2016		
Game Dose Average		**1.060**	**Game**	**1.060**

MEI Wild Game Dose

Potential Dose from Wild Game (MEI)				
Media	**Radionuclide**	**Dose**	**Total Dose**	**mrem**
Deer	Cs-137	3.076		
Hog	Cs-137	Not Sampled in 2016		
Game Dose Average		**3.076**	**Game**	**3.076**

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2016 DOSE DATA

AEI Edible Vegetation Dose

Potential Dose in Edible Vegetation (AEI)						
Media	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**	**Total Dose**	**mrem**
		pCi/g	kg/yr	mrem		
Fruit and Vegetable Dose						
Fruit and Vegetables	tritium	0.658	89	0.004		
	Cs-137	ND	NA	NA		
Fruit and Vegetable Non-NORM Dose Average				**0.004**	**Fruit/Vegetables**	**0.004**
Fungi	tritium	1.78	89	0.010		
	Cs-137	0.472	89	2.100		
Fungi Dose Average				**1.055**	**Fungi**	**2.111**
Combined Vegetation Dose Average				**0.530**	**Vegetation**	**2.114**

2016 MEI Edible Vegetation Dose

Potential Dose in Edible Vegetation (MEI)						
Media	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**	**Total Dose**	**mrem**
		pCi/g	kg/yr	mrem		
Fruit and Vegetable Dose Average						
Fruit and Vegetables	tritium	1.96	89	0.011		
	Cs-137	ND	NA	NA		
Fruit and Vegetable Non-NORM Dose Average				**0.011**	**Fruit/Vegetables**	**0.011**
Fungi	tritium	3.01	89	0.017		
	Cs-137	0.630	89	2.804		
Fungi Dose Average				**1.410**	**Fungi**	**2.821**
Combined Vegetation Dose Average				**0.711**	**Vegetation**	**2.832**

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2016 DOSE DATA

2016 AEI Ingestion from Surface Water and Wells Dose

Ingestion from Surface Water and Wells (AEI)						
Source	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**	**Total Dose**	**mrem**
Savannah River Sourced Drinking Water		pCi/L	L/yr	mrem		
Surface Water	**tritium**	**307**	**300**	**0.006**	**SRSDW**	**0.006**
Groundwater Sourced Drinking Water		pCi/L	L/yr	mrem		
Groundwater	**tritium**	**ND**	**300**	**NA**		
Private Wells Groundwater		pCi/L	L/yr	mrem		
Groundwater		**ND**	**300**	**NA**	**GSDW**	**0.000**
Nonpotable Drinking Water		pCi/L	L/yr	mrem		
Surface Water	**tritium**	**875**	**300**	**0.017**	**NPDW**	**0.017**
Rainwater	**tritium**	**532**	**300**	**0.010**	**NPDW**	**0.010**
All Nonpotable Water Sources Average Dose Potential				**0.014**	**Total**	**0.033**

Note: Nonpotable drinking water is surface water or collected rainwater that has been treated in small batches through boiling or the addition of iodine.

2016 MEI Ingestion from Surface Water and Wells Dose

Ingestion from Surface Water and Wells (MEI)						
Source	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**	**Total Dose**	**mrem**
Savannah River Sourced Drinking Water		pCi/L	L/yr	mrem		
Surface Water	**tritium**	**365**	**800**	**0.019**	**SRSDW**	**0.019**
Groundwater Sourced Drinking Water		pCi/L	L/yr	Mrem		
Groundwater	**tritium**	**ND**	**800**	**NA**		
DNR and Private Wells Groundwater		pCi/L	L/yr	mrem		
Groundwater		**ND**	**800**	**NA**	**GSDW**	**0.000**
Nonpotable Drinking Water		pCi/L	L/yr	Mrem		
Surface Water	**tritium**	**3235**	**800**	**0.166**	**NPDW**	**0.166**
Rainwater	**tritium**	**1776**	**800**	**0.091**	**NPDW**	**0.091**
All Nonpotable Water Sources Average Dose Potential				**0.128**	**Total**	**0.276**

Note: Nonpotable drinking water is surface water or collected rainwater that has been treated in small batches through boiling or the addition of iodine.

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2016 DOSE DATA

AEI Incidental Water Ingestion and Direct Exposure from Water Dose

Incidental Water Ingestion and Direct Exposure from Water (AEI)						
Source	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**	**Total Dose**	**mrem**
Swimming at Savannah River Creek Mouths						
Surface Water Swimming	tritium	pCi/L	hrs/yr	mrem		
Ingestion		**3694**	**9**	**0.000**	**Ingestion**	**0.000**
Swimming at Savannah River Creek Mouths Direct Exposure						
Surface Water Immersion		**3694**	**9**	**0.000**	**Immersion**	**0.000**
Streams and Savannah River Surface Water Dose Total						**0.000**

MEI Incidental Water Ingestion and Direct Exposure from Water Dose

Incidental Water Ingestion and Direct Exposure from Water (MEI)						
Source	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**	**Total Dose**	**mrem**
Swimming at Savannah River Creek Mouths						
Surface Water Swimming	tritium	pCi/L	hrs/yr	mrem		
Ingestion		**24273**	**36**	**0.006**	**Ingestion**	**0.006**
Swimming at Savannah River Creek Mouths Direct Exposure						
Surface Water Immersion		**24273**	**36**	**0.000**	**Immersion**	**0.000**
Streams and Savannah River Surface Water Dose Total						**0.006**

AEI Sediment at Creek Mouths and Boat Landings Dose

Sediment at Creek Mouths and Boat Landings (AEI)						
Source	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**	**Total Dose**	**mrem**
Sediment Dose		pCi/g	hrs/yr	mrem		
Creek Mouths	**Cs-137**	**0.916**	**9**	**0.000**	**Creek Mouths**	**0.000**
Boat Landings	**Cs-137**	**0.440**	**9**	**0.000**	**Boat Landings**	**0.000**
Sediment Dose Average				**0.000**	**Total**	**0.000**

MEI Sediment at Creek Mouths and Boat Landings Dose

Sediment at Creek Mouths and Boat Landings (MEI)						
Source	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**	**Total Dose**	**mrem**
Sediment Dose		pCi/g	hrs/yr	mrem		
Creek Mouths	**Cs-137**	**2.32**	**36**	**0.000**	**Creek Mouths**	**0.000**
Boat Landings	**Cs-137**	**0.592**	**36**	**0.000**	**Boat Landings**	**0.000**
Sediment Dose Average				**0.000**	**Total**	**0.000**

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AEI Surface Soil Ingestion Dose

Surface Soil Ingestion (AEI)						
Source	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**	**Total Dose**	**mrem**
Surface Soil		pCi/g	Mg/day	mrem		
Ingestion	Cs-137	0.112	20	0.000		
Soil Ingestion Dose Average				**0.000**		
Total Surface Soil Ingestion Dose Average					**Total**	**0.000**

Note: This represents soil inadvertently consumed with plants.

MEI Surface Soil Ingestion Dose

Surface Soil Ingestion (MEI)						
Source	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**	**Total Dose**	**mrem**
Surface Soil		pCi/g	Mg/day	mrem		
Ingestion	Cs-137	0.172	20	0.000		
Soil Ingestion Dose Average						
Total Surface Soil Ingestion Dose Average					**Total**	**0.000**

Note: This represents soil inadvertently consumed with plants.

AEI Soil Shine Dose

Soil Shine (AEI)						
Source	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**	**Total Dose**	**mrem**
Surface Soil		pCi/g	hrs/yr	mrem		
Ingestion	Cs-137	0.112	2602	0.000		
Shine Direct Exposure from Farm Soil Dose Average				**0.000**		
Total Surface Soil Shine Dose Average					**Total**	**0.000**

Note: The consumption rate is from Iowa State university, 2012.

2016 MEI Soil Shine Dose

Soil Shine (MEI)						
Source	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**	**Total Dose**	**mrem**
Surface Soil		pCi/g	hrs/yr	mrem		
Ingestion	Cs-137	0.172	2602	0.001		
Shine Direct Exposure from Farm Soil Dose Average						
Total Surface Soil Shine Dose Average						**0.001**

Note: The consumption rate is from Iowa State university, 2012.

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AEI Atmospheric Inhalation Dose

Atmospheric Inhalation (AEI)						
Surface Soil Resuspension and Air Inhalation						
Source	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**	**Total Dose**	**mrem**
Surface Soil Resuspension		**pCi/g**	**m3/yr**	**mrem**	**Soil Resuspension**	
Inhalation	Cs-137	0.112	5000	0.000		0.000
Air Inhalation (Silica Gel)		**pCi/m^3**	**m3/yr**	**mrem**	**Air Inhalation**	
Inhalation	tritium	5.15	5000	0.002		0.002
Atmospheric Inhalation Dose Average				**0.001**	**Total Inhalation**	**0.002**

MEI Atmospheric Inhalation Dose

Atmospheric Inhalation (MEI)						
Surface Soil Resuspension and Air Inhalation						
Source	**Radionuclide**	**Activity**	**Consumption Rate**	**Dose**	**Total Dose**	**mrem**
Surface Soil Resuspension		**pCi/g**	**m3/yr**	**mrem**	**Soil Resuspension**	
Inhalation	Cs-137	0.172	6400	0.000		0.000
Air Inhalation (Silica Gel)		**pCi/m^3**	**m3/yr**	**Mrem**	**Air Inhalation**	
Inhalation	tritium	12.32	6400	0.005		0.005
Atmospheric Inhalation Dose Average				**0.003**	**Total Inhalation**	**0.005**

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Appendix **2016 DHEC List of Acronyms and Units of Measure**

LIST OF ACRONYMS

ABR	Allendale Barricade
AEI	Average Exposed Individual
AIK	Aiken
AKN	Sample locations in Aiken County
ALD	Sample locations in Allendale County
ALN	Allendale
B/J	Beaufort-Jasper
BGN	Burial Grounds North
BOD	Biochemical Oxygen Demand
BWL	Sample locations in Barnwell County
CDC	Centers for Disease Control and Prevention
DIL	Derived Intervention Level
DKH	Dark Horse at the Williston Barricade
DHEC	South Carolina Department of Health and Environmental Control
DNR	South Carolina Department of Natural Resources
DO	Dissolved Oxygen
DOE	Department of Energy
DOE-SR	Department of Energy-Savannah River
ESOP	Environmental Surveillance and Oversight Program
EPA	United States Environmental Protection Agency
ESV	Ecological Screening Value
FDA	United States Food and Drug Administration
HLW	High Level Waste
Hwy. 17	United States Highway 17
Hwy. 301	United States Highway 301
IAEA	International Atomic Energy Agency
JAK	Jackson
LLD	Lower Limit of Detection
LLW	Low Level Waste
MCL	Maximum Contaminant Level
MDA	Minimum Detectable Activity
MDC	Minimum Detectable Concentration
MDL	Minimum Detection Level
MEI	Maximum Exposed Individual
NA	Not Applicable
ND	Not Detected
NEL	New Ellenton
NORM	Naturally Occurring Radioactive Material
NS	No Sample
NSBLD	New Savannah Bluff Lock & Dam
PCB	Polychlorinated Biphenyls
PRG	Preliminary Remediation Goals
RM	River Mile
RSL	Regional Screening Level
RSW	Radiological Surface Water
SCAT	South Carolina Advanced Technology
SRNS	Savannah River Nuclear Solutions
SRS	Savannah River Site
SSL	Soil Screening Level
TKN	Total Kjeldahl Nitrogen
TLD	Thermoluminescent Dosimeter
TSP	Total Suspended Particulates
TSS	Total Suspended Solid

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USFS	United States Forestry Service
USGS	United States Geological Survey
VOC	Volatile Organic Compound

LIST OF ISOTOPES AND ABBREVIATIONS

Ac-228	Actinium-228
Am-241	Americium-241
Be-7	Beryllium-7
Ce-144	Cerium-144
Co-58	Cobalt-58
Co-60	Cobalt-60
Cs-134	Cesium-134
Cs-137	Cesium-137
Eu-152	Europium-152
Eu-154	Europium-154
Eu-155	Europium-155
I-129	Iodine-129
I-131	Iodine-131
K-40	Potassium-40
Mn-54	Manganese-54
Na-22	Sodium-22
Pb-212	Lead-212
Pb-214	Lead-214
Ra-226	Radium-226
Ru-103	Ruthenium-103
Sb-125	Antimony-125
Sr-89/90	Strontium-89/90
Sr-90	Strontium-90
Th-234	Thorium-234
Y-88	Yttrium-88
Zn-65	Zinc-65
Zr-95	Zirconium-95

UNITS OF MEASURE

<	Less than
±	Plus or minus. Refers to one standard deviation unless otherwise stated
±2	Plus or minus 2 standard deviations.
°C	temperature in Celsius
Ci	Curie
cnt	counts
g/ml	grams per milliliter
hrs/yr	hours per year
kg/yr	kilograms per year
L/yr	liters per year
m^3/yr	cubic meters per year
mg/day	milligrams per day
mg/kg	milligrams per kilogram
mg/L	milligrams Per Liter
mL	milliliter
ml/L	milliliter per liter
mrem	millirem or milliroentgen equivalent man

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NTU	Nephelometric Turbidity Unit
pCi/g	picocuries per gram
pCi/L	Picocuries per liter
pCi/m³	picoCuries per cubic meter
pCi/mL	picocuries per milliliter
SU	standard units

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