Contract No:

This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-08SR22470 with the U.S. Department of Energy (DOE) Office of Environmental Management (EM).

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Assessment of SRS Ambient Air Monitoring Network

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August 3, 2016

SRNL-STI-2016-00403, Revision 1

SRNL.DOE.GOV

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Printed in the United States of America

Prepared for
U.S. Department of Energy

SRNL-STI-2016-00403
Revision 1

Keywords: *air monitoring; air sampling; dose assessment, meteorological monitoring, radionuclide release detection*

Retention: *Permanent*

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ACKNOWLEDGEMENTS

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KELSEY MOORE (SRNL) – POPULATION-DISTRIBUTION MAP, ASSISTANCE WITH CAP-88

BROOKE STAGICH (SRNL) – POPULATION DATA FROM 2010 CENSUS

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EXECUTIVE SUMMARY

Three methodologies have been used to assess the effectiveness of the existing ambient air monitoring system in place at the Savannah River Site in Aiken, SC. Effectiveness was measured using two metrics that have been utilized in previous quantification of air-monitoring network performance; frequency of detection (a measurement of how frequently a minimum number of samplers within the network detect an event), and network intensity (a measurement of how consistent each sampler within the network is at detecting events). In addition to determining the effectiveness of the current system, the objective of performing this assessment was to determine what, if any, changes could make the system more effective.

Methodologies included 1) the Waite method of determining sampler distribution, 2) the CAP88-PC annual dose model, and 3) a puff/plume transport model used to predict air concentrations at sampler locations. Data collected from air samplers at SRS in 2015 compared with predicted data resulting from the methodologies determined that the frequency of detection for the current system is 79.2% with sampler efficiencies ranging from 5% to 45%, and a mean network intensity of 21.5%. One of the air-monitoring stations had an efficiency of less than 10%, and detected releases during just one sampling period of the entire year, adding little to the overall network intensity. By moving or removing this sampler, the mean network intensity increased to about 23%. Further work in increasing the network intensity and simulating accident scenarios to further test the ambient air system at SRS is planned.

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LIST OF ABBREVIATIONS

SRNL	Savannah River National Laboratory
SRS	Savannah River Site
DOE	Department of Energy
MDC	Minimum Detectable Concentration
CAP88	Clean Air Assessment Package – 1988
CDT	Concentration Detected over Time
DCL	Dose Concentration Limit
FD	Frequency of Detection
NI	Network Intensity

1.0 Introduction

Radiological air monitoring programs exist at nuclear facilities worldwide, ensuring the detection of potential releases from the site that could expose the surrounding population via inhalation, absorption, or ingestion pathways. Ambient air monitoring is a central part of these programs to track potential releases based on meteorological patterns, population distribution, and sampler locations. In addition, ambient air monitoring serves as an important measurement of the effectiveness of environmental and engineered controls, and as an authoritative record of compliance with applicable federal environmental and radiological dose limit regulations. The air monitoring program at the Savannah River Site (SRS) has been in operation since 1951, and has undergone a vast number of modifications to adapt to changes in operations at the site and to the growth of the surrounding area (Abbott 2016).

Prior to the mid-1990s, the technical rationale regarding the placement of air-monitoring stations was limited to "best-guess" methods, and led to some redundancy through over-surveillance. In 1991, the U.S. Department of Energy (DOE) published technical reference DOE/EH-173T, which provided recommendations on designing and implementing environmental surveillance programs, including air-monitoring systems (DOE 1991). Systems are recommended to include a background or control sampling location, and a representative location of the maximum predicted ground-level concentration from a stack release (averaged over 1 calendar year, out to where the off-site population would reside). In addition, DOE (1991) recommends placing sampling locations in communities within a 10 mile radius and any other locations deemed necessary to confirm modeling or characterize the impacts of a release. DOE (1991) was recently replaced by a DOE handbook, DOE-HDBK-1216-2015 (DOE 2015), however the guidance remains essentially the same.

While there are several vetted methods in place to aid in determining the correct design and execution of air monitoring programs, every nuclear site with an environmental surveillance program has different needs and challenges associated with the nature of the site and the ongoing operations. The overall effectiveness of an air-monitoring network is dependent on the number and placement of samplers, flow rates, and sampling periods of the samplers, and the analytical methods used to measure radionuclides in air (Rood et al. 2016). DOE (2015) specifically suggests using the Waite method in order to determine a suggested number and broad-spectrum placement of samplers, based on population distribution and wind conditions.

The "effectiveness" of a system or network is characterized by Ritter et al. (2013) as the probability that the concentration collected by a minimum number of samplers in the ambient air system will be greater than or equal to the Minimum Detectable Concentration (MDC). Ritter and his group created the metrics of "frequency of detection" and "network intensity" (discussed below) in order to assess this probability. In addition, as the MDC is independent of dose limits, the ability of the system to detect concentrations corresponding to a specific dose limit should also be examined. An assessment of the effectiveness of the ambient air monitoring system were performed at the Idaho National Laboratory (INL) in 2016 using a Lagrangian dispersion model to account for the complex geographical and meteorological conditions of the site (Rood et al 2016). The INL study adapted Ritter's metrics for measuring effectiveness, and laid the groundwork for such an assessment to be performed at SRS, although a significantly simpler puff/plume model is required as SRS is a fairly homogenous site with less varied meteorological conditions.

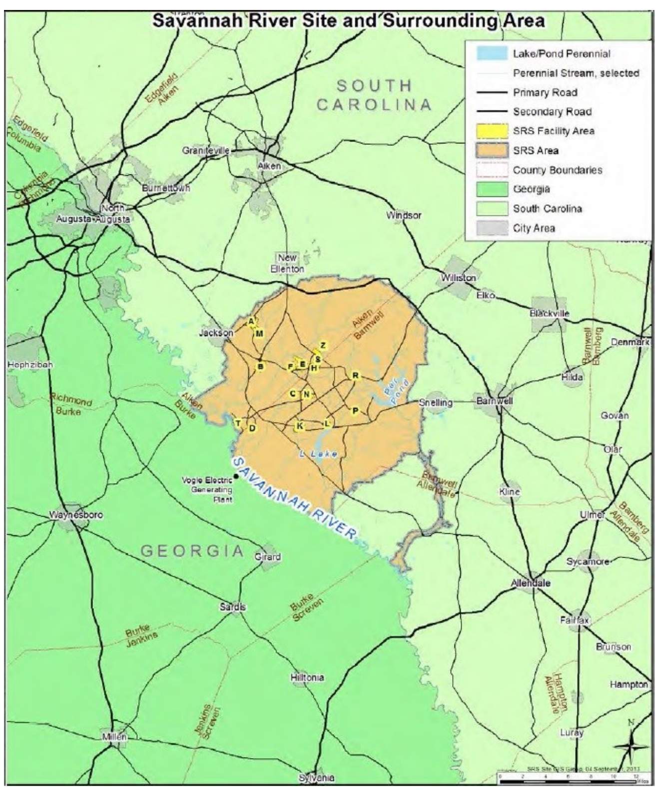
Utilizing Ritter's metrics, also employed by the INL study, a "frequency of detection" may be defined using a combination of simulated releases and existing meteorological data used to predict resultant concentrations, and independent, historical data on how frequently and by what percentage of samplers events were detected in a calendar year. Using a combination of simulated and historical results, the frequency of detection for the network at large, as well as efficiencies for each individual sampler (defined as the “network intensity”) was determined for SRS. Results produced recommended measures that could be taken to improve and optimize the existing ambient air system at SRS.

1.1 Savannah River Site (SRS)

SRS covers 310 square miles in South Carolina; it borders the Savannah River on the south-west side of the site, and is located 12 miles south of Aiken, SC and 15 miles south-east of Augusta, GA. The population within a 50 mile radius of the center of site is approximately 781,060 people, with the largest population concentrated in the Augusta metropolitan area (SRNS-RP-2015-00009). The site itself sits on the south-eastern Atlantic Coastal Plain, with the center of site located 25 miles south-east of the geological fall line that separates the Coastal Flats from the Piedmont region. 90% of the SRS land area is comprised of natural or managed forests, with an emphasis on pine-hardwoods and Carolina Bay wetlands.

The site is made up of a number of areas marked by non-consecutive letters, each corresponding to various operations that have taken place throughout the history of the site (Figure 1-1). Five reactors operated onsite until 1988, along with a number of support facilities including two chemical separations plants, a heavy water extraction plant, nuclear fuel and target fabrication facilities, a tritium extraction facility, and waste management facilities. While most of these operations are now shut down, some are still active (primarily tritium production and waste management). The main priorities of SRS today lie in waste processing and treatment, environmental cleanup and remediation, and protection of nuclear materials.

Figure 1-1. Map of Savannah River Site and Surrounding Area.



Airborne releases from SRS are monitored throughout the year, and radiological surveillance data from this monitoring is used to estimate potential doses to individuals and populations near the site. Three main methods of air surveillance are employed at SRS; glass-fiber filters (used to monitor gamma-emitting and alpha/beta-emitting nuclides in airborne particulate material), charcoal canisters (used to gamma-emitting nuclides, principally gaseous forms of radioiodine), and silica gel canisters (used to detect tritiated water vapor). As of 2016, there are 14 sampling locations (one onsite, 10 at the site perimeter, and three at a 25 mile radius to the site) to monitor radiological hazards potentially released from SRS. All filters are collected every two weeks for processing and analysis. The average flow rate for the tritium silicon column system is 150 cm^3 min^{-1}, or 0.15 L min^{-1}, and the MDC is 10.8 pCi/m^3.

*1.2 **Relevant Radionuclides***

The main radionuclide of concern at SRS is tritium (H-3) (Jannik and Hartman 2016), which accounts for over 90% of the releases and dose on site. The distance from the sampling stations to H-Area (the primary area from which a tritium is released) are listed in Table 1-1. Environmental tritium is found predominantly in two forms; tritiated molecular hydrogen gas, and tritiated water vapor (tritium oxide). In terms of exposure potential, tritium oxide yields a dose equivalent of approximately 25,000 times that of tritium gas for the same concentration (IOS 2010). The exposure pathways of concern when tritium oxide is released into the atmosphere are inhalation, ingestion, and absorption.

Table 1-1. Perimeter Air Monitoring Station Distances to H-Area

Receptor/Air Monitoring Station	Distance (m) from H-Area	Sector
Talatha Gate	10830	N
Green Pond	11748	NW
East Talatha	12355	N
D-Area	12489	SW
Jackson	13320	NW
Dark Horse	15882	NE
Hwy 21/167	16308	E
Barnwell Gate	16199	E
Patterson Mill Rd	18209	SE
Allendale Gate	18925	S
Savannah Lock & Dam	29986	NW
Aiken Airport	39926	N
US 301 Bridge	41149	S

2.0 Methods

This section describes the methods and metrics used to evaluate the effectiveness of the SRS ambient air-monitoring system; the Waite method, which served as an update and initial technical basis for the placement of the air sampling stations, CAP88, which provided initial data predicting the efficiency of the air samplers in their current location, and a puff/plume atmospheric transport model, which predicted the frequency of detection for the system based on meteorological data from 2015.

2.1 __Metrics__

The effectiveness of the air-monitoring system was measured using two metrics; frequency of detection, and network intensity. Frequency of detection is defined as the fraction of events that are detected by at least one sampler within the network; 100% corresponds to all samplers detecting an event, whereas 50% corresponds to only half of the samplers detecting an event. An event is defined as a release of radionuclides, routine or non-routine, into the atmosphere that may lead to a potential dose to a receptor in the surrounding population. Network intensity is defined as the percentage of samplers within the network that detect an event (this can also provide information on the efficiency of each sampler within the network).

2.2 __Waite Method__

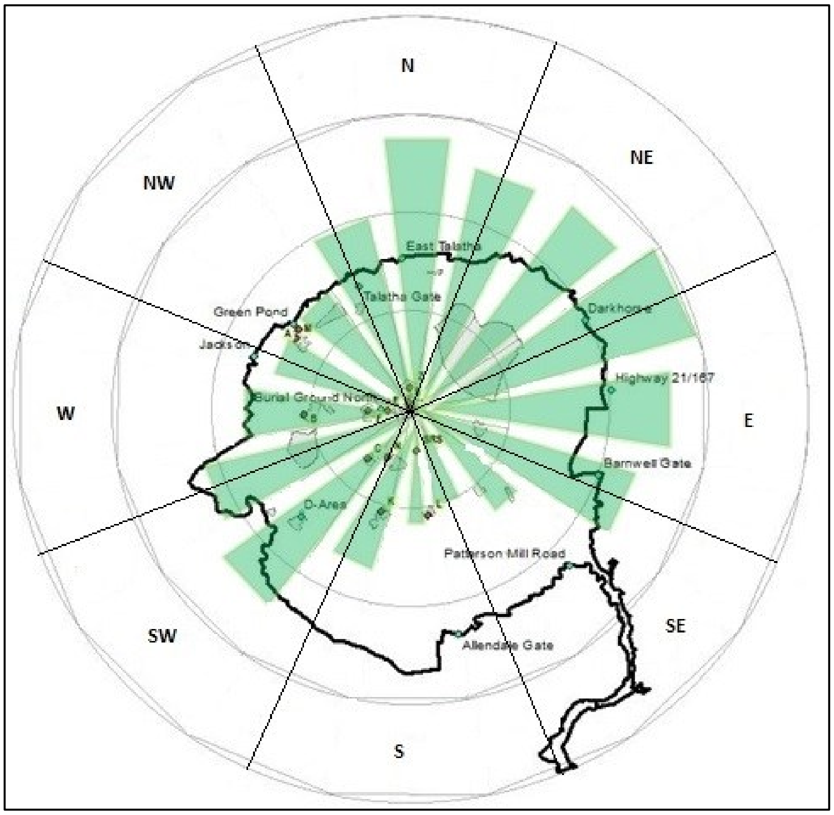
DOE (2015) recommends evaluating air-monitoring station placement using the analytical method developed by Waite (Waite 1973). This technique utilizes a wind rose and population distribution data in order to determine a weighting factor for each directional sector surrounding a nuclear facility (in the case of SRS, 8 sectors). Based on the available resources (the number of monitoring stations) and a scaling factor, this weighting factor may be used to determine the number of samplers recommended to be placed in each sector considered. Equation 1 details the original Waite method equation for the weighting factor:

$$\text{Weighting Factor (W)} = \frac{\text{fraction of total population}}{\text{distance}} + \text{fraction of time sector is downwind from source} \qquad (1)$$

The initial assessment of the air-surveillance system at SRS was a reevaluation of the Waite method (previously performed in 2003), using a modified method. By means of the original Waite method weighting factor, the effect of the population distribution on the factor is significantly diminished for nuclear sites with a radius larger than 10 miles and carries very little impact on the factor in comparison to the fraction of time that the sector is downwind of the source. In addition, any population beyond the range limit of 10 miles was not factored into the placement of air-monitoring stations. For smaller facilities, such as nuclear reactors, this is not an issue as the site is typically small enough that a 10 mile radius provides a representative sample of the population distribution. However, for a facility on the scale of SRS, wherein the population distribution does not become concentrated until approaching the 10-mile limit, maintaining this limited distance range neglects a large percentage of the population that could be affected by potential releases from the site (Abbott 2016a).

In addition, even if the population beyond a 10 mile radius is included in the weighting factor calculation, the distance aspect of the factor severely diminishes the importance of the populations further out. Due to this aspect, the waiting factor does not respond well to drastic changes in the sector populations beyond 20 miles. This adds significant weight to the far smaller populations living directly adjacent to the site (for SRS, just over a thousand individuals), leading to a poor representation of the population slightly further out (200,000 individuals around the 20 mile mark in two sectors) and leading to ineffectively placed monitoring stations.

Figure 2-1. Map of Savannah River Site with H-Area Wind Rose (In direction in which wind blows).

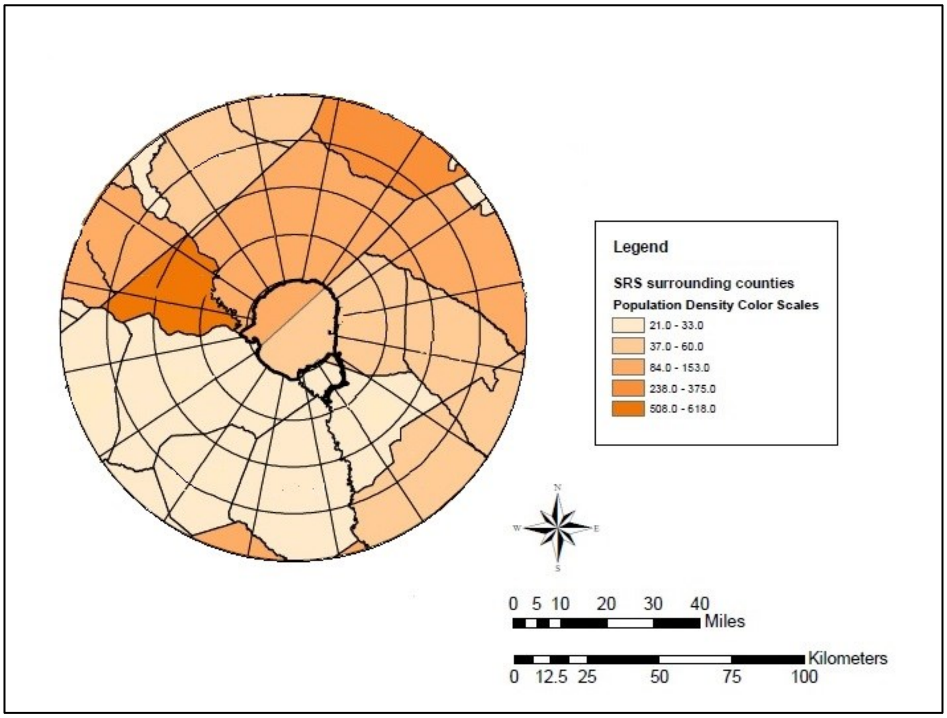


A modified version of the original Waite method was used for this study, wherein the weighting factor is dependent only on the wind direction and frequency, and the population distribution out to 50 miles in each sector, with the population percentage being half as important as the wind frequency. A map of the site with the directional sectors and wind rose from H-Area overlaid may be seen in Figure 2-1. Equation 2 details the modified version of the Waite method weighting factor as applied to each sector in this evaluation:

$$\text{Weighting Factor (W)} = \frac{\text{fraction of total population}}{2} + \text{fraction of time sector is downwind of source} \qquad (2)$$

The modified Waite method was tested by evaluating its response to changes in population at varying distances from the site. Various directional sectors will show fewer or more recommended samplers based on the population; this trend shows agreement between the number of samplers recommended and the population distribution surrounding the site. Figure 2-2 shows the population distribution from the 2010 census over a 50 mile range; the darkest gradient of the map corresponds to the population centers of Augusta, Ga and Aiken, SC. The modified method removes the issue of giving a significantly higher weight to the directly-adjacent population, and gives a more representative picture of the population distribution affected by operations at SRS.

Figure 2-2. Population Density – 50 miles (Average persons per square mile).



Examples of the weighting factors (both original and unmodified) are shown as a comparison between the 2003 census data and 2010 census data in Table 2-1. As there are 10 samplers located at the site perimeter, the main calculations were performed assuming that availability; however the case of 9 samplers was also examined to determine how a reduction in the number of available samplers would change the factors. The weighting factors may be viewed as a metric of the importance of monitoring that particular sector; the smaller the weighting factor, the more reduced the population is within that sector, and the smaller a percentage of the time the wind blows in that particular direction. Taking this into account, the conclusion may be drawn that the S and SE sectors (which also have the smallest population distribution located particularly close to the site, where a release would have less time to disperse before reaching receptors) require the least amount of surveillance in the system, as the weighting factors from both the S and SE sectors combined scarcely add up to any of the other sector weighting factors.

Table 2-1. Scaled Weighting Factor Comparison, 2003-2016 (original and modified).

Sector	Scaled Weighting Factor (2003)		Scaled Weighting Factor (2016)		Scaled Modified Weighting Factor (2016)	
# of samplers	10	9*	10	9	10	9
NW	1.3267	N/A	1.5387	1.3848	2.0789	1.8710
N	1.5368	N/A	1.5228	1.3705	1.7525	1.5527
NE	1.5228	N/A	1.6022	1.4420	1.2906	1.1615
E	1.6061	N/A	0.7441	0.6697	1.4033	1.2629
SE	0.7481	N/A	0.7677	0.6909	0.6117	0.5885
S	0.7740	N/A	1.4533	1.3079	0.6059	0.5825
SW	1.4435	N/A	1.0474	0.9427	1.1450	1.0991
W	1.0419	N/A	1.3234	1.1910	1.1389	1.0250

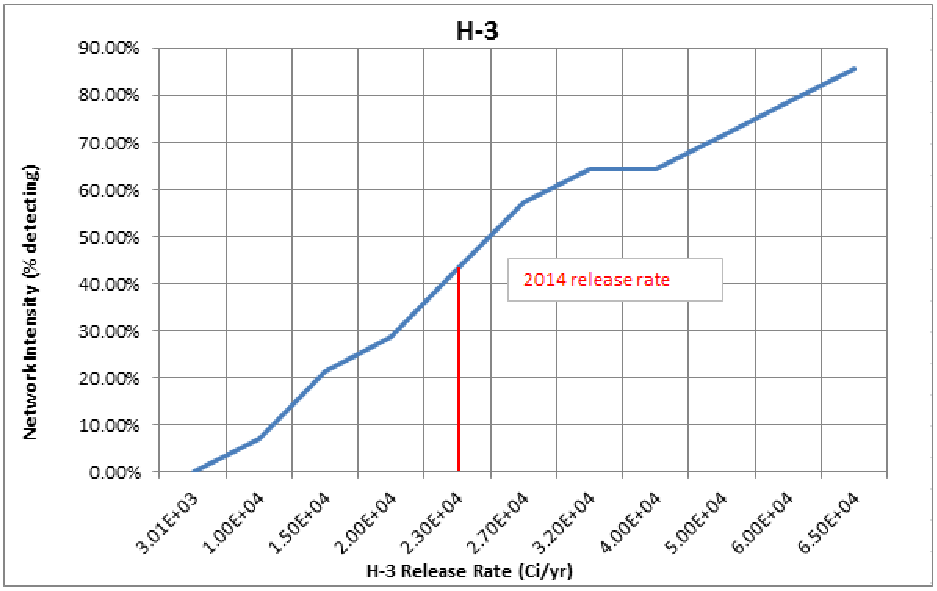
The Waite method provides a useful initial assessment of whether the general distribution of samplers agrees with the population and wind patterns surrounding the site, however it does not provide any measurement of efficiency or effectiveness for the network. CAP88-PC and puff/plume model were used in order to determine the predicted concentrations that determined the frequency of detection and network intensity of the system as a whole.

2.3 CAP88-PC

CAP88-PC Version 4 (CAP88) is an Environmental Protection Agency (EPA) environmental dosimetry code used to estimate the doses and risks from radionuclide emissions in air (modified from AIRDOS and DARTAB), and is used to demonstrate compliance with the National Emissions Standards for Hazardous Air Pollutants (NESHAP) (EPA 2006). For the purpose of this assessment, CAP88 was used to determine the minimum release rate which would still allow for a minimum number of samplers (at least 1) to detect an event (this requires a concentration at the sampler location of greater than or equal to the MDC), and to determine the minimum release rate which corresponds to a specific dose limit, assuming the release continues for a full calendar year. The EPA's total effective dose limit for members of the public exposed to radionuclides released to the atmosphere from DOE facilities is 10 mrem/yr; to be conservative, a dose limit of 1 mrem/yr (10% of the EPA limit) was adopted for this study (USEPA 2006, 40CFR61H).

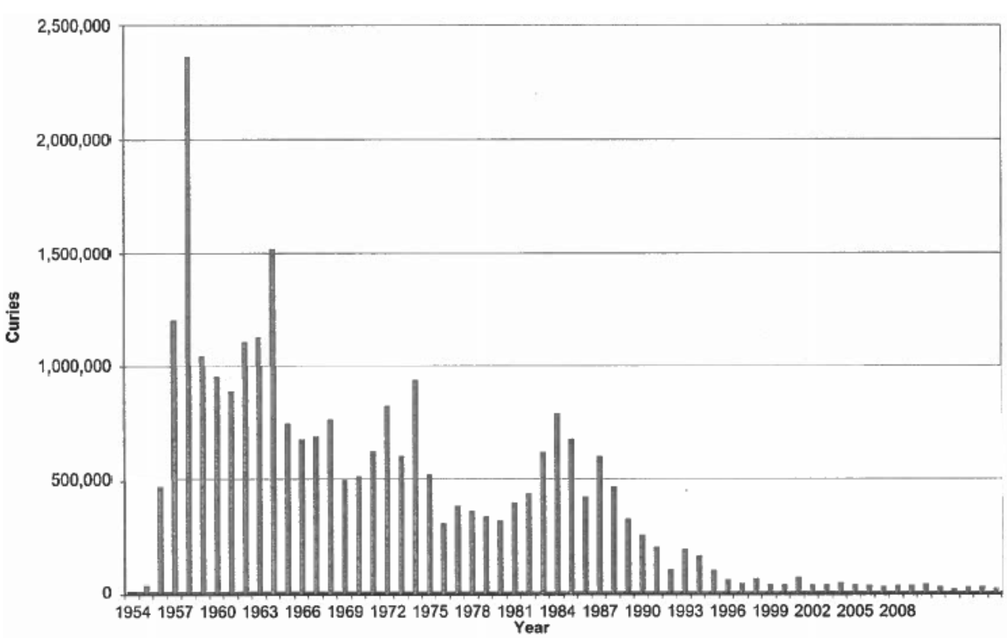
The minimum annual release rate of tritium oxide from H-Area which will still allow for a frequency of detection equal to 100% (meaning that the event will be detected by at least one air sampler) was determined to be about 1E+04 Ci/yr. A release rate input of 7.35E+05 Ci/yr corresponded with a 1 mrem/yr dose at the site perimeter (from H-Area, in the N direction), assuming that the release was continuous during the year. Figure 2-3 details the approximately linear trend of the decreasing network intensity as the release rate is reduced, down to the bounding lower limit (corresponding to the MDC for tritium). The red line shown in Figure 2-3 corresponds to the release rate from 2014, and indicates that only 45% of the air-monitoring stations in their current locations at the site perimeter were capable of detecting a release of this size. In addition, below a release rate of 3.01E+04 Ci/yr, there were no perimeter stations capable of detecting a release.

Figure 2-3. Network Intensity Trends for H-3 Release.



It should be noted that one reason behind the seemingly-low network intensity for the 2014 release rates is simply the fact that any releases from SRS over the past 15 years have been quite low. Figure 2-4 shows a histogram of the tritium release rates for SRS from 1954 to 2015; from approximately 1996 onward, the levels of release are consistently quite low. This trend of decreasing release rates from the site indicates that the lower network intensity of the monitoring network may be due in part to the concentrations of the dispersed radionuclide approaching the MDC more quickly. Release rates such as those seen in the 1960s, or even the 1980s, would most certainly have led to an increased network intensity. Regardless of this fact, it is still important to look at the individual samplers to determine whether the network intensity could be improved by alterations in sampler location.

Figure 2-4. H-3 Total Atmospheric Releases from 1954-2015.



During the determination of the minimum release rates for each criteria, it was noted that the "elimination order" (the order in which the concentration measured by the sampler, over the two week sampling period, would drop below the MDC) was not entirely dependent on the distance from the sampler to the simulated release point. A second, heavily-impacting factor defining the elimination order were the wind patterns surrounding the site; those sampler sites with a higher wind frequency in their direction would continue to detect events for longer after the initial release than their more-closely-placed contemporaries.

An unexpected result of the elimination order was the discovery of the low efficiency of the Patterson Mill Rd and Allendale sampling stations; both stations appeared to be eliminated at approximately the same rate as the 25 mile stations (Aiken Airport, Savannah Lock & Dam, and the US 301 Bridge), regardless of being located on the site perimeter. This indicates that these stations may not be placed in the optimal location, and could be decreasing the network intensity of the system. This, combined with the 45% network intensity seen in Figure 2-3 for the release rate measured for 2014, lends credibility to the idea that the network intensity could be improved by changing some locations or even discontinuing one or more of the sampling stations.

2.4 Atmospheric Transport Model

In previous assessments of air-monitoring networks, a steady-state Gaussian plume model has been used to characterize dispersion conditions during a release to the atmosphere (Pelletier 1970, USDOE 1991, NCRP 2010); a similar model was used in this assessment due to the homogenous geologic and meteorological nature of SRS.

The puff/plume model used in this assessment is a Gaussian atmospheric transport model, including deposition, real-time meteorological inputs, dose estimates from both inhalation and ground-shine, and puff or plume dispersion modes. It is the primary model used for emergency response of atmospheric releases at SRS, and for that reason it is used primarily for first-cut, rapid results (OCFM 1999). The model may access forecasted or actual wind speed, direction, and turbulence data from statistical regression equations, which are updated twice-daily. The deposition module for tritium oxide is based on a resistance model for tritium oxide fluxes in the atmosphere, vegetation, and in the soil. Radioactive decay is considered within the dose module, and radionuclides are assumed to produce dose through gamma shine from clouds, and internal dose through inhalation. The distance scales out to 100 miles and each regression equation utilizes a time scale of several hours. The simplicity of this model allows for rapid response, an advantage in emergency release scenarios.

The model output gives the concentration found at a set number of receptor-distance (in this case, the air monitoring stations), and bases true/false detections on limiting conditions of those concentrations. Two limiting concentrations were used to determine whether a sampler had detected an event; the dose concentration limit corresponding to a 1 mrem/yr dose at the site perimeter (509 pCi/m^3) and the minimum detectable concentration (MDC) limit, below which a sampler cannot detect a specific radionuclide (10.8 pCi/m^3 for tritium oxide).

2.4.1 Assessment methods and relevant release quantities:

As the methods used in the INL Study were similar to the methods being employed in this study, comparable equations were used in both studies in order to find the frequency of detection and network intensity.

The frequency of detection for any single sampler *s* within the network is characterized as:

$$FD_s = \frac{\sum_{i=1}^{N} f(D_{s,i})}{N} \quad (4)$$

Where

$f(D_{s,i})$ = a binary function that returns 0 if the detection ($D_{s,i}$) is false (meaning no samplers detected the event) and 1 if the detection is true for the nuclide at sampler *s* for event *i* (meaning that sampler *s* did detect the event);

N = number of events (releases);
s = sampler index; and
i = event index (where an event corresponds to a release of H-3, routine or non-routine).

Detection ($D_{s,i}$) depends on whether or not a concentration above a particular level is seen on the filter after being collected and analyzed. Detection is assigned a true value if, and only if, one of the following conditions is met:

$$CDT_{s,RR,RD} \geq MDC \text{ or } DCL \quad (5)$$

Where

$CDT_{S,RR,RD}$= concentration detected over-time at sampler *s* for release rate *RR* [Ci/hour] over release duration *RD* [hours];
MDC = minimum detectable concentration [pCi/m^3]; and
DCL = dose concentration limit [pCi/m^3] (this corresponds to a 1 mrem/year dose rate)

In general, only the MDC limit would be examined, however this limit is based on the instrumentation limitations, as opposed to a dose limit to the public. In addition to the MDC limit, the dose concentration limit (DCL) was defined in order to ensure detection of radionuclides before DOE-mandated dose limits were approached. The DCL is defined as 10% of the yearly dose limit, or 1 mrem/yr (assuming the release continued for 1 calendar year). The release quantity leading to a dose of 1 mrem/yr to a member of the public at the perimeter of the site from a tritium oxide release was found to be 7.35E+05 Ci/yr, and corresponded to a concentration of 509 pCi/m^3 detected on the filter (determined using CAP88). Due to the relatively high release rate required to produce a dose to a member of the public of 10% the regulated limit, background may be assumed to be negligible for this particular study and, therefore, equation (3) does not take background into account.

The concentration on the filter is integrated over the sampling period time (T_{sp}), which is typically two weeks at SRS, although the sampling period time is superfluous so long as the release duration takes place during the sampling period time. Each sampler *s* has a CDT associated with each release, based on the size of the release, the placement of the sampler, and the meteorology throughout the release.

$$CDT_{s,RR,RD} = \int_0^{T_{sp}} C_{s,RR,RD}(t)dt \quad (6)$$

Each integrated concentration will either return a true or false value (seen in Equation (3)) based on the full concentration detected by the sampler for the duration of the release (or the sampling period, should the release last longer than the sampling period). For the purposes of the data discussed in this paper, a release is assumed to have occurred every hour on the hour of each sampling period. Once a true/false value has been assigned to each sampler (FD_s) for each simulated event, a net frequency of detection for the system at large may be defined:

$$FD_{net} = \frac{\sum_{i=1}^{N} fn(D_{s,i})}{N} \tag{7}$$

Where

$fn(D_{s,i})$ = a binary function that returns 0 if none of the samplers return a 'true' value of 1 (in other words, if none of the samplers in the network have a detection of the event), or returns a 1 if at least one of the samplers returns a 'true' value of 1 (at least one of the samplers in the network has detected the event);

FD_{net} = frequency of detection for the entire network; and

N = the number of events/sampling periods.

While the frequency of detection gives valuable information regarding what percentage of the time an event is detected at all, it does not give information on the efficiency of the individual samplers, and their placement. In order to determine that, an overall network intensity is defined:

$$NE = \frac{\sum_{s=1}^{N_S} \sum_{i=0}^{N} f(D_{s,i})}{(N_S \times N)} \tag{8}$$

Where

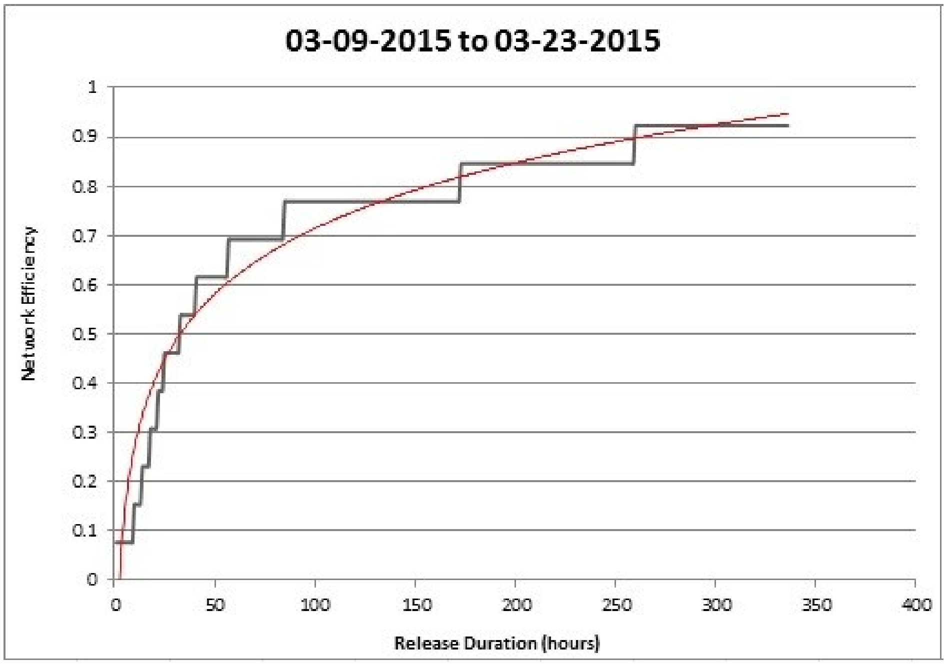
$f(D_{s,i})$ = a binary function that returns 0 if the detection ($D_{s,i}$) is false, and 1 if the detection is true for sampler s and event i;

N_s = number of samplers; and

N = number of events.

An example of predicted data resulting from the puff/plume dispersion model network intensity evaluation is shown in Figure 2-5, using meteorological data from the hypothetical sampling period of 9 March 2015 to 23 March 2015 (two weeks). The network intensity ranges from 0.1 to 1 (N_s = 10), with each step-wise feature of the plot corresponding to an additional sampler detecting the release through a concentration greater than or equal to the limiting concentration (in this case, the MDC). The last samplers to detect the release (the steps shown furthest to the right along the x-axis) correspond to samplers with the lowest efficiency. The simulated release for this scenario was a 336-hour release, with every-hour, on-the-hour release of tritium oxide with a release rate of 83.78 Ci/hr (corresponding to 10% dose rate). The trend expected to be seen if the release took place only over the first hour of the sampling period would be an initial increase in the network intensity, followed by a sharp decline as the material dispersed and became too spread out to maintain higher than MDC levels.

Figure 2-5. Network Intensity over Release Duration Example.



3.0 Results and Discussion

3.1 2015 Collected Sampler Data & Comparison to Other Methods

3.1.1 Correction Factors

Releases at nuclear facilities are not generally constant throughout the year, meaning that throughout some sampling periods the size of a release may be assumed to be negligible. During sampling periods of negligible release, the CDT for a sampler may be marked by the algorithms discussed previously as a failure to detect, since the sampler will detect no events. In order to remedy this, data on releases from each month of 2015 were examined to determine which, if any, months (and their corresponding sampling periods) had negligible releases. Those sampling periods with negligible releases (that had been marked by the algorithm as failing to detect any events) were then marked as "true" in the analysis of the 2015 collected sampler data, in an attempt to gain a more realistic picture of the performance of the system in cases of inconsistent releases.

3.1.2 Efficiencies

Excluding the correction for inconsistent releases, the frequency of detection for the existing network placement is 62.5%; with the correction it increased to 79.2% (as a result of a larger number of sampling periods being marked as "true"). In addition, the mean network intensity increased from 17.9% to 21.5%, without removing any sampling stations. The actual efficiency of each individual air-monitoring station without this correction is listed in Table 3-1, and the efficiencies with the correction can be seen in Table 3-2. The stations are presented in order of distance from H-Area (where releases would take place) to the sampler location (increasing in distance from top to bottom). The trend described previously of sampler placement and meteorological patterns as well as distance from source to receptor playing an important role in the efficiency and ability to detect events is supported by the fact that the most closely located samplers do not have the highest efficiency. D-Area specifically, while being further away than three other samplers, has a higher frequency of wind in its direction, and as a result, has a considerably higher efficiency.

Table 3-1. Sampling Station Individual Efficiency without Correction.

Sampling Station	Directional Sector	Distance from H-Area (m)	Efficiency (%)
Talatha Gate	N	10830	25.0%
Green Pond	NW	11748	12.5%
East Talatha	N	12355	20.8%
D-Area	SW	12489	37.5%
Jackson	W	13320	25.0%
Dark Horse	NE	15882	16.7%
Hwy 21/167	E	16199	12.5%
Barnwell Gate	E	16308	16.7%
Patterson Mill Rd	SE	18209	8.3%
Allendale Gate	S	18925	4.2%

Table 3-2. Sampling Station Individual Efficiency with Correction.

Sampling Station	Directional Sector	Distance from H-Area (m)	Efficiency (%)
Talatha Gate	N	10830	30.0%
Green Pond	NW	11748	15.0%
East Talatha	N	12355	25.0%
D-Area	SW	12489	45.0%
Jackson	W	13320	30.0%
Dark Horse	NE	15882	20.0%
Hwy 21/167	E	16199	15.0%
Barnwell Gate	E	16308	20.0%
Patterson Mill Rd	SE	18209	10.0%
Allendale Gate	S	18925	5.0%

Some discussion is obligatory on the actual order in which samplers become unable to detect a release. While the majority of the order remained consistent between CAP88, the Gaussian dispersion model, and the actual 2015 data, there were a few incongruities between them (note that the Waite method did not provide any information on the efficiency of the sampling locations). Specifically, the Jackson and Green Pond sampling stations appeared in vastly different areas of the CAP88 and actual 2015 data order of elimination; for CAP88, both stations were located approximately in the middle of the order, whereas for the 2015 data and the Gaussian dispersion model, the Green Pond sampling location were eliminated very quickly, and the Jackson sampling location remained capable of detecting events longer than all but two other samplers.

There were a few small discrepancies on the longer-detecting end of the elimination order; however the sampling stations of interest in this study were on the shortest-detecting or least efficient, end of the elimination order. All of the methods agreed that the two stations the furthest from the source while still being located at the perimeter, Patterson Mill Rd and Allendale, were the first two stations to be unable to detect any events for all simulated releases. The efficiencies for both stations were low enough that they become unable to detect an event at approximately the same rate as the stations located 25 miles from the center of site (Aiken Airport, Savannah Lock and Dam, and US 301 Bridge).

4.0 Conclusions

Taking into consideration the results found using the Waite method, CAP88, the puff/plume dispersion model, and the 2015 collected concentration data, conclusions may be drawn regarding the overall frequency of detection of the system, and the network intensity of the network of samplers. As mentioned in the discussion of efficiencies, two of the samplers in particular showed individual efficiencies at or below 10%; Patterson Mill Rd (10%) and Allendale (5%). Combined with the early elimination rate of these stations (approximately the same rate as the 25-mile stations), these trends indicate that moving or eliminating at least one of these stations could increase the network intensity of the ambient air system at SRS. The results of removing one of these stations, compared with the existing frequency of detection and network intensity, are listed in Table 4-1.

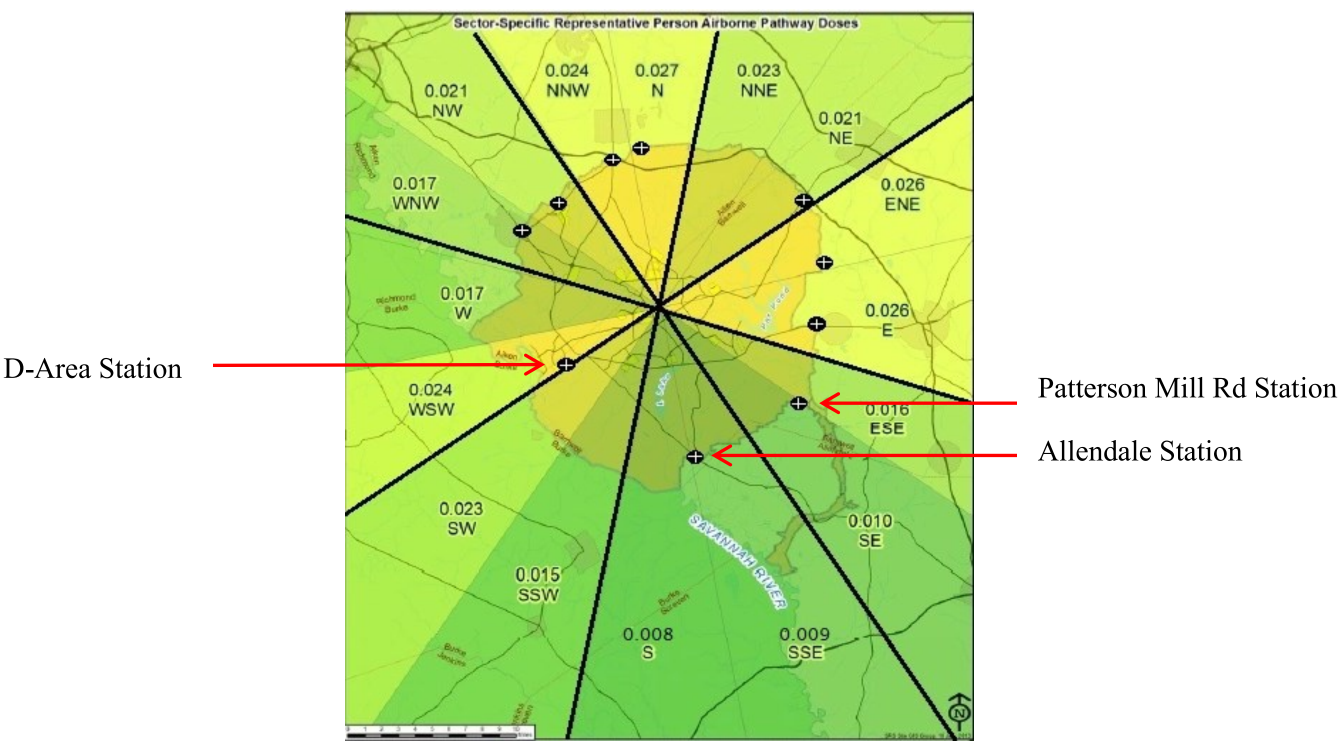
Table 4-1. Network Intensity with Sampler Removal.

		All Existing Samplers	Minus Patterson Mill	Minus Allendale
Network Intensity	Min	0%	0%	0%
	Max	90.0%	88.9%	100.0%
	Mean	21.5%	22.8%	23.3%
Frequency of Detection*		79.2%	79.2%	79.2%

*As frequency of detection is only affected by the removal of a sampler if that sampler is the only one in the system to detect a release, it would not be affected by the removal of either the Patterson Mill Rd or Allendale stations.

Although removing the Allendale station instead of the Patterson Mill Rd station makes sense from a numerical point of view, there is a concern when the network is viewed geographically. Figure 4-1 shows a map of the site with perimeter air-monitoring stations listed (corresponding to the black dots with white crosses) with the doses (in units of mrem) expected to be seen from exposure to a representative person due to airborne exposure pathways over the course of 1 calendar year.

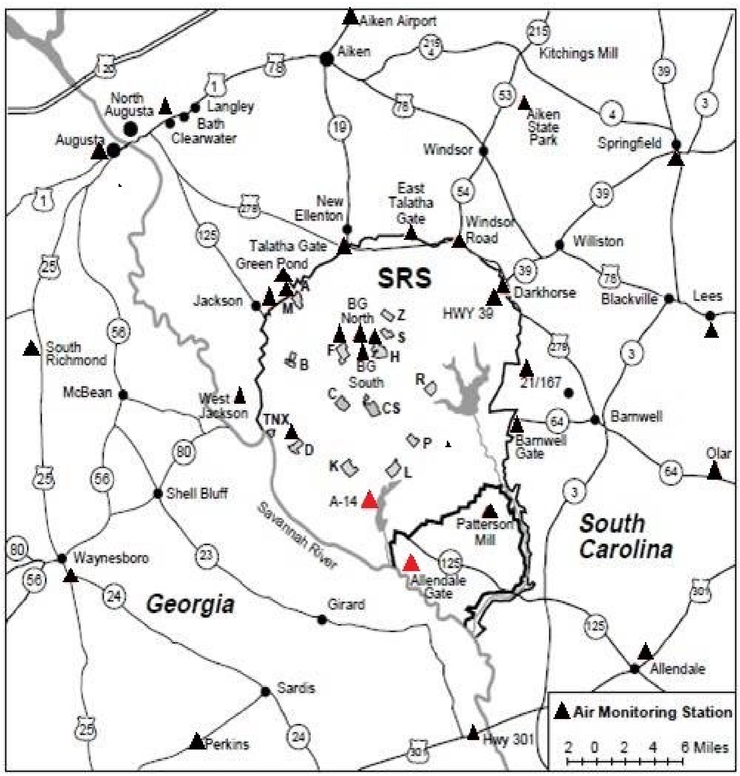
Figure 4-1. Airborne Pathway Sector Dose Map.



While removing Allendale would lead to larger overall network intensity, it leaves a large gap between the stations of D-Area and Patterson Mill Rd, increasing the possibility of a release taking place within those sectors without detection. Due to the small frequency of wind and small population in the S and SE sectors, it is unlikely that such a release would get offsite before dispersing to undetectable concentrations; however it should be taken into account when considering removing that station. In addition, the network intensity adjustment between removing the Patterson Mill Rd station or the Allendale station differs by just over 0.5%, lessening the concern of losing increased network intensity by removing the Patterson Mill Rd station instead of Allendale station.

Another potential option to improve the network intensity of the site would be moving the Allendale station to an older, discontinued-sampler location. Figure 4-2 shows a map of the air monitoring stations that existed in 1993; in particular the A-14 station would seem to be optimally located to replace the Allendale station, leaving the sampling station not only closer to the source, but further over as well, increasing the wind frequency towards the sampling location. Further work will be performed in determining how exactly replacing the Allendale station with the discontinued A-14 location would change the network intensity.

Figure 4-2. 1993 Site Map of Air Monitoring Stations



5.0 Recommendations, Path Forward or Future Work

Runs performed using the Gaussian dispersion model in this study were assumed to have a release occurring throughout the entire sampling period (a release of the same amount, beginning every hour of the sampling period, and discontinuing at the end of that hour); this led to a higher concentration of the radionuclide, as a secondary release would begin before the initial release could be fully dispersed in air. While this is a relevant accident or routine-release scenario, examining how the sampler detection system would operate with releases varying in hours would widen the information base about the performance of the system in general. A program to view the results of a simulated release lasting any duration of hours, with a sampling period of less than or equal to 1 calendar year has been created, and will be used in future work to flesh out the performance evaluation of the ambient air system.

Network intensity could be improved from its current mean of 21.5% to 22.8% by eliminating the Patterson Mill Rd monitoring station or to 23.3% by eliminating the Allendale monitoring station. An additional option is to move the Allendale monitoring station to the discontinued A-14 monitoring station. Future work in this area includes examining the potential of simply moving Allendale or both of the afore-mentioned stations, as opposed to eliminating one altogether. Although the logical choice seems to be a recommendation to eliminate the Allendale station (and thus achieve higher network intensity), eliminating Allendale would leave a large gap in the radiological surveillance system in the S and SE sectors. Although both of these sectors have very small weighting factors in terms of population, wind frequency, and potential dose to a member of the public given an exposure, there is a concern with leaving such a wide swath of the site perimeter without air-monitoring. For that reason, we recommended the elimination of the Patterson Mill Rd station, which will still bring the network intensity up by nearly 1.5%, or the replacement of the Allendale station with the discontinued A-14 monitoring station.

Other potential locations for replacement could be examined, however this option would need to take into account the geographic challenges associated with the heavily-forested site, and ensure the capability to easily reach the site in order to change out the sampler filters. Location A-14 was specifically chosen, as it coincides with a location with utilities already in place from its previous monitoring site, and ease of ability to get to the sampler. Further investigation into the improved network intensity given this move is planned.

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