Tennessee Valley Authority, P.O. Box 2000, Spring City, Tennessee 37381-2000

WBL-20-016

May 14, 2020

10 CFR 50.4

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Watts Bar Nuclear Plant, Units 1 and 2
Facility Operating License Nos. NPF-90 and NPF-96
NRC Docket Nos. 50-390 and 50-391

Subject: **Watts Bar Nuclear Plant – Annual Radiological Environmental Operating Report - 2019**

Enclosed is the subject report for the period of January 1, 2019, through December 31, 2019. This report is being submitted as required by Watts Bar Nuclear Plant (WBN) Units 1 and 2, Technical Specification (TS) 5.9.2, "Annual Radiological Environmental Operating Report," and the WBN Offsite Dose Calculation Manual (ODCM), Administrative Control Section 5.1. This report is required to be submitted to the Nuclear Regulatory Commission (NRC) by May 15 of each year.

There are no new regulatory commitments in this letter. If you have any questions concerning this matter, please contact Tony Brown, WBN Licensing Manager, at (423) 365-7720.

Respectfully,

Anthony L. Williams IV
Site Vice President
Watts Bar Nuclear Plant

Enclosure:

Annual Radiological Environmental Operating Report - Watts Bar Nuclear Plant 2019

cc: See Page 2

cc (Enclosure):

NRC Regional Administrator – Region II
NRC Project Manager – Watts Bar Nuclear Plant
NRC Senior Resident Inspector - Watts Bar Nuclear Plant

ENCLOSURE

TENNESSEE VALLEY AUTHORITY
WATTS BAR NUCLEAR PLANT

Annual Radiological Environmental Operating Report
Watts Bar Nuclear Plant 2019

2019 Annual Radiological Environmental Operating Report

Tennessee Valley Authority Watts Bar Nuclear Plant

May 2020

Prepared under contract by
Chesapeake Nuclear Services, Inc. and GEL Laboratories, LLC

Chesapeake Nuclear Services

GEL Laboratories LLC
a member of The GEL Group INC

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EXECUTIVE SUMMARY

This report describes the Radiological Environmental Monitoring Program (REMP) conducted by the Tennessee Valley Authority (TVA) near the Watts Bar Nuclear Plant (WBN) during the 2019 monitoring period. The program is conducted in accordance with regulatory requirements to monitor the environment per 10 CFR 20, 10 CFR 50, applicable NUREGs (U.S. NRC, 1991) and TVA requirements (TVA, 2019). The REMP includes the collection and subsequent determination of radioactive material content in environmental samples. Various types of samples are collected within the vicinity of the plant, including air, water, food crops, soil, fish and shoreline sediment; and direct radiation levels are measured. The radiation levels of these samples are measured and compared with results from control stations, which are located outside the plant's near vicinity, and with environmental data collected at Watts Bar Nuclear Plant prior to operations (preoperational data). This report contains an evaluation of the results from this monitoring program and resulting potential impact of WBN operations on the environment and the general public.

All environmental samples in support of the REMP were collected by TVA and/or contractor personnel. All environmental media were analyzed by GEL Laboratories, LLC except for environmental dosimeters, which were analyzed by Landauer. The evaluation of all results and the generation of this report were performed by Chesapeake Nuclear Services, Inc. and GEL Laboratories.

The radioactivity measured in environmental samples in the WBN program can mostly be attributed to naturally occurring radioactive materials. There is no indication that WBN activities increased the background direct radiation levels normally observed in the areas surrounding the plant, as measured by environmental dosimeters. In 2019, trace quantities of cesium-137 (Cs-137) were measured in most soil samples from both indicator and control locations. The concentrations were typical of the levels expected to be present in the environment from past nuclear weapons testing. The fallout from accidents at the Chernobyl plant in the Ukraine in 1986 and the Fukushima plant in Japan in 2011 may have also contributed to the low levels of Cs-137 measured in environmental samples.

Tritium (H-3) was detected in approximately 5% (11 of 212) of atmospheric moisture samples, from both indicator and control locations.

Low levels of tritium were detected in several drinking water samples collected from both control and indicator locations; however, the levels were not statistically different indicating that WBN contribution, if any, was a small component of the background levels. Several samples from onsite groundwater wells identified similarly low levels of tritium, less than 3% of the EPA drinking water limit of 20,000 pCi/L. Some drinking water samples identified gross beta, which can be attributed to natural occurring radioactivity. Only naturally occurring radioactivity was identified in all shoreline sediment, pond sediment, milk, fish and food products samples.

In summary, the measured levels of radioactivity in the environmental samples were typical of background levels; there was no detectable increase in radiation exposure to members of the public attributable to the operations of the Watts Bar Nuclear Plant.

INTRODUCTION

This report describes and summarizes the results of radioactivity measurements made in the vicinity of WBN and laboratory analyses of samples collected in the area. The measurements are made to comply with the requirements of 10 CFR 50, Appendix A, Criterion 64 and 10 CFR 50, Appendix I, Section IV.B.2, IV.B.3 and IV.C to determine potential effects on public health and safety. This report satisfies the annual reporting requirements of WBN Technical Specification 5.6.2 and Offsite Dose Calculation Manual (ODCM) Administrative Control 5.1. In addition to reporting the data prescribed by specific requirements, other information is included to correlate the significance of results measured by this monitoring program to the levels of environmental radiation resulting from naturally occurring radioactive materials.

Naturally Occurring and Background Radioactivity

Most materials in our world today contain trace amounts of naturally occurring, primordial radioactivity. Potassium-40 (K-40), with a half-life of 1.3 billion years, is a common radioactive element found naturally in our environment. Approximately 0.01 percent of all potassium is radioactive potassium-40. Other examples of naturally occurring radioactivity are beryllium-7 (Be-7), bismuth-212 and 214 (Bi-212 and Bi-214), lead-210 and 214 (Pb-210 and Pb-214), thallium-208 (Tl-208), actinium-228 (Ac-228), uranium-235 and uranium-238 (U-235 and U-238), thorium-234 (Th-234), radium-226 (Ra-226), radon-220 and radon-222 (Rn-220 and Rn-222), carbon-14 (C-14), and hydrogen-3 (H-3, commonly called tritium). These naturally occurring radioactive elements are in the soil, our food, our drinking water, and our bodies. Radiation emitted from these materials make up part of low-level natural background radiation exposures. Radiation emitted from cosmic rays is the remainder.

It is possible to get an idea of the relative significance by examining the amount of radiation the U.S. population receives from the different source of radiation exposure in our environment. The information in Table 1 is primarily adapted from the U.S. Nuclear Regulatory Commission (U.S. NRC, February 1996) and National Council on Radiation Protection (NCRP, March 2009).

Table 1 - U.S. General Population Average Dose Equivalent Estimates

Source	millirem (mrem)[i] per year per person
Natural Background Dose Equivalent	
Cosmic	33
Terrestrial	21
In the body	29
Radon	228
Total	311
Medical (effective dose equivalent)	300
Nuclear energy	0.28
Consumer Products	13
TOTAL	624.28

[i] One-thousandth of a Roentgen Equivalent Man (rem). By comparison, the NRC's annual radiation dose limit for the public from any licensed activity, such as a nuclear plant, is 100 mrem.

As can be seen from the data presented above, natural background radiation dose equivalent to the U.S. population exceeds that normally received from nuclear plants by several thousand times. This illustrates that routine nuclear plant operations result in population radiation doses that are insignificant compared to the dose from natural background radiation. As Table 1 shows, the use of radiation and radioactive materials for medical uses results in an effective dose equivalent on average to the U.S. population that is essentially the same as that caused by natural background cosmic and terrestrial radiation.

Electric Power Production

Nuclear power plants are similar in many respects to conventional coal burning (or other fossil fuel) electrical generating plants. The basic process behind electrical power production in power plants is that fuel is used to heat water to produce steam, which provides the force to turn turbines and generators. In a nuclear power plant, the fuel is uranium and the heat is produced in the reactor through the fission of the uranium. Nuclear plants include many complex systems to control the nuclear fission process and to safeguard against the possibility of reactor malfunction. The nuclear reactions produce radionuclide byproducts, commonly referred to as fission and activation products. Very small amounts of these fission and activation products are released into the plant systems. This radioactive material can be transported throughout plant systems and some of it may be released to the environment in an authorized and controlled manner.

Paths through which radioactivity from a nuclear power plant is routinely released are monitored. Liquid and gaseous effluent monitors record the radiation levels for each release. These monitors also provide alarm mechanisms to prompt termination of any abnormal releases before limits are exceeded.

Releases are monitored at the onsite points of release. The radiological environmental monitoring program, which measures the environmental radiation in areas around the plant, provides a confirmation that releases are being properly controlled and monitored in the plant and that any resulting levels in the environment are within the established regulatory limits and a small fraction of the natural background radiation levels. In this way, the release of radioactive materials from the plant is tightly controlled, and verification is provided that the public is not exposed to significant levels of radiation or radioactive materials as the result of plant operations.

The WBN ODCM, which describes the program required by the plant technical specifications, prescribes limits for the release of radioactive effluents, as well as limits for doses to the general public from the release of these effluents.

The NRC's annual dose limit to a member of the public for all licensees is 100 mrem. The NRC's regulations for nuclear power plants require implementing a philosophy of "as low as reasonably achievable," where the dose to a member of the public from radioactive materials released from nuclear power plants to unrestricted areas is further limited on a per unit operating basis to the following:

Liquid Effluents

Total body	≤ 3 mrem/yr
Any organ	≤ 10 mrem/yr

Gaseous Effluents

Noble gases:	
Total body	≤ 5 mrem/yr
Gamma air	≤ 10 mrad/yr
Beta air	≤ 20 mrad/yr
Particulates:	
Any organ	≤ 15 mrem/yr

In addition to NRC's regulations, the EPA standard for the total dose to the public in the vicinity of a nuclear power plant, established in the Environmental Dose Standard of 40 CFR 190, is as follows:

Total body	≤ 25 mrem/yr
Thyroid	≤ 75 mrem/yr
Any other organ	≤ 25 mrem/yr

Table E-1 of this report presents a comparison of the nominal lower limits of detection (LLD) for the WBN monitoring program with the regulatory limits for maximum annual average concentration released to unrestricted areas. The table also includes the concentrations of radioactive materials in the environment that would require a special report to the NRC. It should be noted that the levels of radioactive materials in the environmental samples are typically not detected, being below the required detection level, with only naturally occurring radionuclides having measurable levels.

SITE AND PLANT DESCRIPTION

The WBN site is in Rhea county, Tennessee, on the west bank of the Tennessee River at Tennessee River Mile (TRM) 528. Figure 1 shows the site in relation to other TVA projects. The WBN site, containing approximately 1770 acres on Chickamauga Lake, is approximately 2 miles south of the Watts Bar Dam and approximately 31 miles north-northeast of TVA's Sequoyah Nuclear Plant (SQN) site. Also located within the reservation are the Watts Bar Dam and Hydro-Electric Plant, the Watts Bar Steam Plant (not in operation), the TVA Central Maintenance Facility, and the Watts Bar Resort Area.

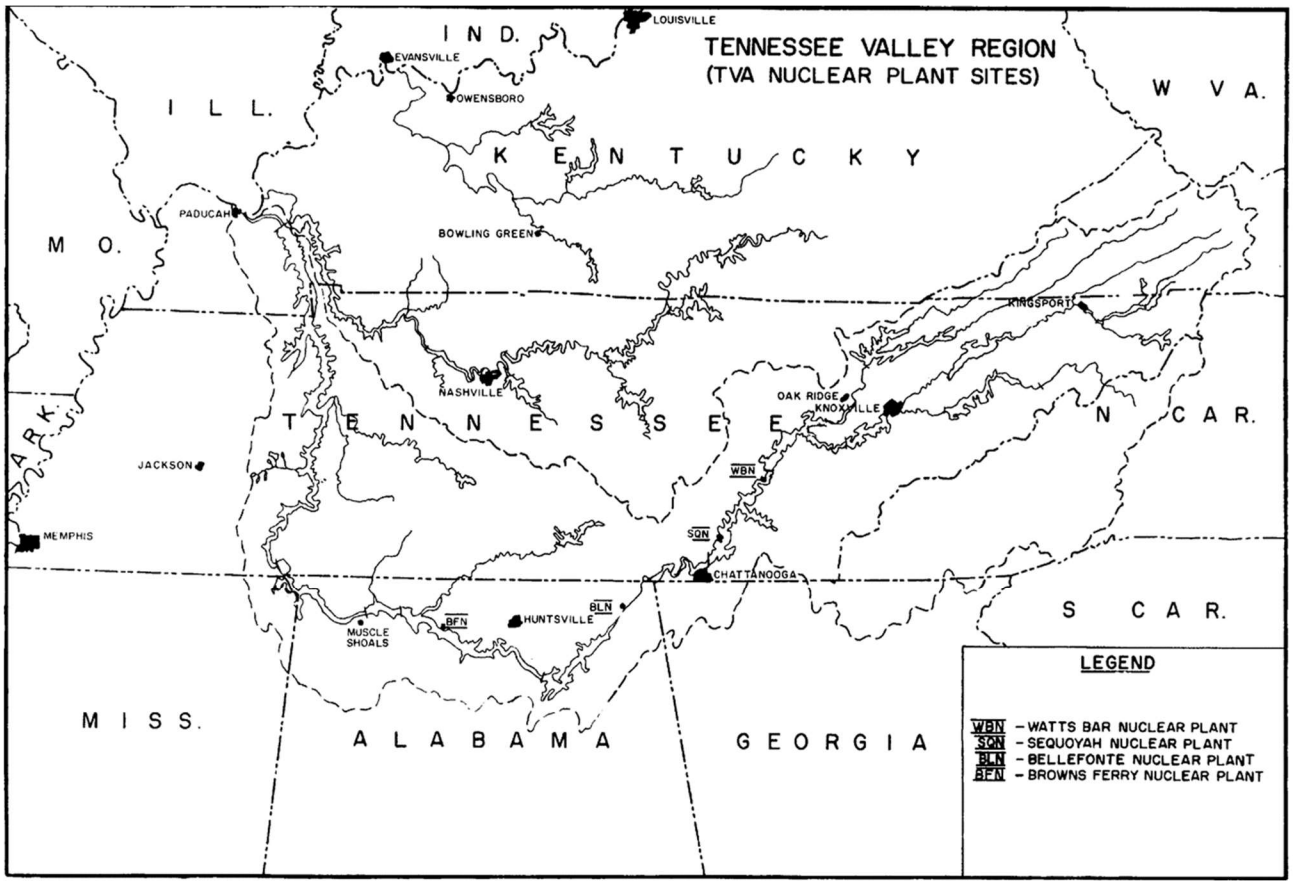
Approximately 18,500 people live within 10 miles of the WBN site. More than 80 percent of these live between 5 and 10 miles from the site. Two small towns, Spring City and Decatur, are in this area. Spring City, with a population of approximately 2,200, is northwest and north-northwest from the site, while Decatur, with about 1,500 people, is south and south-southwest from the plant. The remainder of the area within 10 miles of the site is sparsely populated, consisting primarily of small farms and individual residences.

The area between 10 and 50 miles from the site includes portions of the cities of Chattanooga and Knoxville. The largest urban concentration in this area is the city of Chattanooga, located to the southwest and south-southwest. The city of Chattanooga has a population of about 170,000, with approximately 80 percent located between 40 and 50 miles from the site and the remainder located beyond 50 miles. The city of Knoxville is located to the east-northeast, with not more than 10 percent of its 185,000 plus people living within 50 miles of the site. Three smaller urban areas of greater than 20,000 people are located between 30 and 40 miles from the site. Oak Ridge is approximately 40 miles to the northeast, the twin cities of Alcoa and Maryville are located 45 to 50 miles to the east-northeast, and Cleveland is located about 30 miles to the south.

Chickamauga Reservoir is one of a series of highly controlled multiple-use reservoirs whose primary uses are flood control, navigation, and the generation of electric power. Secondary uses include industrial and public water supply, fishing, and recreation. Public access areas, boat docks, and residential subdivisions have been developed along the reservoir shoreline.

WBN consists of two pressurized water reactors. WBN Unit 1 received a low power operating license (NPF-20) on November 9, 1995 and achieved initial criticality in January 1996. The full power operating license (NPF-90) was received on February 7, 1996. Commercial operation was achieved May 25, 1996. WBN Unit 2 was deferred October 24, 2000, in accordance with the guidance in Generic Letter 87-15, "Policy Statement on Deferred Plants." On August 3, 2007, TVA provided notice of its intent to reactivate and complete construction of WBN Unit 2. WBN Unit 2 resumed construction in late 2007. October 22, 2015 the operating license was issued. Initial criticality was achieved on May 23, 2016 and commercial operation was achieved on October 19, 2016.

Figure 1 – TVA Region



RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

By design, the radiation and radioactive materials generated in a nuclear reactor are contained within the reactor and plant support systems. There are planned routine releases from these plant systems, but plant effluent radiation monitors are designed to monitor these releases to the environment. Environmental monitoring is a final verification that the systems are performing as designed and planned. The monitoring program is designed to monitor the pathways between the plant and the people in the immediate vicinity of the plant. Sample types are chosen so that the potential for detection of radioactivity in the environment will be maximized. The Radiological Environmental Monitoring Program (REMP) and sampling locations for WBN are outlined in Appendix A.

There are two primary pathways by which radioactivity can move through the environment to humans: air and water (reference Figure 2). The air pathway can be separated into two components: the direct (airborne) pathway and the indirect (ground or terrestrial) pathway. The direct airborne pathway consists of direct radiation and inhalation by humans. In the terrestrial pathway, radioactive materials may be deposited on the ground, with direct exposure to individuals, and/or uptake by plants and the subsequently ingested by animals and/or humans. Human exposure through the liquid pathway may result from drinking water, eating fish, or by direct exposure at the shoreline. The types of samples collected in this program are designed to monitor these pathways.

Many factors were considered in determining the locations for collecting environmental samples. The locations for the atmospheric monitoring stations were determined from a critical pathway analysis based on weather patterns, dose projections, population distribution, and land use. Terrestrial sampling stations were selected after reviewing the local land uses, including the locations of dairy animals and gardens in conjunction with the air pathway analysis. Liquid pathway stations were selected based on dose projections, water use information, and availability of media such as fish and sediment. Table A-2 lists the sampling stations and the types of samples collected. Modifications made to the WBN monitoring program in 2019 are reported in Appendix B. Deviations to the sampling program during 2019 are included in Appendix C.

To determine the amount of radioactivity in the environment prior to the operation of WBN, a preoperational radiological environmental monitoring program was initiated in December 1976 and operated through December 1995. Measurements of the same pathways of exposure and types of radioactive materials that are measured currently were assessed during the preoperational phase to establish normal background levels for various radionuclides in the environment.

The preoperational monitoring program is a very important part of the overall program. During the 1950s, 1960s, and 1970s, atmospheric nuclear weapons testing released radioactive material to the environment causing increases in background radiation levels. Knowledge of preexisting radionuclide patterns in the environment permits a determination, through comparison and trending analyses, of any increase attributable to WBN operation.

The determination of environmental impact during the operating phase also examines changes in the background that may be attributable to sources other than WBN. This potential contribution is determined with control stations that have been established in the environment outside any likely influence from the plant. Results of environmental samples taken at control stations (far from the plant)

are compared with those from indicator stations (near the plant) to aid in the determination of any contribution from WBN operation.

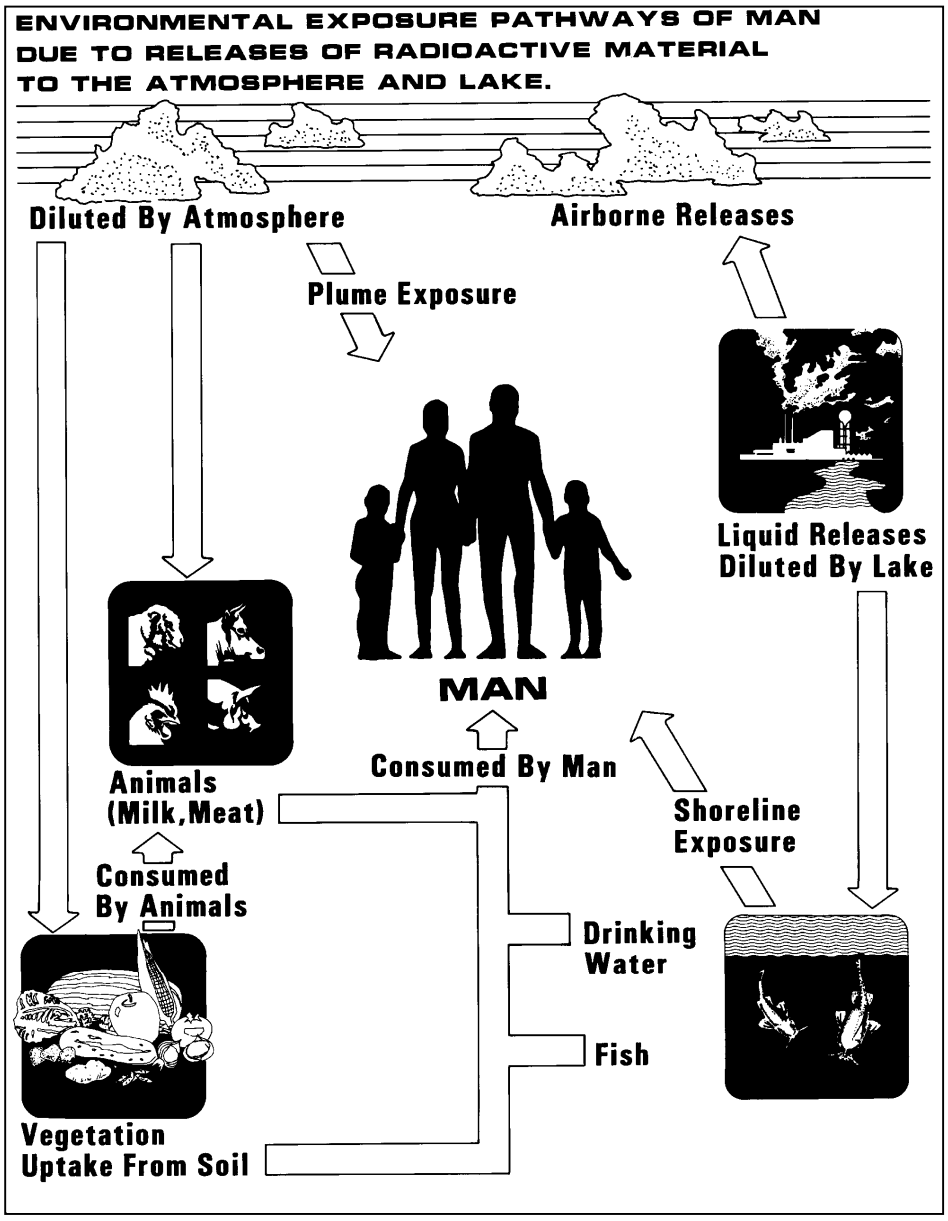
In 2019 the sample analyses were performed by the contracted laboratory, GEL Laboratories, LLC, based in Charleston, SC. Analyses were conducted in accordance with written and approved procedures and are based on industry established standard analytical methods. A summary of the analysis techniques and methodology is presented in Appendix D.

As shown in Table E-1, the analytical methods used to determine the radionuclide content of samples collected in the environment are very sensitive and capable of detecting small amounts of radioactivity. The sensitivity of the measurement process is defined in terms of the lower limit of detection (LLD). A description of the nominal LLDs for the Radioanalytical Laboratory is presented in Appendix E.

The laboratory applies a comprehensive quality assurance/quality control program to monitor laboratory performance throughout the year. One of the key purposes of the QA/QC program is to provide early identification of any problems in the measurement process so they can be corrected in a timely manner. This program includes instrument checks, to ensure that the radiation measurement instruments are working properly, and the analysis of quality control samples. As part of an interlaboratory comparison program, the laboratory participates in a blind sample program administrated by Eckert & Ziegler Analytics. A complete description of the quality control program is presented in Appendix F.

An annual land use census is conducted for the purpose of identifying changes in the land uses around the plant and potential for changes in exposure pathways and locations. Appendix G contains the results of the annual land use census. Data tables summarizing the sample analysis results are presented in Appendix H. Finally, Appendix I contains any errata from previous AREORs.

Figure 2 – Environmental Exposure Pathways



DIRECT RADIATION MONITORING

Direct radiation levels are measured at various monitoring points around the plant site. These measurements include contributions from cosmic radiation, radioactivity in the ground, fallout from atmospheric nuclear weapons tests conducted in the past, and any radioactivity that may be present from plant operations. The plant contribution to the total direct radiation component is small compared to that from background. Therefore, an in-depth analysis, comparing the variation in measurements and the background fluctuation, is undertaken to identify any significant plant contribution. This process is further described below.

Measurement Techniques

The Landauer InLight environmental dosimeter is used in the radiological environmental monitoring program for the measurement of direct radiation. This dosimeter contains four elements consisting of aluminum oxide detectors with open windows as well as plastic and copper filters. The dosimeter is processed using optically stimulated luminescence (OSL) technology to determine the amount of radiation exposure.

The dosimeters are placed approximately one meter above the ground, with two at each monitoring location. Sixteen monitoring points are located around the plant near the site boundary, one location in each of the 16 compass sectors. One monitoring point is also located in each of the 16 compass sectors at a distance of approximately four to five miles from the plant.

Dosimeters are also placed at additional monitoring locations out to approximately 15 miles from the site. The dosimeters are exchanged every three months. The dosimeters are sent to Landauer for processing and results reporting. The values are corrected for transit and shielded background exposure. An average of the two dosimeter results is calculated for each monitoring point. The system meets or exceeds the performance specifications outlined in American National Standards Institute (ANSI) N545-1975 and ANSI N13.37-2014 for environmental applications of dosimeters.

WBN Technical Specification 5.9.2, Annual Radiological Environmental Operating Report, requires that the Annual Radiological Environmental Operating Report identify dosimeter results that represent collocated dosimeters in relation to the NRC's program and the exposure period associated with each result. The NRC collocated environmental dosimetry program was terminated by the NRC at the end of 1997, therefore, there are no results that represent collocated dosimeters included in this report.

Results

For reporting dose, all results for environmental dosimeter measurements are normalized to a standard quarter (91 days). The monitoring locations are grouped according to the distance from the plant. The first group consists of all monitoring points within 2 miles of the plant. The second group is made up of all locations greater than 2 miles from the plant. Past data have shown that the average results from the locations more than 2 miles from the plant are essentially the same. Therefore, for purposes of this report, monitoring points 2 miles or less from the plant are identified as "onsite" stations and locations greater than 2 miles are considered "offsite."

The quarterly and annual gamma radiation levels determined from the dosimeters deployed around WBN in 2019 are summarized in Table 2. For comparison purposes, the average direct radiation measurements made in the preoperational phase of the monitoring program are also shown.

Table 2 - Average External Gamma Radiation Levels at Various Distances from WBN for Each Quarter - 2019

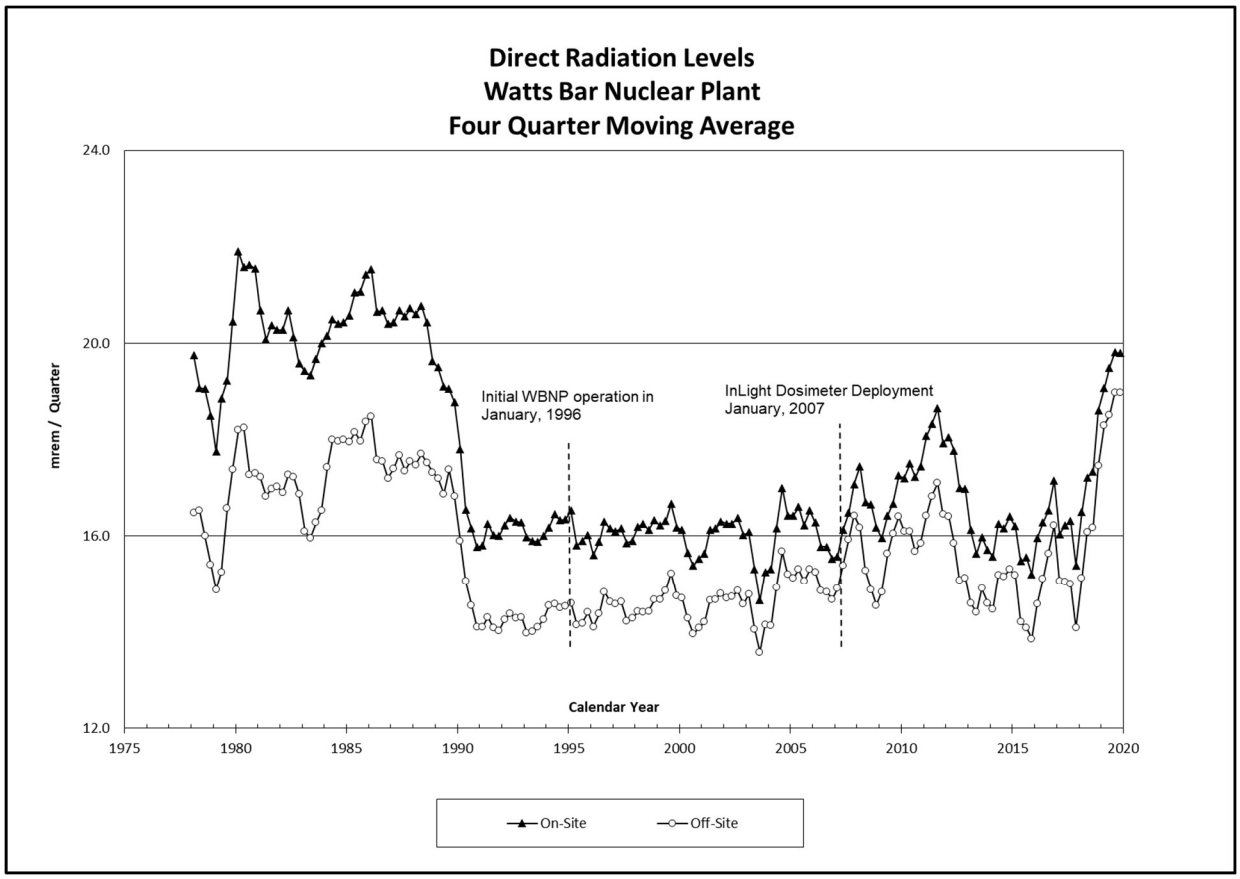
	Average External Gamma Radiation Levels					
	Q1 (mrem/qtr)	Q2 (mrem/qtr)	Q3 (mrem/qtr)	Q4 (mrem/qtr)	Annual (mrem/yr)	Preoperational (mR/yr)
Average 0-2 miles (onsite)[a]	19.0	21.9	19.7	18.5	79.2	65
Average >2 miles (offsite)[a]	19.1	20.2	19.2	17.4	75.9	57

NOTES

a. Average of the individual measurements in the set

The data in Table 2 indicate that the average quarterly direct radiation levels at the WBN onsite stations are approximately 0.8 mrem/quarter higher than levels at the offsite stations. This equates to 3.3 mrem/year increase at the onsite locations, which is less than the difference observed during the preoperational program. Even considering this 3.3 mrem/yr increase for onsite locations attributable to plant operations, it falls well below the 25 mrem total body limit for 40 CFR 190. As identified, the difference in onsite and offsite averages is consistent with levels measured for the preoperational and construction phases of TVA nuclear power plant sites, where the average levels onsite were slightly higher than levels offsite. Figure 3 compares plots of the data from the onsite stations with those from the offsite stations over the period from 1977 through 2019. Landauer InLight Optically Stimulated Luminescence (OSL) dosimeters have been deployed since 2007, replacing the Panasonic UD-814 dosimeters used during the previous years. Beginning with 2018, the methodology for evaluating and reporting the environmental direct radiation exposure was modified, to reflect recommendations contained in ANSI N13.37-2014. A study was performed to determine the dose received by dosimeters that are used as unexposed controls to account for the transit dose to all dosimeters and the shielded storage dose to the unexposed control dosimeters. This in turn was used to more accurately account for the extraneous dose that should be removed from the gross measurements as measured by the field dosimeters.

Figure 3 - Average Direct Radiation



The data in Table H-1 contains the results of the individual monitoring stations. The results reported in 2019 are consistent with historical and preoperational results, indicating that there is no measurable increase in direct radiation levels in the offsite environment attributable to the operation of WBN.

ATMOSPHERIC MONITORING

The atmospheric monitoring network is divided into three groups identified as local, perimeter, and remote. Four local air monitoring stations are located on or adjacent to the plant site in the general directions of higher wind frequency. Four perimeter air monitoring stations are located between 6 to 11 miles from the plant, and two air monitors are located out to 15 miles and used as control or baseline stations. The monitoring program and the locations of monitoring stations are identified in the tables and figures of Appendix A.

Results from the analysis of samples in the atmospheric pathway are presented in Table H-2 through Table H-5. Radioactivity levels identified in this reporting period are consistent with background and preoperational program data. There is no indication of an increase in atmospheric radioactivity due to WBN operations.

Sample Collection and Analysis

Air particulates are collected by continuously sampling air at a flow rate of approximately 2 cubic feet per minute (cfm) through a 2-inch glass fiber filter. The sampling system consists of a Vacuum Florescent Display (VFD), an oil-less carbon vane vacuum pump and a precision-machined mechanical differential pressure flow sensor. It is equipped with automatic flow control, on-board data storage, and alarm notifications for flow, temperature, or higher filter differential pressure. This system is housed in a weather resistant environmental enclosure approximately 3 feet by 2 feet by 4 feet. The filter is contained in a sampling head mounted on the outside of the monitoring building. The filter is replaced weekly. Each filter is analyzed for gross beta activity at least 3 days after collection to allow time for the natural occurring radon daughters to decay. Monthly composites of the filters from each location are analyzed by gamma spectroscopy.

Atmospheric radioiodine is sampled using a commercially available cartridge containing triethylenediamine (TEDA)-impregnated charcoal. This system is designed to collect iodine in both the elemental form and as organic compounds. The cartridge is in the same sampling head and downstream of the air particulate filter. The cartridge is changed at the same time as the particulate filter and samples the same volume of air. Each cartridge is analyzed for I-131 by gamma spectroscopy.

Atmospheric moisture sampling is conducted by pulling air at a constant flow rate through a column loaded with approximately 400 grams of silica gel. Every two weeks, the column is exchanged on the sampler. The atmospheric moisture is removed from silica gel by heating followed by condensation and the collected water analyzed for tritium.

Results

The results from the analysis of air particulate samples are summarized in Table H-2. Gross beta activity in 2019 was consistent with levels reported in previous years. The average gross beta activity measured for air particulate samples was 0.037 pCi/m^3 for indicator locations and 0.035 pCi/m^3 for control locations. The annual averages of the gross beta activity in air particulate filters at these stations for the period 1977-2019 are presented in Figure H-1. Increased levels due to fallout from atmospheric nuclear weapons testing are evident in the years prior to 1981 and a small increase from the Chernobyl accident can be

seen in 1986. These patterns are consistent with data from monitoring programs conducted by TVA at other nuclear power plant sites. In 2017, GEL Laboratories, LLC took over radiochemistry analysis for the WBN REMP program. Since that change, the air filter gross beta results increased from a long-term average of approximately 0.02 pCi/m^3 to approximately 0.03 pCi/m^3. This is the result of the new laboratory using a different calibration source (Tc-99) than the prior laboratory (Sr-90), which resulted in a slightly higher correlation of the instrument measurement to the corresponding calculated air concentration. The current results are consistent between indicator and control samples, and consistent with results from other nuclear power plant environmental monitoring programs, including both TVA and non-TVA facilities.

As shown in Table H-3, I-131 was not detected in any charcoal cartridge samples. Only natural radioactive materials were identified by the monthly gamma spectral analysis of the air particulate samples collected in 2019 (see Table H-4).

The results for atmospheric moisture sampling are reported in Table H-5. Tritium in atmospheric moisture was detected in several samples from both indicator and control locations. There was a total of 11 positive results from 212 samples, and the highest concentration from an indicator location was 0.046 pCi/m^3. Tritium is present in the atmosphere both naturally and as a result of past weapons testing, and the observed levels are not indicative of releases from the WBN site.

TERRESTRIAL MONITORING

Terrestrial monitoring is accomplished by collecting samples of environmental media representing the transport of radioactive material from the atmosphere to humans. For example, radioactive material may be deposited on vegetation and be ingested by consuming vegetables; or it may be deposited on pasture grass where dairy cattle are grazing. Milk from the dairy cows represents an exposure pathway to humans. Therefore, samples of milk, soil, and food crops are collected and analyzed to determine potential impacts from exposure through these pathways. The results from the analysis of these samples are shown in Table H-6 through Table H-8.

A land use census is conducted annually between April and October to identify the location of the nearest milk animal, the nearest residence, and the nearest garden of greater than 500 square feet producing fresh leafy vegetables in each of 16 meteorological sectors within 5 miles from the plant. This land use survey satisfies the requirements 10 CFR 50, Appendix I, Section IV.B.3. The results of the 2019 land use census are presented in Appendix G.

Sample Collection and Analysis

Milk samples are collected every two weeks from indicator dairies and from at least one control dairy. Milk samples are placed on ice for transport to the radioanalytical laboratory. A radiochemical separation analysis for I-131 and gamma spectroscopy are performed on each sample and a Sr-89 and Sr-90 analysis is performed quarterly.

The monitoring program includes a provision for sampling of vegetation from locations where milk is being produced and when milk sampling cannot be conducted. There were no periods during this year when vegetation sampling was necessary. There were no changes to the milk sampling program in 2019, as one indicator and one control location were sampled all year.

Soil samples are collected annually from the area surrounding each air monitoring station. The samples are collected with either a “cookie cutter” or an auger type sampler. After drying and grinding, the sample is analyzed by gamma spectroscopy. When the gamma analysis is complete, the sample is analyzed for Sr-89 and Sr- 90.

Samples representative of food crops raised in the area near the plant are obtained from individual gardens. Types of foods may vary from year to year due to changes in the local vegetable gardens. Samples of cabbage, corn, green beans, and tomatoes were collected from local vegetable gardens and/or farms. Samples of the same food products grown in areas that would not be affected by the plant were obtained from area produce markets as control samples. The edible portion of each sample is analyzed by gamma spectroscopy.

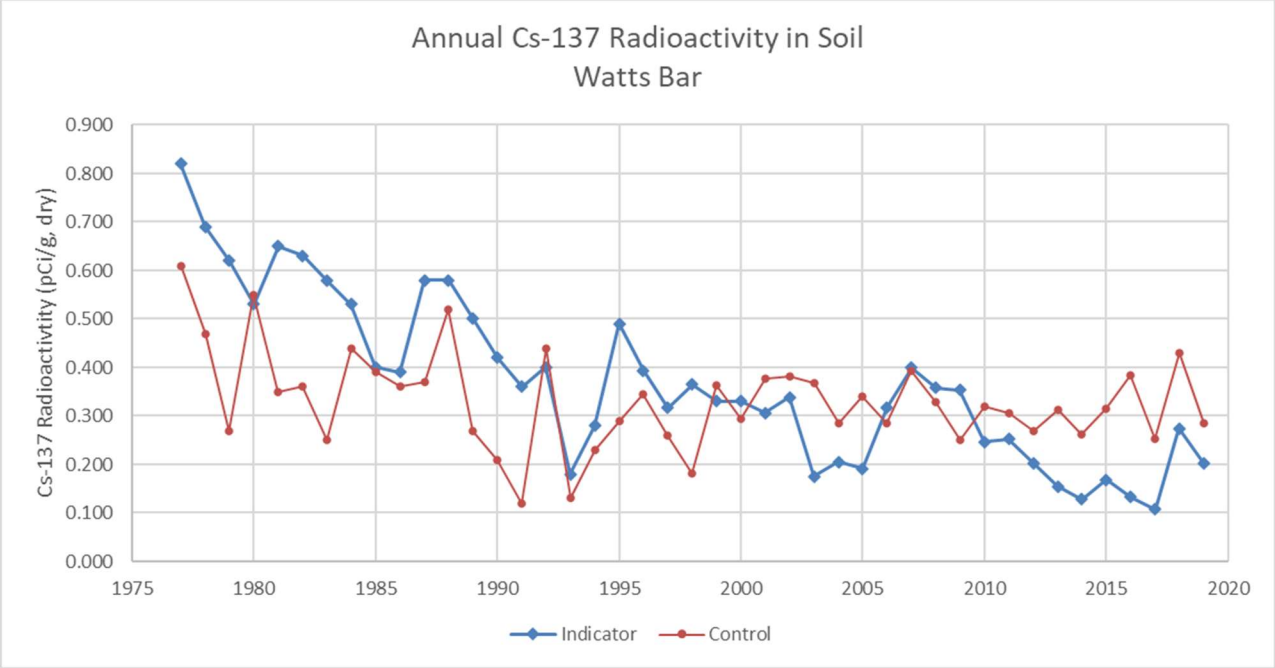
Results

The results from the analysis of milk samples are presented in Table H-6. No radioactivity attributable to WBN Plant operations was identified. All I-131 values were below the established nominal LLD of 1.0 pCi/liter. The gamma isotopic analysis detected only naturally occurring radionuclides. Milk samples are analyzed quarterly for Sr-89 and Sr-90, but no positive results were identified.

Cs-137 was detected in some annual soil samples collected in 2019. The maximum concentration of Cs-137 was 556 pCi/kg, identified at an indicator location. The concentrations were consistent with levels previously reported resulting from past weapons testing fallout. All other radionuclides reported were naturally occurring. The results of the analysis of soil samples are summarized in Table H-7.

A plot of the annual average Cs-137 concentrations in soil is presented in Figure 4. This figure only averages the Cs-137 concentrations of identified positive results. Samples that were not positive for Cs-137 are not included. Concentrations of Cs-137 in soil are steadily decreasing as a result of the cessation of weapons testing in the atmosphere, the 30-year half-life of Cs-137, and transport through the environment.

Figure 4 - Radioactivity in Soil



In 2019, cabbage, corn, green beans and tomatoes were sampled from both indicator and control locations. The only radionuclides measured in these food samples were naturally occurring. The results are reported in Table H-8.

LIQUID PATHWAY MONITORING

Potential exposures from the liquid pathway can occur from drinking water, ingestion of fish, or from direct radiation exposure from radioactive materials deposited in shoreline sediment. The aquatic monitoring program includes the collection of samples of river (surface) water, ground water, drinking water, fish, and shoreline sediment. Indicator samples were collected downstream of the plant and control samples collected within the reservoir upstream of the plant or in the next upstream reservoir (Watts Bar Lake).

Sample Collection and Analysis

Samples of surface water are collected from the Tennessee River using automatic sampling systems from two downstream stations and one upstream station. A timer turns on the system at least once every two hours. The line is flushed and a sample is collected into a composite container. A one-gallon sample is removed from the container monthly and the remaining water is discarded. The monthly composite samples are analyzed by gamma spectroscopy and tritium.

Samples are also collected by an automatic sampling system at the first two downstream drinking water intakes. These samples are collected in the same manner as the surface water samples. These monthly samples are analyzed by gamma spectroscopy, gross beta analysis and tritium analysis. The samples collected by the automatic sampling device are taken directly from the river at the intake structure. Since these samples are untreated water collected at plant intake, the upstream surface water sample is used as a control sample for drinking water.

Ground water is sampled from one onsite well down gradient from the plant, one onsite well up gradient from the plant, and four additional onsite ground water monitoring wells located on-site to monitor for potential leaks in underground lines. The onsite wells are sampled with a continuous sampling system. A composite sample is collected from the onsite wells every month and analyzed by gamma spectroscopy, gross beta analysis and tritium analysis.

Samples of commercial and game fish species are collected semiannually from each of two reservoirs: the reservoir on which the plant is located (Chickamauga Reservoir) and the upstream reservoir (Watts Bar Reservoir). The samples are collected using a combination of netting techniques and electrofishing. The ODCM specifies analysis of the edible portion of the fish. To comply with this requirement, filleted portions are taken from several fish of each species. The samples are analyzed by gamma spectroscopy.

Samples of shoreline sediment are collected from recreation areas near the plant. The samples are dried, ground, and analyzed by gamma spectroscopy.

Results

The gamma isotopic analysis of all surface water samples identified only naturally occurring radionuclides. Low levels of tritium were detected in some surface water samples. The highest average tritium concentration was 453 pCi/liter at an indicator location. This tritium concentration represents a small fraction of the Environmental Protection Agency (EPA) drinking water limit of 20,000 pCi/liter. A summary table of the results for surface water samples is shown in Table H-9.

No fission or activation products were identified by the gamma spectroscopy analysis of drinking water samples from the two downstream monitoring locations. Gross beta was not identified in the control locations, but one sample at an indicator station identified 5.04 pCi/liter gross beta. Water samples occasionally are positive for gross beta at those levels, attributable to natural background radiation. Low levels of tritium were detected in some of the samples collected from the two downstream public water sampling locations. The highest tritium concentration was 547 pCi/liter. The tritium levels were significantly below the EPA drinking water limit of 20,000 pCi/liter. The results are shown in Table H-10.

The gamma spectroscopy analysis of ground water samples, from either monitoring or drinking water wells, identified only naturally occurring radionuclides. Gross beta concentrations in samples from the onsite indicator locations averaged 3.47 pCi/liter. This level of gross beta result is not uncommon, and can be attributed to natural background. No samples from control locations identified any positive results for gross beta activity. Tritium was detected in samples from the onsite monitoring wells located near plant discharge lines. The tritium in onsite ground water was the result of previously identified leaks from plant systems. Repairs have been made to resolve the leaks, but the plume of contaminated ground water continues to move slowly across the site toward the river. The highest tritium concentration in samples from these monitoring locations was 617 pCi/liter. There was no tritium detected in the onsite up gradient well. The results are presented in Table H-11.

Beginning in 2019, well drinking water sampling and monitoring was added to the Watts Bar ODCM. Per the ODCM, a sample is collected monthly and analyzed for tritium from indicator location ID 3166, Hornsby Farm. The results are presented in Table H-12.

In 2019, game fish (largemouth bass) and commercial fish (channel catfish) were sampled and analyzed from both control and indicator locations. No fission or activation products were identified in any of the samples. The results are summarized in Table H-13.

In past years, Cs-137 activities consistent with the concentrations present in the environment as the result of past nuclear weapons testing or other nuclear operations in the area was measured in shoreline sediment samples or on-site pond sediment samples. In 2019, no plant related nuclides were identified in shoreline sediment samples. One sample from pond sediment was positive for Cs-137, at a level of 149 pCi/kg. The results are summarized in Table H-14 and Table H-15. This level is consistent with the expected range of values that can be observed from past weapons testing fallout.

ASSESSMENT AND EVALUATION

Results

As stated earlier in this report, the estimated increase in radiation dose equivalent to the general public resulting from the operation of WBN is insignificant when compared to the dose from natural background radiation. The results from each environmental sample are compared with the concentrations from the corresponding control stations and appropriate preoperational and background data to determine influences from the plant. During this report period, Cs-137 was detected in soil collected for the WBN program. The Cs-137 concentrations were consistent with levels measured during the preoperational monitoring program. The levels of tritium measured in water samples from the Tennessee River represented concentrations that were a small fraction of the EPA drinking water limit.

The levels of tritium detected in the onsite ground water monitoring wells indicate a decreasing trend from past samples and are not reflective of any increase in risk of exposure to the public. These tritium levels were limited to the owner-controlled area and do not represent a direct exposure pathway for the general public.

Conclusions

The 2019 radiological environmental monitoring program results demonstrate that exposure to members of the general public, which may have been attributable to WBN, is a small fraction of regulatory limits and essentially indistinguishable from the natural background radiation. The radioactivity reported herein is primarily the result of fallout or natural background. Any activity, which may be present in the environment as a result of plant operations, does not represent a significant contribution to the exposure of members of the public. The results confirm that radioactive effluents from the plant are controlled, maintaining releases as low as reasonably achievable (ALARA) and to a small fraction of the limits for doses to members of the public.

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APPENDIX A RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM AND SAMPLING LOCATIONS

Table A-1 - Watts Bar Nuclear Power Plant Radiological Environmental Monitoring Program

Exposure Pathway and/or Sample	Number of Samples and Locations[a]	Sampling and Collection Frequency	Type and Frequency of Analysis
1. DIRECT			
a. Dosimeters	2 or more dosimeters placed at or near the site boundary in each of the 16 sectors. 2 or more dosimeters placed at stations located approximately 5 miles from the plant in each of the 16 sectors. 2 or more dosimeters in at least 8 additional locations of special interest, including at least 2 control stations.	Quarterly (once per 92 days)	Gamma dose quarterly (at least once per 92 days)
2. AIRBORNE			
a. Particulates	4 samples from locations (in different sectors) at or near the site boundary (LM-1, 2, 3 and 4) 4 samples from communities approximately 6-10 miles from plant (PM-2, 3, 4 and 5) 2 samples from control locations > 10 miles from the plant (RM-2 and 3)	Continuous sampler operation with sample collection weekly (more frequently if required by dust loading)	Analyze for gross beta radioactivity ≥ 24 hours following filter change. Perform gamma isotopic analysis on each sample if gross beta > 10 times yearly mean of control sample. Composite at least once per 31 days (by location) for gamma spectroscopy.
b. Radioiodine	Samples from same locations as air particulates	Continuous sample operation with filter collection weekly.	I-131 at least once per 7 days. Analysis is performed by gamma spectroscopy.

Table A-1 - Watts Bar Nuclear Power Plant Radiological Environmental Monitoring Program (Continued)

Exposure Pathway and/or Sample	Number of Samples and Locations	Sampling and Collection Frequency	Type and Frequency of Analysis
c. Atmospheric Moisture	4 samples from locations (in different sectors) at or near the site boundary (LM-1, 2, 3, and 4) 2 samples from communities approximately 4-10 miles distance from the plant (PM-2, 5). 2 samples from control location greater than 10 miles from the plant (RM-2 and RM-3).	Continuous sampler operation with sample collection biweekly.	Analyze each sample for tritium.
d. Soil	Samples from same location as air particulates	Annually	Gamma spectroscopy, Sr-89, Sr-90 annually
3. WATERBORNE			
a. Surface Water	2 samples downstream from plant discharge (TRM 517.9 and TRM 523.1). 1 sample at a control location upstream from the plant discharge (TRM 529.3).	Collected by automatic sequential-type sampler[b] with composite samples collected over a period of approximately 31 days.	Gross beta, gamma spectroscopy, and tritium analysis of each sample.
b. Ground water	Five sampling locations from ground water monitoring wells adjacent to the plant (Wells No. 7, A, B, C, and F). 1 sample from ground water source up gradient (Well No. 5).	Collected by automatic sequential-type sampler[c] with composite samples collected over a period of approximately 31 days.	Gross beta, gamma spectroscopy, and tritium analysis of each sample.
	1 sampling location for the nearest (within 5 mile radius) offsite users of groundwater as the source of drinking water	At least once per 31 days	Tritium analysis of each sample

Table A-1 - Watts Bar Nuclear Power Plant Radiological Environmental Monitoring Program (Continued)

Exposure Pathway and/or Sample	Number of Samples and Locations	Sampling and Collection Frequency	Type and Frequency of Analysis
c. Drinking Water	1 sample at the first two potable surface water supplies, downstream from the plant (TRM 503.8 and TRM 473.0). 1 sample at a control location (TRM 529.3)[c]	Collected by automatic sequential-type sampler[c] with composite sample collected monthly.	Gross beta, gamma scan, and tritium analysis of each sample.
d. Shoreline Sediment	1 sample downstream from plant discharge (TRM 513.0) 1 sample from a control location upstream from plant discharge (TRM 530.2)	Semi-Annually (at least once per 184 days)	Gamma spectroscopy of each sample
e. Pond Sediment	1 sample from at least three locations in the Yard Holding Pond	Annually	Gamma spectroscopy of each sample
4. INGESTION			
a. Milk	1 sample from milk producing animals in each of 1-3 areas indicated by the cow census where doses are calculated to be highest. 1 or more samples from control locations	Every 2 weeks	I-131 and gamma spectroscopy on each sample. Sr-89 and Sr-90 quarterly.
b. Fish	One sample of commercially important species and one sample of recreationally important species. One sample of each species from downstream of Watts Bar Nuclear Plant, Chickamauga and Watts Bar Reservoirs. One control sample of the same species in areas not influenced by plant discharge.	Semi-Annually (at least once per 184 days)	Gamma spectroscopy on edible portions

Table A-1 - Watts Bar Nuclear Power Plant Radiological Environmental Monitoring Program (Continued)

Exposure Pathway and/or Sample	Number of Samples and Locations	Sampling and Collection Frequency	Type and Frequency of Analysis
c. Food Products	1 sample each of principal food products grown at private gardens and/or farms in the vicinity of the plant. A control sample from similar food products grown 15 to 30 km distant in the least prevalent wind direction.	At least once per 365 days at the time of harvest. The types of foods will vary. Following is a list of typical foods which may be available: • Cabbage and/or lettuce • Corn • Green Beans • Potatoes • Tomatoes	Gamma scan on edible portions
d. Vegetation[d] (Pasturage and grass)	Samples from farms producing milk but not providing a milk sample	Monthly (at least once per 31 days)	I-131 analysis and gamma spectroscopy of each sample

[a] Sample locations are shown on Figure A-1 through Figure A-3.
[b] Samples shall be collected by collecting an aliquot at intervals not exceeding 2 hours
[c] The surface water sample collected at TRM 529.3 is considered a control for the raw drinking water sample.
[d] Vegetation sampling is applicable only for farms that meet the criteria for milk sampling and when milk sampling cannot be performed

Table A-2 - Watts Bar Nuclear Power Plant REMP Sampling Locations

Map Location Number[a]	Station	Sector	Distance (miles)	Indicator (I) or Control (C)	Samples Collected[b]
2	PM-2	NW	7.0	I	AP, CF, S, AM
3	PM-3	NNE	10.4	I	AP, CF, S
4	PM-4	NE/ENE[c]	7.6	I	AP, CF, S
5	PM-5	S	8.0	I	AP, CF, S, AM
6	RM-2	SW	15.0	C	AP, CF, S, AM
7	RM-3	NNW	15.0	C	AP, CF, S, AM
8	LM-1	SSW	0.5	I	AP, CF, S, AM
9	LM-2	NNE	0.4	I	AP, CF, S, AM
10	LM-3	NNE	1.9	I	AP, CF, S, AM
11	LM-4	SE	0.9	I	AP, CF, S, AM
18	Well #7	S	0.6	I	W
20	Farm N	ESE	4.1	I	M
23	Well #5	N	0.5	C	W
25	TRM 517.9	--	9.9[d]	I	SW
26	TRM 523.1	--	4.7[d]	I	SW
27	TRM 529.3	--	1.5[d]	C	SW, PW[e]
31	TRM 473.0 (C. F. Industries)	--	54.8[d]	I	PW
32	TRM 513.0	--	14.8[d]	I	SS
33	TRM 530.2	--	2.4[d]	C	SS
35	TRM 503.8 (Dayton)	--	24.0[d]	I	PW
37	TRM 522.8-527.8 (downstream of WBN)	--	--	I	F
38	TRM 471-530 (Chickamauga Lake)	--	--	I	F
39	TRM 530-602 (Watts Bar Reservoir)	--	--	C	F
81	Yard Pond	SSE/S/SSW	Onsite	I	PS
82	Well A	SSE	0.6	I	W
83	Well B	SSE	0.5	I	W
84	Well C	ESE	0.3	I	W
85	Well F	SE	0.3	I	W
86	Farm HH	SSW	1.4	I	W
88	Farm SV	ENE	23.4	C	M

[a] See Figure A-1 through Figure A-3

[b] Sample Codes:

AM =	Atmospheric moisture	PW =	Public water	SS =	Shoreline sediment
AP =	Air particulate filter	PS =	Pond sediment	SW =	Surface water
F =	Fish	S =	Soil	W =	Well water
CF =	Charcoal Filter	M =	Milk	V =	Vegetation (not currently required)

[c] Station located on the boundary between these two sectors.

[d] Distance from the plant discharge at Tennessee River Mile (TRM) 527.8

[e] The surface water sample is also used as a control for public water.

Table A-3 - Watts Bar Environmental Dosimeter Locations

Map Location Number[a]	Station	Sector	Distance (miles)	Onsite or Offsite[b]
2	NW-3	NW	7.0	Off
3	NNE-3	NNE	10.4	Off
4	ENE-3	NE/ENE	7.6	Off
5	S-3	S	7.8	Off
6	SW-3	SW	15.0	Off
7	NNW-4	NNW	15.0	Off
10	NNE-1A	NNE	1.9	On
11	SE-1A	SE	0.9	On
12	SSW-2	SSW	1.3	On
14	W-2	W	4.8	Off
40	N-1	N	1.2	On
41	N-2	N	4.7	Off
42	NNE-1	NNE	1.2	On
43	NNE-2	NNE	4.1	Off
44	NE-1	NE	0.9	On
45	NE-2	NE	2.9	Off
46	NE-3	NE	6.1	Off
47	ENE-1	ENE	0.7	On
48	ENE-2	ENE	5.8	Off
49	E-1	E	1.3	On
50	E-2	E	5.0	Off
51	ESE-1	ESE	1.2	On
52	ESE-2	ESE	4.4	Off
54	SE-2	SE	5.3	Off
55	SSE-1A	SSE	0.6	On
56	SSE-2	SSE	5.8	Off
57	S-1	S	0.7	On
58	S-2	S	4.8	Off
59	SSW-1	SSW	0.8	On
60	SSW-3	SSW	5.0	Off
62	SW-1	SW	0.8	On
63	SW-2	SW	5.3	Off
64	WSW-1	WSW	0.9	On
65	WSW-2	WSW	3.9	Off
66	W-1	W	0.9	On
67	WNW-1	WNW	0.9	On
68	WNW-2	WNW	4.9	Off
69	NW-1	NW	1.1	On
70	NW-2	NW	4.7	Off
71	NNW-1	NNW	1.0	On

Table A-3 - Watts Bar Environmental Dosimeter Locations (Continued)

Map Location Number	Station	Sector	Distance (miles)	Onsite or Offsite
72	NNW-2	NNW	4.5	Off
73	NNW-3	NNW	7.0	Off
74	ENE-2A	ENE	3.5	Off
75	SE-2A	SE	3.1	Off
76	S-2A	S	2.0	Off
77	W-2A	W	3.2	Off
78	NW-2A	NW	3.0	Off
79	SSE-1	SE	0.5	On

[a] See Figure A-1 through Figure A-3.

[b] Dosimeters designated “onsite” are located 2 miles or less from the plant; “offsite” are located more than 2 miles from the plant

Figure A-1- REMP Sampling Locations Within 1 Mile of Plant

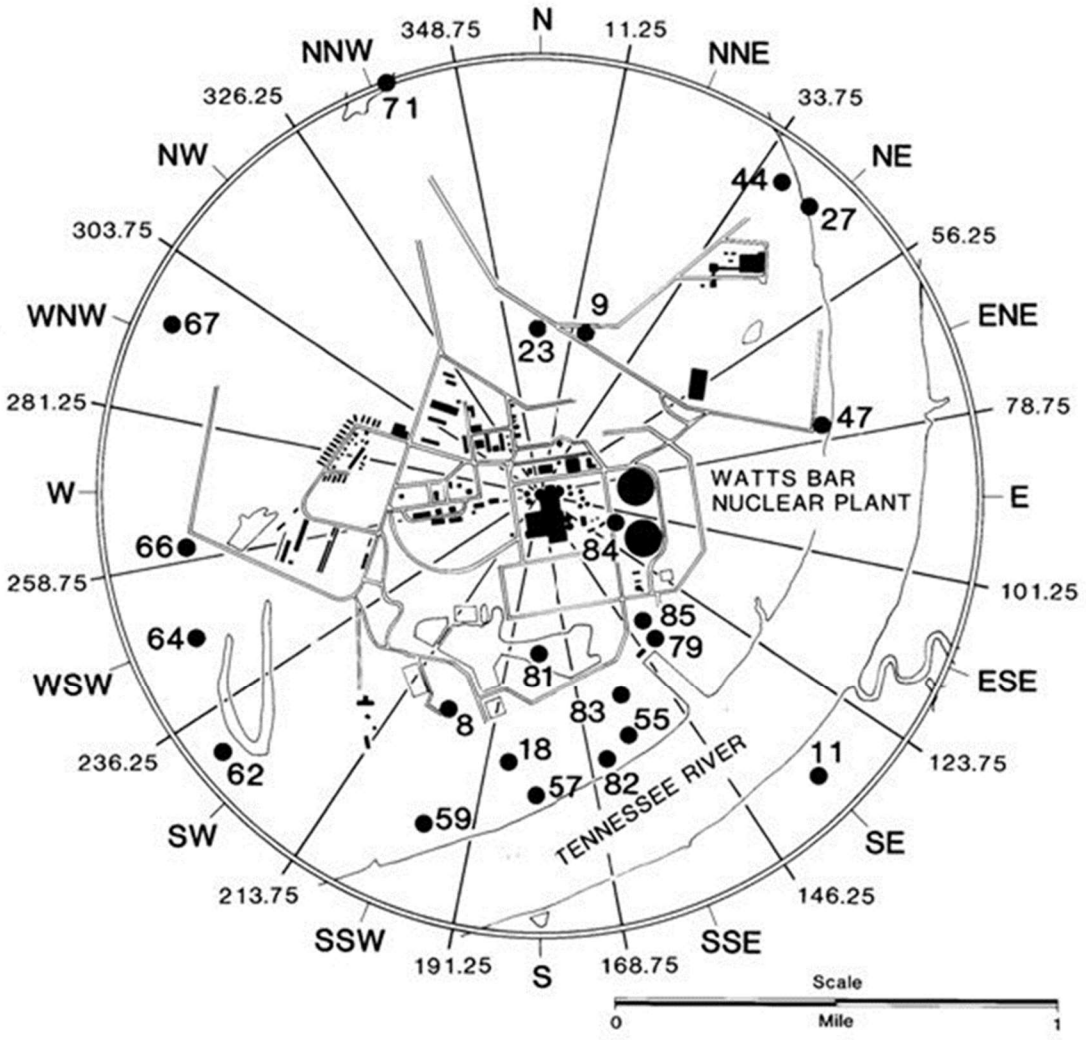


Figure A-2 - REMP Sampling Locations from 1 to 5 Miles from Plant

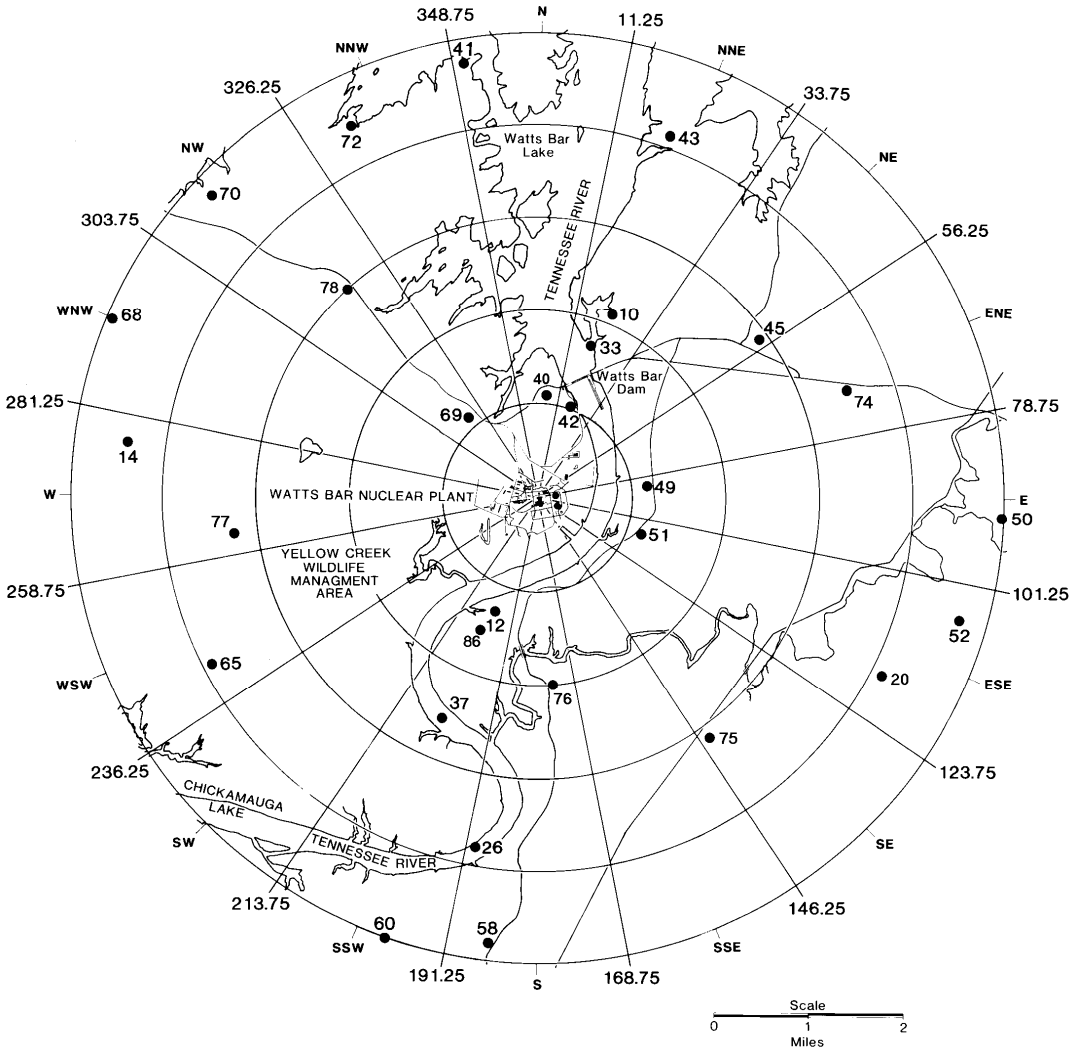
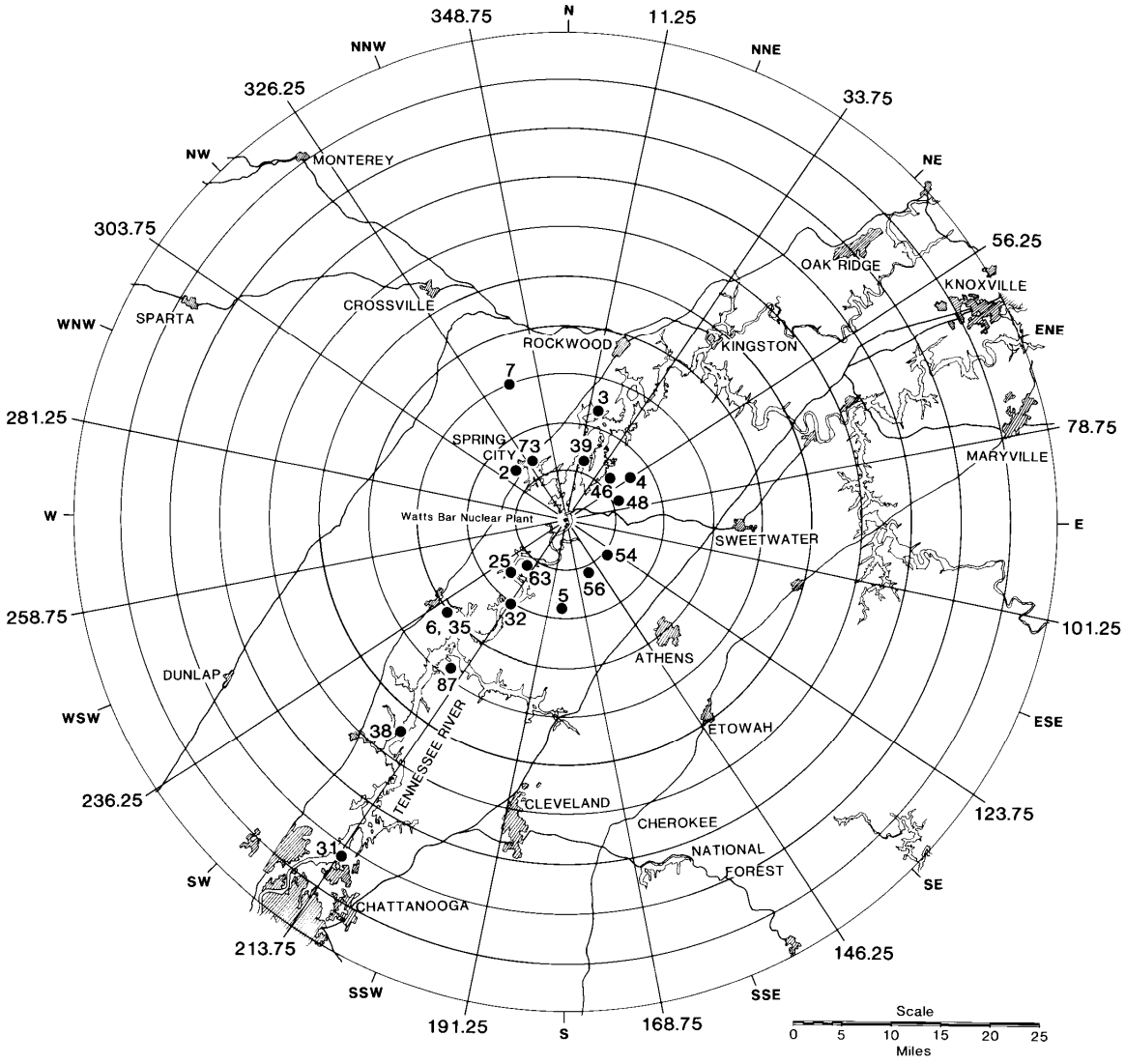


Figure A-3 - REMP Sampling Locations Greater Than 5 Miles from Plant



APPENDIX B PROGRAM MODIFICATIONS

Radiological Environmental Monitoring Program Modifications

In 2019, well drinking water sampling and monitoring was added to the Watts Bar Offsite Dose Calculation Manual (ODCM), Revision 5. Per the ODCM, a sample is collected monthly and analyzed for tritium from location ID 3166, Hornsby Farm.

The analysis of this pathway is included in the discussion of the ground water results.

APPENDIX C PROGRAM DEVIATIONS

Media	Location	Date	CR	Issue
Direct Radiation	WBS-1 (25A and B)	4/18/19 Q1	1509650	These OSLDs were missing in the field and could not be found.
Air Filter Charcoal Filter	RM-2 (3298)	1/1/19 1/8/19 1/15/19	1495778	Loss of power to sampling station. CR initiated in 2018.
Air Filter Charcoal Filter	LM-3 (3203)	1/8/19	1524393	Loss of power to sampling station.
Air Filter Charcoal Filter	LM-3 (3203)	7/23/19	1534948	Vandalism of the air sample station, which is located near a public recreation area. The air sample filter head assembly had been removed from the air sampler and could not be found. A new filter head assembly was placed on the air sampler and sampling was resumed on 7/23/19.
Direct Radiation	WBNNW-3 (19A and 19B) WBNE-3 (37A and 37B)	7/25/19 Q2	1535727	These OSLDs are located in publicly accessible areas and it is suspected that they were vandalized or stolen.
Well Water	MW-C, MW-B, Well #5 ID 3264, 3265, 3125	8/6/19	1542172	Samples were lost in transit. The samples were shipped to the vendor laboratory for analysis but were not received by the vendor laboratory.
Atmospheric Moisture	LM-2 ID 3102	8/29/19	1544965	A sample was missed due to a lost shipment of silica gel canisters.
Direct Radiation	WBN NNE-1A (28 A and B)	Q3 10/10/19	1556043	These OSLDs are located in a publicly accessible area and it is suspected that they were vandalized or stolen.
Atmospheric Moisture	RM-2	11/18/19	1570172	Insufficient quantity of moisture collected to perform tritium analysis. Atmospheric moisture samples are collected by flow of air through canisters containing silica gel, and the quantity of moisture collected varies depending on ambient humidity. In this case, insufficient moisture was absorbed by the silica gel during the collection period.

APPENDIX D ANALYTICAL PROCEDURES

Analytical Procedures

Analyses of environmental samples are performed by GEL Laboratories, LLC in Charleston, SC. Analysis of environmental dosimeters are performed by Landauer, Inc. in Glenwood, IL. Analysis procedures are based on accepted methods and summarized below.

The gross beta measurements are made with an automatic low background counting system. Normal counting times are 50 minutes. Water samples are prepared by evaporating 400 milliliter (mL) of samples to near dryness, transferring to a stainless steel planchet, and completing the evaporation process. Air particulate filters are counted directly in a shallow planchet.

Gamma analyses are performed in various counting geometries depending on the sample type and volume. All gamma counts are obtained with germanium type detectors interfaced with a high resolution gamma spectroscopy system. All samples requiring gamma analysis are analyzed in this manner.

The necessary efficiency values, weight-efficiency curves, and geometry tables are established and maintained on each detector and counting system. A series of daily and periodic quality control checks are performed to monitor counting instrumentation. System logbooks and control charts are used to document the results of the quality control checks.

The specific analysis of I-131 in milk is performed by first isolating and purifying the iodine by radiochemical separation and then counting the final precipitate on a beta-gamma coincidence counting system. The normal count time is 480 minutes. Then the I-131 is counted by gamma spectroscopy utilizing high resolution Ge detectors.

After a radiochemical separation, milk samples analyzed for Sr-89 and Sr-90 are counted on a low background beta counting system. The sample is counted a second time after a minimum ingrowth period of six days. From the two counts, the Sr-89 and Sr-90 concentrations can be determined.

Water samples are analyzed for tritium content by first distilling a portion of the sample and then counting by liquid scintillation. A commercially available scintillation cocktail is used.

The Landauer InLight Environmental Dosimetry System is used for measuring direct radiation in the REMP. Landauer has performed type testing of this system in accordance with ANSI N13.37-2014 standards.

APPENDIX E LOWER LIMITS OF DETECTION

Lower Limits of Detection

Many factors influence the Lower Limit of Detection (LLD) for a specific analysis method, including sample size, count time, counting efficiency, chemical processes, radioactive decay factors, and interfering isotopes encountered in the sample. Nominal LLD values for the environmental monitoring program are calculated based on system parameter values for each of the components as identified above, in accordance with the methodology prescribed in the ODCM. The current nominal LLD values achieved by the radioanalytical lab are listed in Table E-2 and Table E-3. For comparison, the maximum values for the lower limits of detection specified in the ODCM are given in Table E-4.

Table E-1 - Comparison of Program Lower Limits of Detection with the Regulatory Limits for Maximum Annual Average Effluent Concentration Released to Unrestricted Areas and Reporting Levels

	Concentrations in Water (pCi/Liter)			Concentrations in Air (pCi/m^3)		
Analysis	10 CFR 20 Effluent Concentration Limit[a]	Reporting Level[b] [c]	Lower Limit of Detection[d]	10 CFR 20 Effluent Concentration Limit	Reporting Level	Lower Limit of Detection
H-3	1,000,000	20,000	270	100,000	--	--
Cr-51	500,000	--	45	30,000	--	0.02
Mn-54	30,000	1000	5	1,000	--	0.005
Fe-59	10,000	400	10	500	--	0.005
Co-58	20,000	1000	5	1,000	--	0.005
Co-60	3,000	300	5	50	--	0.005
Zn-65	5,000	300	10	400	--	0.005
Sr-89	8,000	--	--	1,000	--	--
Sr-90	500	--	--	6	--	--
Nb-95	30,000	400	5	2,000	--	0.0005
Zr-95	20,000	400	10	400	--	0.005
Ru-103	30,000	--	5	900	--	0.005
Ru-106	3,000	--	40	20	--	0.02
I-131	1,000	2	0.4	200	0.9	0.03
Cs-134	900	30	5	200	10	0.005
Cs-137	1,000	50	5	200	20	0.005
Ce-144	3,000	--	30	40	--	0.01
Ba-140	8,000	200	25	2,000	--	0.015
La-140	9,000	200	10	2,000	--	0.01

[a] Source: Table 2 of Appendix B to 10 CFR 20.1001-20.2401

[b] For those reporting levels and lower limits of detection that are blank, no value is given in the reference

[c] Source: WBN Offsite Dose Calculation Manual, Table 2.3-2

[d] Source: Table E-2 and Table E-3 of this report

Table E-2- Nominal LLD Values - Radiochemical

Analysis	Airborne Particulate or Gases (pCi/m^3)	Water (pCi/L)	Milk (pCi/L)	Wet Vegetation (pCi/kg, wet)	Sediment and Soil (pCi/kg, dry)
Gross beta	0.002	1.9	--	--	--
H-3	3.0	270	--	--	--
I-131	--	0.4	0.4	6.0	--
Sr-89	--	--	3.5	--	1.6
Sr-90	--	--	2.0	--	0.4

Table E-3 - Nominal LLD Values – Gamma Analysis

Analysis	Airborne Particulate (pCi/m^3)	Charcoal Filter (pCi/m^3)	Water and Milk (pCi/L)	Wet Vegetation (pCi/kg, wet)	Sediment and Soil (pCi/kg, dry)	Fish (pCi/kg, wet)	Food Products (pCi/kg, wet)
Ce-141	0.005	0.02	10	35	0.10	0.07	20
Ce-144	0.01	0.07	30	115	0.20	0.15	60
Cr-51	0.02	0.15	45	200	0.35	0.30	95
I-131	0.005	0.03	10	60	0.25	0.20	20
Ru-103	0.005	0.02	5	25	0.03	0.03	25
Ru-106	0.02	0.12	40	190	0.20	0.15	90
Cs-134	0.005	0.02	5	30	0.03	0.03	10
Cs-137	0.005	0.02	5	25	0.03	0.03	10
Zr-95	0.005	0.03	10	45	0.05	0.05	45
Nb-95	0.005	0.02	5	30	0.04	0.25	10
Co-58	0.005	0.02	5	20	0.03	0.03	10
Mn-54	0.005	0.02	5	20	0.03	0.03	10
Zn-65	0.005	0.03	10	45	0.05	0.05	45
Co-60	0.005	0.02	5	20	0.03	0.03	10
K-40	0.04	0.30	100	400	0.75	0.40	250
Ba-140	0.015	0.07	25	130	0.30	0.30	50
La-140	0.01	0.04	10	50	0.20	0.20	25
Fe-59	0.005	0.04	10	40	0.05	0.08	25
Be-7	0.02	0.15	45	200	0.25	0.25	90
Pb-212	0.005	0.03	15	40	0.10	0.04	40
Pb-214	0.005	0.07	20	80	0.15	0.10	80

Table E-3 - Nominal LLD Values – Gamma Analysis (continued)

Analysis	Airborne Particulate (pCi/m^3)	Charcoal Filter (pCi/m^3)	Water and Milk (pCi/L)	Wet Vegetation (pCi/kg, wet)	Sediment and Soil (pCi/kg, dry)	Fish (pCi/kg, wet)	Food Products (pCi/kg, wet)
Bi-214	0.005	0.05	20	55	0.15	0.10	40
Bi-212	0.02	0.20	50	250	0.45	0.25	130
Tl-208	0.002	0.02	10	30	0.06	0.03	30
Ra-224	--	--	--	--	0.75	--	--
Ra-226	--	--	--	--	0.15	--	--
Ac-228	0.01	0.07	20	70	0.25	0.10	50
Pa-234m	--	--	800	--	4.0	--	--

Table E-4 - Maximum Values for Lower Limits of Detection (LLD)

Analysis	Water (pCi/L)	Airborne Particulate or Gases (pCi/m^3)	Fish (pCi/kg, wet)	Milk (pCi/L)	Food Products (pCi/kg, wet)	Sediment (pCi/kg, dry)
Gross beta	4	0.01	--	--	--	--
H-3	2000[a]	--	--	--	--	--
Mn-54	15	--	130	--	--	--
Fe-59	30	--	260	--	--	--
Co-58, 60	15	--	130	--	--	--
Zn-65	30	--	260	--	--	--
Zr-95	30	--	--	--	--	--
Nb-95	15	--	--	--	--	--
I-131	1[b]	0.07	--	1	60	--
Cs-134	15	0.05	130	15	60	150
Cs-137	18	0.06	150	18	80	180
Ba-140	60	--	--	60	--	--
La-140	15	--	--	15	--	--

Notes

a. If no drinking water pathway exists, a value of 3000 pCi/L may be used
b. If no drinking water pathway exists, a value of 15 pCi/L may be used.

APPENDIX F QUALITY ASSURANCE / QUALITY CONTROL PROGRAM

Quality Assurance / Quality Control Program

A quality assurance program is employed by the offsite vendor laboratory to ensure that the environmental monitoring data are reliable. This program includes the use of written, approved procedures in performing the work, provisions for staff training and certification, internal self-assessments of program performance, audits by various external organizations, and a laboratory quality control program.

The quality control program employed by the radioanalytical laboratory is designed to ensure that the sampling and analysis process is working as intended. The program includes equipment checks and the analysis of quality control samples, along with routine field samples. Instrument quality control checks include background count rate and counts reproducibility. In addition to these two general checks, other quality control checks are performed on the variety of detectors used in the laboratory. The exact nature of these checks depends on the type of device and the method it uses to detect radiation or store the information obtained.

Quality control samples of a variety of types are used by the laboratory to verify the performance of different portions of the analytical process. These quality control samples include blanks, field duplicates, process duplicates, matrix spikes, laboratory control samples, and independent cross-checks.

Blanks are samples which contain no measurable radioactivity of the type being measured. Such samples are analyzed to determine whether there is any contamination or cross-contamination of equipment, reagents, processed samples, or interferences from isotopes other than the ones being measured.

Duplicate field samples are generated at random by the sample computer program which schedules the collection of the routine samples. For example, if the routine program calls for four milk samples every week, on a random basis each farm might provide an additional sample several times a year. These duplicate samples are analyzed along with other routine samples. They provide information about the variability of radioactive content in the various sample media. If enough sample is available for a particular analysis, the laboratory staff can split the sample taking two individual aliquots, known as process duplicates. Duplicate samples provide information about the variability of the entire sampling and analytical process.

Matrix spikes are field samples that have been spiked with known low levels of specific target isotopes. Recovery of the known amount allow the analyst to determine if any interferences are exhibited from the field sample's matrix.

Laboratory control samples are another type of quality control sample. A known amount of radioactivity is added to a sample medium and processed along with the other QC and field samples in the analytical batch. Laboratory control samples provide the assurance that all aspects of the process have been successfully completed within the criteria established by Standard Operating Procedure.

Another category of quality control samples are cross-checks. The laboratory procures single-blind performance evaluation samples from Eckert & Ziegler Analytics to verify the analysis of sample matrices processed at the laboratory. Samples are received on a quarterly basis. The laboratory's Third-Party Cross-Check Program provides environmental matrices encountered in a typical nuclear utility REMP. Once performance evaluation samples have been prepared in accordance with the instructions from the performance evaluator provider, samples are managed and analyzed in the same manner as

environmental samples. These samples have a known amount of radioactivity added and are presented to the lab staff labeled as cross-check samples. The laboratory does not know the amount of radioactivity added to the sample. Such samples test the best performance of the laboratory by determining if the laboratory can find the "right answer." These samples provide information about the accuracy of the measurement process. Further information is available about the variability of the process if multiple analyses are requested on the same sample. Like matrix spikes or laboratory control samples, these samples can also be spiked with low levels of activity to test detection limits. The analysis results for internal cross-check samples met program performance goals for 2019.

The quality control data are routinely collected, examined and reported to laboratory supervisory personnel. They are checked for trends, problem areas, or other indications that a portion of the analytical process needs correction or improvement. The result is a measurement process that provides reliable and verifiable data and is sensitive enough to measure the presence of radioactivity far below the levels which could be harmful to humans.

Per the GEL 2019 Annual Environmental Quality Assurance (QA) Report (GEL, 2019), forty-five (45) radioisotopes associated with seven (7) matrix types (air filter, cartridge, water, milk, soil, liquid and vegetation) were analyzed under GEL's Performance Evaluation program in participation with ERA, Department of Energy Mixed Analyte Performance Evaluate Program (MAPEP), and Eckert & Ziegler Analytics. Matrix types were representative of client analyses performed during 2019. Of the four hundred twenty-five (425) total results, 97.2% (413 of 425) were found to be acceptable within the PT providers three sigma or other statistical criteria. For the Eckert & Ziegler Analytics Environmental Cross Check Program, GEL was provided eighty-nine (89) individual environmental analyses. The accuracy of each result reported to Eckert & Ziegler Analytics, Inc. is measured by the ratio of GEL's result to the known value. All results fell within GEL's acceptance criteria (100% within acceptance).

The radioanalytical lab performance in 2019 meets the criteria described in Reg. Guide 4.15 and ANSI/HPS N13.37-2014.

APPENDIX G LAND USE CENSUS

Land Use Census

A land use census was conducted in accordance with the provisions of ODCM Control 1.3.2 to identify the location of the nearest milk animal, the nearest residence, and the nearest garden of greater than 500 square feet producing fresh leafy vegetables in each of 16 meteorological sectors within a distance of 5 miles (8 km) from the plant.

The land use census was conducted between April 1 and October 1 using appropriate techniques such as door-to-door survey, mail survey, telephone survey, aerial survey, or information from local agricultural authorities or other reliable sources.

There were no changes to the nearest resident in 2019. The locations of the nearest garden greater than 500 ft^2 were updated in four sectors. There is currently just one milk production location within 5 miles of Watts Bar. The updated locations did not result in any changes in the required sampling locations or sampling media; new locations are summarized below:

Table G-1 - 2019 Updated Nearest Garden

Sector	2018 Nearest Garden Distance (meters)	2019 Nearest Garden Distance (meters)
WSW	3080	3701
W	3138	5809
NW	2065	3057
WNW	2456	3138

Results of the 2019 Land Use Census did not identify the need for any changes to the sampling locations or sampling media as currently required by the WBN REMP.

Table G-1 - Watts Bar Land Use Census Results

Meteorological Sector	Nearest Resident (meters)	Nearest Garden (meters)	Nearest Milk Production (meters)
N	4474	6295	-
NNE	3750	5030	-
NE	3399	3661	-
ENE	3072	3072	-
E	4388	4656	-
ESE	4654	7297	6706
SE	1409	1409	-
SSE	1646	1711	-
S	1550	2349	-
SSW	1832	2286	-
SW	3789	-	-
WSW	2422	3701	-
W	2901	5809	-
WNW	1448	3138	-
NW	2065	3057	-
NNW	4376	4742	-

APPENDIX H DATA TABLES AND FIGURES

Table H-1 - Individual Dosimeter Stations at Watts Bar Nuclear Plant

Map Loc. No.	Station Number	Dir. (degrees)	Distance (miles)	Q1 2019	Q2 2019	Q3 2019	Q4 2019	Annual Exposure (mrem/yr)
				(mrem/qtr)				
2	NW-3	317	7.0	23.6	23.7	21.8	19.3	88.4
3	NNE-3	17	10.4	19.1	19.3	16.8	16.8	72.0
4	ENE-3	56	7.6	14.6	19.9	17.8	15.3	67.6
5	S-3	185	7.8	21.6	19.9	18.0	16.6	76.1
6	SW-3	225	15.0	15.4	17.2	14.8	19.0	66.3
7	NNW-4	337	15.0	14.6	18.3	18.3	16.8	67.9
10	NNE-1A	22	1.9	17.6	21.5	N/A	17.8	56.9
11	SE-1A	138	0.9	20.1	23.7	23.3	22.8	89.9
12	SSW-2	200	1.3	21.6	23.0	21.0	15.1	80.7
14	W-2	277	4.8	15.6	17.5	15.0	16.1	64.2
40	N-1	10	1.2	19.6	21.9	24.4	19.2	85.1
41	N-2	350	4.7	18.1	22.5	18.5	17.6	76.7
42	NNE-1	21	1.2	20.6	23.6	20.5	19.2	83.8
43	NNE-2	20	4.1	16.1	21.9	19.2	19.2	76.4
44	NE-1	39	0.9	23.1	23.0	21.5	20.2	87.7
45	NE-2	54	2.9	18.6	23.6	18.8	19.0	79.9
46	NE-3	47	6.1	16.6	N/A	19.5	14.3	50.4
47	ENE-1	74	0.7	19.6	19.1	15.5	14.6	68.9
48	ENE-2	69	5.8	16.9	21.0	21.5	17.0	76.3
49	E-1	85	1.3	18.6	20.3	21.3	16.8	76.9
50	E-2	92	5.0	21.1	21.9	21.3	19.8	84.1
51	ESE-1	109	1.2	16.1	18.6	19.3	16.3	70.3
52	ESE-2	106	4.4	22.1	26.9	21.5	18.0	88.5
54	SE-2	128	5.3	18.6	19.7	18.0	17.0	73.3
55	SSE-1A	161	0.6	18.1	19.1	16.8	16.8	70.8
56	SSE-2	156	5.8	23.1	20.8	19.0	18.8	81.7
57	S-1	182	0.7	N/A	18.6	18.8	17.8	55.2
58	S-2	185	4.8	18.1	19.7	16.0	15.3	69.1
59	SSW-1	199	0.8	24.1	23.0	23.3	20.3	90.7
60	SSW-3	199	5.0	18.6	20.8	17.5	16.8	73.7
62	SW-1	226	0.8	22.1	22.5	22.8	19.3	86.7
63	SW-2	220	5.3	23.1	24.7	25.9	21.3	95.0
64	WSW-1	255	0.9	18.1	21.4	18.8	16.3	74.5
65	WSW-2	247	3.9	21.6	23.0	20.0	20.2	84.8
66	W-1	270	0.9	17.6	20.3	22.3	17.8	77.9
67	WNW-1	294	0.9	27.1	31.9	24.1	26.7	109.7
68	WNW-2	292	4.9	23.1	28.0	22.9	20.2	94.2
69	NW-1	320	1.1	21.1	22.5	19.3	17.8	80.7
70	NW-2	313	4.7	18.6	26.9	21.8	18.3	85.6
71	NNW-1	340	1.0	15.1	20.3	18.8	15.8	69.9
72	NNW-2	333	4.5	22.1	23.6	16.8	17.8	80.3
73	NNW-3	329	7.0	17.9	N/A	16.8	14.3	49.0
74	ENE-2A	69	3.5	17.1	19.1	16.8	15.4	68.4
75	SE-2A	144	3.1	19.6	21.9	22.5	16.1	80.1
76	S-2A	177	2.0	20.6	23.0	22.5	19.2	85.2
77	W-2A	268	3.2	20.6	20.8	21.5	17.1	80.0
78	NW-2A	321	3.0	18.1	22.5	17.8	14.3	72.7
79	SSE-1	146	0.5	20.1	21.4	19.2	21.0	81.7

NOTES: Locations and Quarters marked “N/A” are not available, due to missing dosimeters. See Appendix C.

Table H-2 - Weekly Airborne Particulate Gross Beta

Sample Pathway (Measurement Unit)	Type and Number of Analysis Performed	Lower Limit of Detection (LLD)[a]	All Indicator Locations Mean (Count) Range	Location with Highest Annual Mean		All Control Locations Mean (Count) Range	Non-routine Reported Measurements
				Name, Distance and Direction	Mean (Range)		
Air Filter Inhalation (pCi/m³)	Gross Beta 525	0.01	0.037 (422/422) (0.009 – 0.078)	PM-4, 7.6 Mi. NE/ENE	0.037 (52/52) (0.020 – 0.077)	0.035 (103/103) (0.020 – 0.069)	0

NOTES

a. LLD is the a priori limit as prescribed by the ODCM.

Figure H-1 - Average Beta Activity in Air Filters

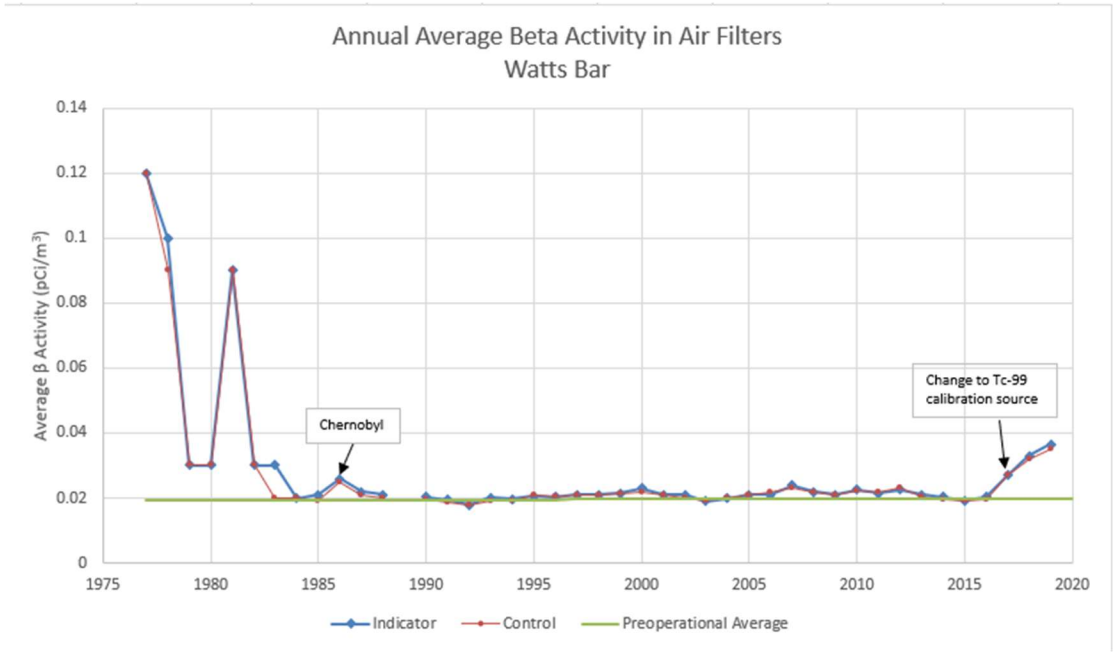


Table H-3 – Weekly Airborne Iodine-131 Radioactivity

Sample Pathway (Measurement Unit)	Type and Number of Analysis Performed	Lower Limit of Detection (LLD)	All Indicator Locations Mean (Count) Range	Location with Highest Annual Mean		All Control Locations Mean (Count) Range	Non-routine Reported Measurements
				Name, Distance and Direction	Mean (Range)		
Activated Charcoal Inhalation (pCi/m³)	I-131 525	0.07	< LLD [a] (0/422)	< LLD	< LLD	< LLD (0/103)	0

NOTES

a. The term "< LLD" as used means that results had no identified activity above the minimum detectable.

Table H-4 - Quarterly Airborne Composite Particulate Gamma Radioactivity

Sample Pathway (Measurement Unit)	Type and Number of Analysis Performed	Lower Limit of Detection (LLD)	All Indicator Locations Mean (Count) Range	Location with Highest Annual Mean		All Control Locations Mean (Count) Range	Non-routine Reported Measurements
				Name, Distance and Direction	Mean (Range)		
Air Filter Inhalation (pCi/m³)	Gamma Isotopic [a] 130	Various	< LLD (0/104)	< LLD	< LLD	< LLD (0/26)	0

NOTES

a. Natural occurring radionuclides were observed in quarterly composite air samples in 2019.

b. See Table E-1 through Table E-4 for the required and nominal LLDs for individual radionuclides via gamma isotopic analysis.

Table H-5 - Biweekly Atmospheric Moisture Radioactivity

Sample Pathway (Measurement Unit)	Type and Number of Analysis Performed	Lower Limit of Detection (LLD)	All Indicator Locations Mean (Count) Range	Location with Highest Annual Mean		All Control Locations Mean (Count) Range	Non-routine Reported Measurements
				Name, Distance and Direction	Mean (Range)		
Atmospheric Moisture Inhalation (pCi/m³)	Tritium 212	3.0	0.020 (9/161) 0.010 – 0.046	LM-1, 0.4 mi NNE	0.046 (1/27) 0.046 – 0.046	0.016 (2/51) 0.015 – 0.018	0

Table H-6 - Biweekly Milk Radioactivity

Sample Pathway (Measurement Unit)	Type and Number of Analysis Performed		Lower Limit of Detection (LLD)	All Indicator Locations Mean (Count) Range	Location with Highest Annual Mean		All Control Locations Mean (Count) Range	Non-routine Reported Measurements
					Name, Distance and Direction	Mean (Range)		
Milk Ingestion (pCi/L)	Gamma Isotopic [a]	54	Various	< LLD (0/27)	< LLD	< LLD	< LLD (0/27)	0
	Sr-89	8	3.5	< LLD (0/4)	< LLD	< LLD	< LLD (0/4)	0
	Sr-90	8	2	< LLD (0/4)	< LLD	< LLD	< LLD (0/4)	0
	I-131	54	1	< LLD (0/27)	< LLD	< LLD	< LLD (0/27)	0

NOTES

a. Natural occurring radionuclides were observed in milk samples in 2019.

Table H-7 - Annual Soil Radioactivity

Sample Pathway (Measurement Unit)	Type and Number of Analysis Performed		Lower Limit of Detection (LLD)	All Indicator Locations Mean (Count) Range	Location with Highest Annual Mean		All Control Locations Mean (Count) Range	Non-routine Reported Measurements
					Name, Distance and Direction	Mean (Range)		
Soil Direct Radiation (pCi/kg)	Gamma Isotopic [a]	10	Various	< LLD (0/8)	< LLD	< LLD	< LLD (0/2)	0
	Cs-137[b]	10	180	203 (5/8) 70 - 556	PM-2, 7.0 mi NW	556 (1/1) 556 – 556	285 (2/2) 236 – 333	0
	Sr-89	10	1.6	< LLD (0/8)	< LLD	< LLD	< LLD (0/2)	0
	Sr-90	10	0.4	< LLD (0/8)	< LLD	< LLD	< LLD (0/2)	0

NOTES

a. Natural occurring radionuclides were observed in soil samples in 2019.

b. Cs-137 is the only non-natural radionuclide positively identified as part of the gamma isotopic analysis

Table H-8 - Annual Local Crop Radioactivity

Sample Pathway (Measurement Unit)	Type and Number of Analysis Performed		Lower Limit of Detection (LLD)	All Indicator Locations Mean (Count) Range	Location with Highest Annual Mean		All Control Locations Mean (Count) Range	Non-routine Reported Measurements
					Name, Distance and Direction	Mean (Range)		
Cabbage Ingestion (pCi/g)	Gamma Isotopic [a]	2	Various	< LLD (0/1)	< LLD	< LLD	< LLD (0/1)	0
Corn Ingestion (pCi/g)	Gamma Isotopic	2	Various	< LLD (0/1)	< LLD	< LLD	< LLD (0/1)	0
Green Beans Ingestion (pCi/g)	Gamma Isotopic	2	Various	< LLD (0/1)	< LLD	< LLD	< LLD (0/1)	0
Tomatoes Ingestion (pCi/g)	Gamma Isotopic	2	Various	< LLD (0/1)	< LLD	< LLD	< LLD (0/1)	0

NOTES

a. Natural occurring radionuclides were observed in local crop samples in 2019.
b. See Table E-1 through Table E-4 for the required and nominal LLDs for individual radionuclides via gamma isotopic analysis.

Table H-9 - Monthly Surface Water Radioactivity

Sample Pathway (Measurement Unit)	Type and Number of Analysis Performed		Lower Limit of Detection (LLD)	All Indicator Locations Mean (Count) Range	Location with Highest Annual Mean		All Control Locations Mean (Count) Range	Non-routine Reported Measurements
					Name, Distance and Direction	Mean (Range)		
Surface Water Direct Exposure (pCi/L)	Gamma Isotopic [a]	41	Various	< LLD (0/28)	< LLD	< LLD	< LLD (0/13)	0
	Tritium	45	2000	399 (2/28) 345 - 453	TRM 517.9	453 (1/14) 453 - 453	448 (2/17) 348 – 547	0

NOTES

a. Natural occurring radionuclides were observed in surface water samples in 2019.

Table H-10 - Monthly Public Drinking Water Radioactivity

Sample Pathway (Measurement Unit)	Type and Number of Analysis Performed		Lower Limit of Detection (LLD)	All Indicator Locations Mean (Count) Range	Location with Highest Annual Mean		All Control Locations Mean (Count) Range	Non-routine Reported Measurements
					Name, Distance and Direction	Mean (Range)		
Drinking Water Ingestion (pCi/L)	Gross Beta	43	4.0	5.04 (1/29) 5.04 – 5.04	TRM 473.0, CF Industries	5.04 (1/16) 5.04 – 5.04	< LLD (0/14)	0
	Gamma Isotopic [a]	43	Various	< LLD (0/29)	< LLD	< LLD	< LLD (0/14)	0
	Tritium	48	2000	448 (2/34) 348 - 547	RM-2, 15.0 Mi, SW	448 (2/17) 348 - 547	< LLD (0/13)	0

NOTES

a. Natural occurring radionuclides were observed in public drinking water samples in 2019.

Table H-11 - Monthly Well (Ground) Water Radioactivity

Sample Pathway (Measurement Unit)	Type and Number of Analysis Performed		Lower Limit of Detection (LLD)	All Indicator Locations Mean (Count) Range	Location with Highest Annual Mean		All Control Locations Mean (Count) Range	Non-routine Reported Measurements
					Name, Distance and Direction	Mean (Range)		
Ground Water Ingestion (pCi/L)	Gross Beta	89	4.0	3.47 (4/77) 2.76 – 4.43	MW-F, 0.3 Mi., SE	3.70 (3/13) 3.03 – 4.43	< LLD (0/12)	0
	Gamma Isotopic [a]	89	Various	< LLD (0/77)	< LLD	< LLD	< LLD (0/12)	0
	Tritium	89	2000	434 (9/77) 325 - 617	MW-C, 0.3 Mi., SSE	499 (5/12) 464 - 617	< LLD (0/12)	0

NOTES

a. Natural occurring radionuclides were observed in ground water samples in 2019.

Table H-12 - Monthly Offsite Drinking Well Water Radioactivity

Sample Pathway (Measurement Unit)	Type and Number of Analysis Performed		Lower Limit of Detection (LLD)	All Indicator Locations Mean (Count) Range	Location with Highest Annual Mean		All Control Locations Mean (Count) Range	Non-routine Reported Measurements
					Name, Distance and Direction	Mean (Range)		
Ground Water Ingestion (pCi/L)	Gross Beta	14	4.0	< LLD (0/14)	< LLD	< LLD	< LLD (0/14)	0
	Gamma Isotopic [a]	14	Various	< LLD (0/14)	< LLD	< LLD	< LLD (0/14)	0
	Tritium	14	2000	< LLD (0/14)	< LLD	< LLD	< LLD (0/14)	0

NOTES

a. Natural occurring radionuclides were observed in ground water samples in 2019.

Table H-13 - Semi-Annual Fish Radioactivity

Sample Pathway (Measurement Unit)	Type and Number of Analysis Performed		Lower Limit of Detection (LLD)	All Indicator Locations Mean (Count) Range	Location with Highest Annual Mean		All Control Locations Mean (Count) Range	Non-routine Reported Measurements
					Name, Distance and Direction	Mean (Range)		
Game Fish – Large Mouth Bass Ingestion (pCi/kg)	Gamma Isotopic [a]	6	Various	< LLD (0/4)	< LLD	< LLD	< LLD (0/2)	0
Commercial Fish - Channel Catfish Ingestion (pCi/kg)	Gamma Isotopic	8	Various	< LLD (0/7)	< LLD	< LLD	< LLD (0/1)	0
Commercial Fish – Blue Catfish Ingestion (pCi/kg)	Gamma Isotopic	2	Various	< LLD (0/1)	< LLD	< LLD	< LLD (0/1)	0

NOTES

a. Natural occurring radionuclides were observed in fish samples in 2019.

Table H-14 - Semi-Annual Shoreline Sediment Radioactivity

Sample Pathway (Measurement Unit)	Type and Number of Analysis Performed	Lower Limit of Detection (LLD)	All Indicator Locations Mean (Count) Range	Location with Highest Annual Mean		All Control Locations Mean (Count) Range	Non-routine Reported Measurements
				Name, Distance and Direction	Mean (Range)		
Shoreline Sediment Direct Radiation (pCi/kg)	Gamma Isotopic [a] 4	Various	< LLD (0/2)	< LLD	< LLD	< LLD (0/2)	0

NOTES

a. Natural occurring radionuclides were observed in shoreline sediment samples in 2019.

Table H-15 – Annual Pond Sediment Radioactivity

Sample Pathway (Measurement Unit)	Type and Number of Analysis Performed	Lower Limit of Detection (LLD)	All Indicator Locations Mean (Count) Range	Location with Highest Annual Mean		All Control Locations Mean (Count) Range	Non-routine Reported Measurements
				Name, Distance and Direction	Mean (Range)		
Pond Sediment Direct Radiation (pCi/kg)	Gamma Isotopic [a] 5	Various	149 (1/5) 149 – 149	YP-3 Yard Pond	149 (1/1) 149 – 149	N/A	0

NOTES

a. Natural occurring radionuclides were observed in pond sediment samples in 2019.

APPENDIX I ERRATA TO PREVIOUS ANNUAL ENVIRONMENTAL OPERATING REPORTS

Errata to Previous AREORs

There are no identified errors in previous AREORs.