



Post Office Box 2000, Decatur, Alabama 35609-2000

May 16, 2022

10 CFR 50.4

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

Browns Ferry Nuclear Plant, Units 1, 2, and 3
Renewed Facility Operating License Nos. DPR-33, DPR-52, and DPR-68
NRC Docket Nos. 50-259, 50-260, and 50-296

Subject: **2021 Annual Radiological Environmental Operating Report**

In accordance with the Browns Ferry Nuclear Plant Technical Specification 5.6.2 and Offsite Dose Calculation Manual Administrative Control Section 5.1, the Tennessee Valley Authority is submitting the 2021 Annual Radiological Environmental Operating Report for Browns Ferry Nuclear Plant, Units 1, 2, and 3. Enclosed is the subject report for the period of January 1, 2021, through December 31, 2021.

There are no new regulatory commitments contained within this letter. If you have any questions, please contact C. L. Vaughn at (256) 729-2636.

Respectfully,

A handwritten signature in black ink, appearing to read 'M. Rasmussen', with a long horizontal flourish extending to the right.

M. Rasmussen
Site Vice President

Enclosure: 2021 Annual Radiological Environmental Operating Report

cc (w/ Enclosures):

NRC Regional Administrator - Region II
NRC Senior Resident Inspector - Browns Ferry Nuclear Plant
NRC Project Manager - Browns Ferry Nuclear Plant

ENCLOSURE

**Browns Ferry Nuclear Plant
Units 1, 2, and 3**

2021 Annual Radiological Environmental Operating Report

See Enclosed

2021 Annual Radiological Environmental Operating Report

Tennessee Valley Authority Browns Ferry Nuclear Plant

May 2022



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



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EXECUTIVE SUMMARY

This report describes the Radiological Environmental Monitoring Program (REMP) conducted by the Tennessee Valley Authority (TVA) for the Browns Ferry Nuclear Plant (BFN) during the 2021 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 BFN Offsite Dose Calculation Manual requirements (Tennessee Valley Authority, 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 Browns Ferry Nuclear Plant prior to operations (pre-operational data). This report contains an evaluation of the results from this monitoring program and resulting potential impact of BFN 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.

There was no detectable increase in the background direct radiation levels normally observed in the areas surrounding the plant, as measured by environmental dosimeters. In 2021, trace quantities of cesium-137 (Cs-137) were measured in most soil and two shoreline sediment samples, from both indicator and control locations. One indicator soil location identified a low-level of Sr-90. The concentrations were typical of the levels expected to be present in the environment from past nuclear weapons. The fallout from accidents at the Chernobyl plant in the Ukraine in 1986 and the Fukushima plant in Japan in 2011 were also potential contributors to the low levels of Cs-137 measured in environmental samples. There was no identified increase in Cs-137 levels attributed by Browns Ferry. Low levels of gross beta activity were detected in some drinking water samples, but this can be attributed to natural radioactivity. Tritium was not detected in any water samples taken in support of the REMP. Only naturally occurring radioactivity was identified in all fish and local crop samples, as well air particulate samples.

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

INTRODUCTION

This report describes and summarizes the results of radioactivity measurements of samples collected in the environment around BFN. 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 BFN 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 hazard of different types of radiation sources by evaluating the amount of radiation the U.S. population receives from each general type of radiation source. 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 (National Council on Radiation Protection and Measurements, 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 is typically several thousand times higher than that normally received from nuclear plants. This perspective illustrates that routine nuclear plant operations result in population radiation doses that are small fractions of 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 BFN 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
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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 BFN 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 detectable, being below the required detection level, with only naturally occurring radionuclides having measurable levels.

SITE AND PLANT DESCRIPTION

BFN is located on the north shore of Wheeler Reservoir at Tennessee River Mile 294 in Limestone County in north Alabama (see Figure 1). Wheeler Reservoir averages 1 to 1-1/2 miles in width in the vicinity of the plant. The BFN site contains approximately 840 acres. The dominant character of land use is small, scattered villages and homes in an agricultural area. Many relatively large farming operations occupy much of the land on the north side of the river immediately surrounding the plant. The principal crops grown in the area are corn and cotton.

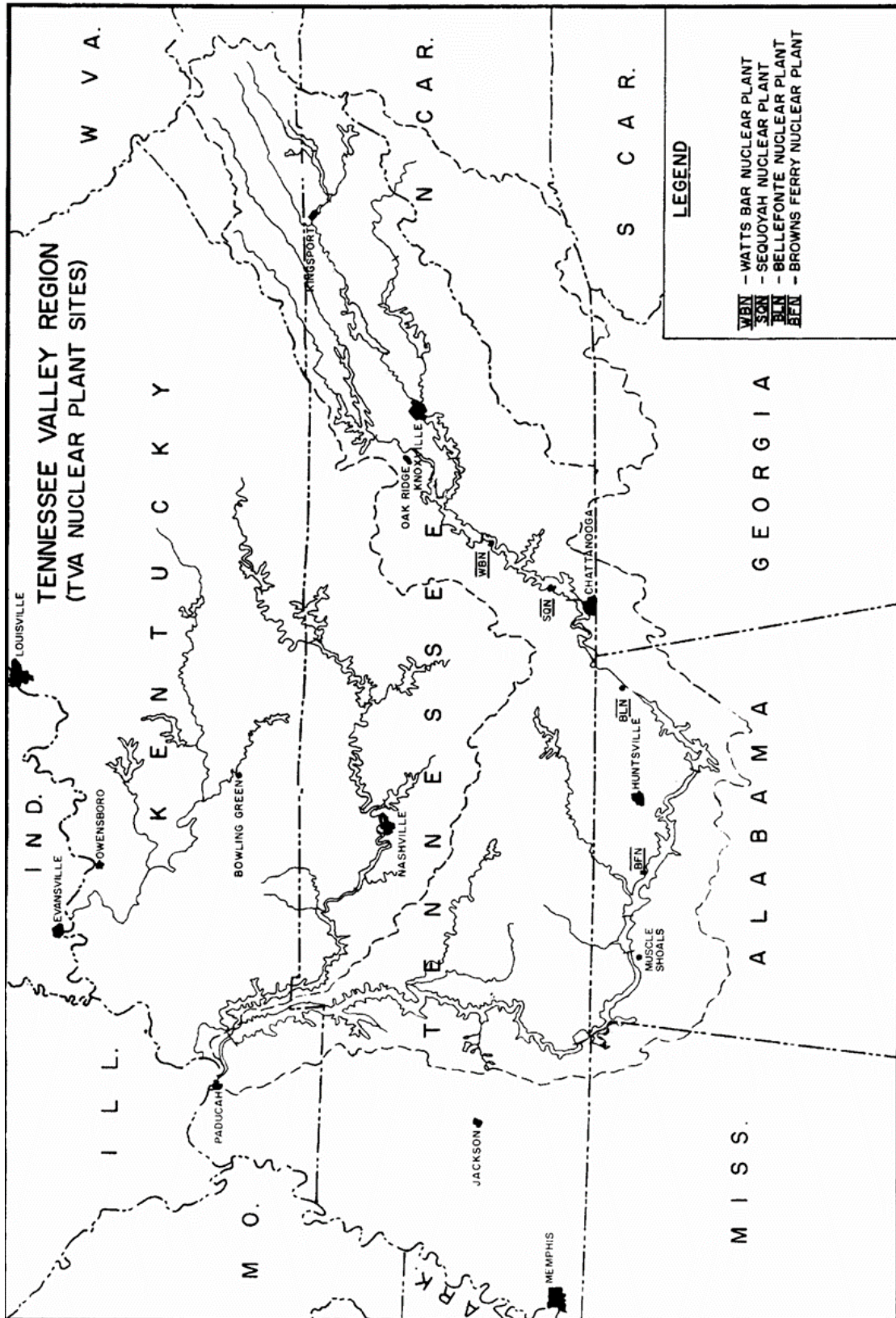
Approximately 1,397 people live within a 5-mile radius of the plant. The town of Athens has a population of about 29,500 and is approximately 10 miles northeast of BFN. Approximately 52,250 people live in the city of Decatur 10 miles southeast. The cities of Madison and Huntsville have a combined population of approximately 227,000 starting 20 miles east of the site.

Area recreation facilities are developed along the Tennessee River. The nearest facilities are public use areas located 2 to 3 miles from the site. The city of Decatur has a large municipal recreation area, Point Mallard Park, approximately 15 miles upstream of the site. The Tennessee River is also a popular sport fishing area.

BFN consists of three boiling water reactors. Unit 1 achieved criticality on August 17, 1973, and began commercial operation on August 1, 1974. Unit 2 began commercial operation on March 1, 1975. A fire in the cable trays on March 22, 1975, forced the shutdown of both reactors. Units 1 and 2 resumed operation and Unit 3 began testing in August 1976. Unit 3 began commercial operation on March 1, 1977.

All three units were shut down from March 1985 to May 1991. Unit 2 was restarted May 24, 1991 and Unit 3 restarted on November 19, 1995. Recovery work for Unit 1 was completed and the unit was restarted on May 22, 2007.

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 BFN are outlined in Appendix A.

There are two primary pathways by which radioactive materials 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 BFN monitoring program in 2021 are reported in Appendix B. Deviations to the sampling program during 2021 are included in Appendix C.

To determine the amount of radioactivity in the environment prior to the operation of BFN, a preoperational REMP was initiated in 1968 and conducted until the plant began operation in 1973. Sampling and analyses conducted during the preoperational phase has provided data that can be used 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 BFN operation.

The determination of environmental impact during the operating phase also examines changes in the background that may be attributable to sources other than BFN. 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 BFN operation.

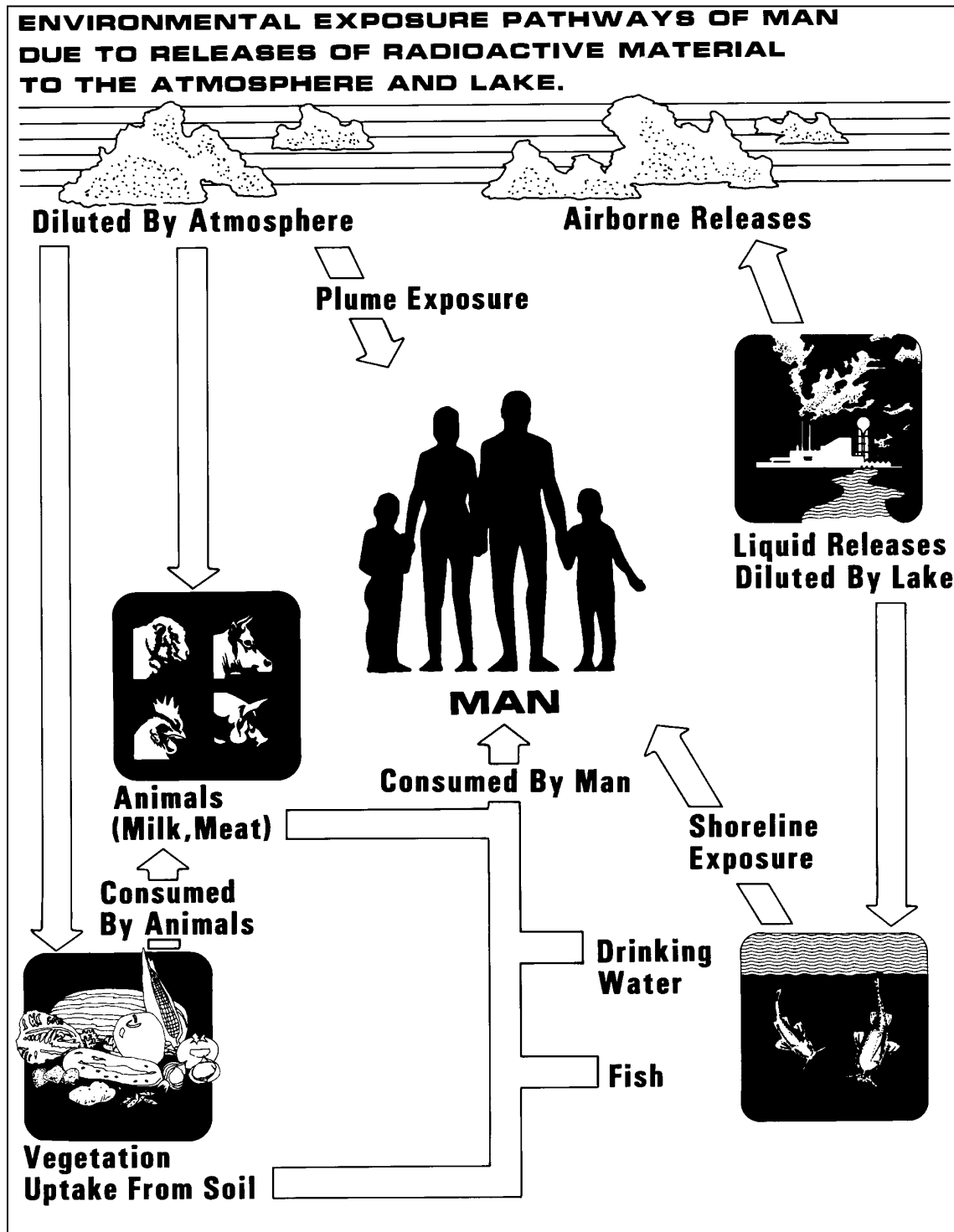
In 2021 the sample analyses were performed by the contracted laboratory, GEL Laboratories, LLC, based in Charleston, SC. Analyses were conducted in accordance with written and approved procedures and are based on industry established standard analytical methods. A summary of the analysis techniques and 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 administered 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. Any 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 approximately four to five miles from the plant.

Dosimeters are also placed at additional monitoring locations out to approximately 32 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. The environmental dosimetry program is conducted in accordance with the specifications outlined in American National Standards Institute (ANSI) and Health Physics Society (HPS) ANSI/HPS N13.37-2014 (Health Physics Society, 2014) for environmental applications of dosimeters.

Results

For reporting dose, all results for environmental dosimeter measurements are normalized to a standard quarter (91 days). In general, two direct radiation measurements are taken in each meteorological sector: one “inner ring” location within approximately 2 miles from the plant, and one “outer ring” location approximately 5 miles from the plant. In addition, control dosimeters are placed at locations further from the plant (approximately 10 – 30 miles).

Beginning in 2021, the BFN environmental dosimeters are evaluated in compliance with ANSI N13.37-2014. The process of this evaluation is summarized below:

1. The average field dosimeter result is determined for each location and normalized to a standard quarter (91 days)
2. The field result is adjusted by the transit and shield (storage) dose to determine the net dose at each location. This is performed at each location for each quarter, and the four quarters are summed to determine the annual net dose.

3. The quarterly and annual historical average net dose was determined for each monitoring location, based on data from 2017 – 2021.
4. The standard deviation of each historical net dose was calculated, to determine the 90th percentile standard deviation for both the quarterly and annual results.
5. The 2021 quarterly and annual net doses are compared to the historical averages (plus 3 times the 90th percentile standard deviation, also known as the minimum differential dose) to determine if any facility related dose was identified at any location during any quarter or the year.

The result of the evaluation of environmental dosimeters is that there is no facility related dose measured in the environment around Browns Ferry (see Table 2). There were no quarterly or annual dosimeters that exceeded the historical baseline plus the calculated minimum differential dose. The dosimeters from location N-1, in the 3rd quarter, were not found during dosimeter change out, so no measurement was recorded for that location and time period (see Appendix C). An average quarterly value was assumed, however, for determination of the annual exposure at this location.

The difference in onsite (< 2 miles) and offsite (> 2 miles) 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 2021. Landauer InLight Optically Stimulated Luminescence (OSL) dosimeters have been deployed since 2007, replacing the Panasonic UD-814 dosimeters used during the previous years. In order to implement the methodology of 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 account for the extraneous dose that should be removed from the gross measurements as measured by the field dosimeters.

Figure 3

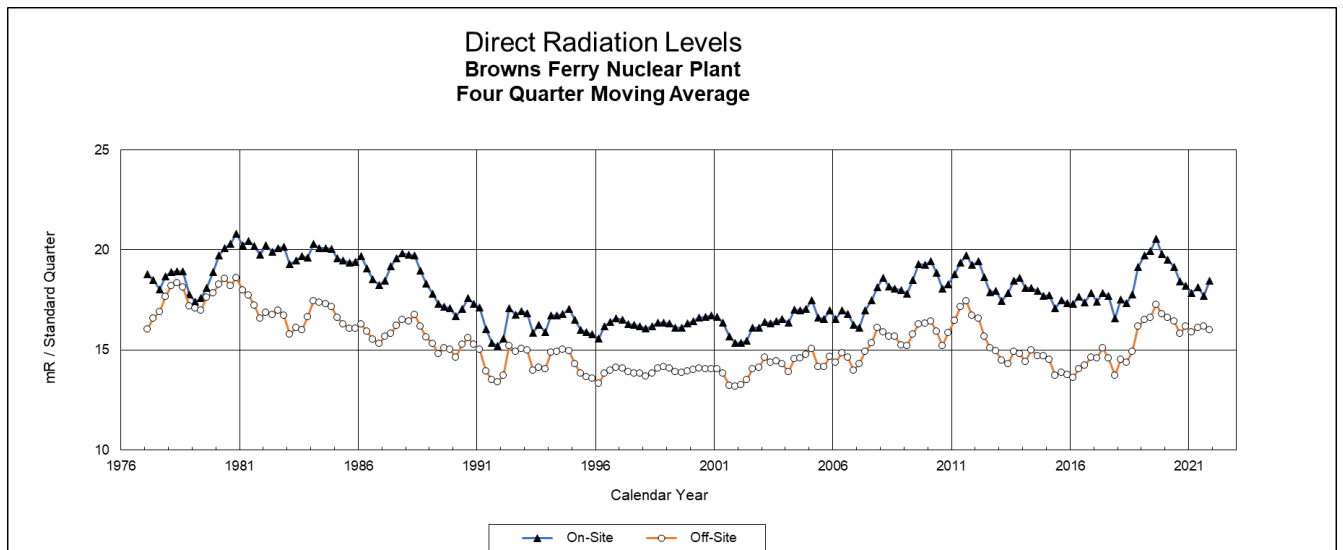


Table 2 – Browns Ferry Environmental Dosimeter Results

Map Location	Land. Ident.	Station	Description	Direction (deg)	Distance (miles)	Quarterly Baseline (mrem/qr)	2021 Quarterly Results (mrem/qr)				Quarterly Baseline Adjusted (mrem/qr)				Annual Baseline (mrem/yr)	Annual Dose (mrem)	Annual Baseline Adjusted (mrem/yr)
							1	2	3	4	1	2	3	4			
5	1	W-3	RM-1 BF WARL	275	31.0	15.7	15.6	15.6	16.7	16.5	ND	ND	ND	ND	62.9	64.4	ND
1	2	NW-3	PM-1 BF Rogersville	310	13.8	15.2	16.6	16.1	15.2	15.0	ND	ND	ND	ND	60.7	62.9	ND
67	3	NW-2	Coxey Creek	321	5.3	17.3	18.1	19.6	19.1	16.5	ND	ND	ND	ND	69.2	73.4	ND
69	4	NNW-3	Ripley Rd	339	5.2	17.2	16.6	21.1	15.2	18.1	ND	ND	ND	ND	68.7	71.0	ND
38	5	N-2	Smith Dairy	1	5.0	15.3	13.1	16.1	14.7	14.0	ND	ND	ND	ND	61.1	57.9	ND
40	6	NNE-3	7 Mile Post Rd	19	5.2	15.3	13.6	16.6	17.7	15.5	ND	ND	ND	ND	61.0	63.4	ND
42	7	NE-2	West of Reid	49	5.0	18.1	20.1	20.6	18.1	17.6	ND	ND	ND	ND	72.4	76.4	ND
43	8	ENE-2	Looney Dairy	62	6.2	17.4	17.1	17.1	16.7	14.5	ND	ND	ND	ND	69.5	65.4	ND
45	9	E-2	Lindsey Rd/Malone Cemetery	91	5.2	17.6	16.6	19.6	20.6	14.5	ND	ND	ND	ND	70.3	71.3	ND
47	10	ESE-2	Cowford Rd	112	3.0	17.3	17.1	17.6	19.1	17.1	ND	ND	ND	ND	69.3	70.9	ND
9	11	ENE-1	#1 E. LM-3 BFN	61	0.9	19.4	17.6	21.1	21.1	20.6	ND	ND	ND	ND	77.7	80.4	ND
44	12	E-1	#5 LLRW	85	0.8	21.6	22.1	22.1	21.6	20.1	ND	ND	ND	ND	86.3	85.9	ND
46	13	ESE-1	#27 behind EDS	110	0.9	18.4	15.6	20.1	21.6	21.1	ND	ND	ND	ND	73.7	78.4	ND
48	14	SE-1	East of Training Center	130	0.5	19.7	20.1	21.6	19.6	17.6	ND	ND	ND	ND	79.0	78.9	ND
39	15	NNE-2	#10 N. Browns Ferry Rd	31	0.7	19.6	17.1	20.1	21.1	21.7	ND	ND	ND	ND	78.3	80.0	ND
41	16	NE-1	#9 S Browns Ferry Rd	51	0.8	20.5	19.1	21.6	20.1	22.2	ND	ND	ND	ND	81.9	83.0	ND
8	17	NNE-1	#12 near LM-2 BFN	12	0.9	19.1	19.1	20.1	23.0	18.1	ND	ND	ND	ND	76.5	80.3	ND
7	18	N-1	LM-1 BFN	348	1.0	20.5	20.1	16.6	N/A	19.1	ND	ND	N/A	ND	81.9	74.4	ND
75	19	N-1A	LM-1 Road Entrance	355	1.0	20.8	20.6	23.1	19.1	21.7	ND	ND	ND	ND	83.3	84.5	ND
68	20	NNW-1	Paradise Shores, South	331	1.0	17.9	16.6	20.1	18.6	17.1	ND	ND	ND	ND	71.4	72.4	ND
10	21	NNW-2	LM-4 BFN	331	1.7	19.1	17.1	18.1	19.1	19.6	ND	ND	ND	ND	76.6	73.9	ND
66	22	NW-1	Poplar Creek	326	2.2	14.1	12.6	12.6	12.3	11.9	ND	ND	ND	ND	56.5	49.4	ND
2	23	NE-3	PM-2 BF Athens	56	10.9	16.3	14.6	17.1	17.2	19.1	ND	ND	ND	ND	65.1	68.0	ND
6	24	E-3	RM-6 BF Madison	90	23.1	17.3	15.1	17.6	18.1	16.0	ND	ND	ND	ND	69.1	66.9	ND
3	25	SSE-2	PM-3 BF Trinity	165	7.5	15.3	14.1	13.6	14.2	15.0	ND	ND	ND	ND	61.4	57.0	ND
49	26	SE-2	Finley Island Road	135	5.4	17.2	14.1	16.6	18.1	15.0	ND	ND	ND	ND	69.0	63.9	ND
50	27	SSE-1	Sewell Road Lewis Lane	163	5.1	16.6	16.1	15.6	15.7	16.0	ND	ND	ND	ND	66.5	63.4	ND
52	28	S-2	Hwy 20, 1 mile W County line	182	4.8	14.9	13.1	15.1	15.2	14.5	ND	ND	ND	ND	59.5	57.9	ND
56	29	SW-2	Mallard Creek Rd/Hwy 20	219	4.7	16.7	13.6	20.1	14.7	20.1	ND	ND	ND	ND	67.0	68.6	ND
54	30	SSW-2	Old Hwy 20/Fish Pond Rd	199	4.4	16.4	14.1	16.6	18.1	14.0	ND	ND	ND	ND	65.4	62.8	ND
51	31	S-1	Baker Bottom Rd	185	3.1	16.5	15.1	18.1	18.6	17.6	ND	ND	ND	ND	66.0	69.4	ND
53	32	SSW-1	Baker Bottom Rd/Fish Pond Rd	203	3.0	14.8	14.1	14.1	16.7	14.0	ND	ND	ND	ND	59.3	58.9	ND
55	33	SW-1	#55 South River Bank	228	1.9	15.7	11.1	11.1	13.3	13.0	ND	ND	ND	ND	62.8	48.4	ND
59	34	WSW-2	BF Rd/Graves Cemetery	251	5.1	17.2	15.6	17.6	16.7	16.0	ND	ND	ND	ND	68.9	65.9	ND
62	35	W-2	1.5 miles North WSW-2	268	4.7	15.3	13.1	16.6	15.2	15.5	ND	ND	ND	ND	61.2	60.4	ND
58	36	WSW-1	LM-5 BF, Davis Farm	244	2.7	14.4	13.6	13.6	14.7	14.5	ND	ND	ND	ND	57.5	56.4	ND
61	37	W-1	Lakeview	275	1.9	16.9	13.6	16.6	18.6	15.5	ND	ND	ND	ND	67.8	64.4	ND
64	38	WNW-1	Terry Farm	291	3.3	16.5	15.1	17.1	17.2	16.0	ND	ND	ND	ND	65.9	65.4	ND
65	39	WNW-2	Farrior Kennels	293	4.4	16.7	13.6	18.1	19.1	17.6	ND	ND	ND	ND	67.0	68.4	ND
60	40	WSW-3	PM-4 BF Courtland	257	10.5	15.4	13.6	15.6	16.2	15.5	ND	ND	ND	ND	61.6	60.9	ND

ATMOSPHERIC MONITORING

The atmospheric monitoring network is divided into three groups identified as local, perimeter, and remote. In the current program, six local air monitoring stations are located on or adjacent to the plant site in the general direction of highest wind frequency. Three of these stations (LM-1, LM-2, and LM-3) are located on the plant side of the Tennessee River and two stations (LM-6 and LM-7) are located immediately across the river from the plant site. One additional station (station LM-4) is located at the point of maximum predicted offsite concentration of radionuclides based on historical meteorological data. Three indicator air monitoring stations (PM-1, PM-2 and PM-3) are in communities out to 13 miles from the plant, and two control stations (RM-1 and RM-6) are located out to 32 miles. 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-1 through Table H-3. Radioactivity levels identified in this reporting period are consistent with background radioactivity levels.

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 pump, a magnehelic gauge for measuring the pressure drop across the system, and a dry gas meter. This allows for an accurate determination of the volume of air passing through the filter. The sampling system is housed in a metal structure. The filter is contained in a sampling head mounted on the outside of the monitoring structure. The filter is replaced weekly. Each filter is analyzed for gross beta activity at least 3 days after collection to allow time for the naturally occurring radon daughters to decay. Monthly composites of the filters from each location are analyzed by gamma spectroscopy.

Atmospheric radioiodine is collected 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 as the air particulate filter and is downstream of the 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 iodine-131 (I-131) by gamma spectroscopy analysis.

Results

The results from the analysis of air particulate samples are summarized in Table H-1. Gross beta activity levels in 2021 were consistent with levels reported in previous years. The annual average gross beta concentration was 0.037 pCi/m³ in indicator and 0.037 pCi/m³ in control locations. The annual averages of the gross beta activity in air particulate filters for the years 1968-2021 are presented in Figure H-1. Increased levels due to fallout from atmospheric nuclear weapons testing are evident, especially in 1969, 1970, 1971, 1977, 1978, and 1981. Evidence of a small increase resulting from the Chernobyl accident can also be seen in 1986. These patterns are consistent with data from monitoring programs conducted by TVA at other nuclear power plant sites. GEL Laboratories, LLC took over radiochemistry analysis for the BFN REMP program in 2017. Since that change, the air filter gross beta results increased from a long-term average of approximately 0.02 pCi/m³ to approximately 0.03 pCi/m³. This slight increase 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.

Only naturally occurring radionuclides were identified by the monthly gamma spectral analysis of the air particulate samples. There was no I-131 detected in any charcoal cartridge samples during 2021. The charcoal cartridge analysis results are reported in Table H-2, and the gamma spectroscopy results are reported in Table H-3.

TERRESTRIAL MONITORING

Terrestrial monitoring is accomplished by collecting samples of environmental media representing the transport of radioactive material from the atmosphere to the ground and various food products. 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. When the cow ingests the radioactive material, some of it may be transferred to the milk and consumed by humans who drink the milk. Therefore, samples of milk (if applicable), 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-4 and Table H-5.

A land use census is conducted annually to locate milk producing animals and gardens within a 5-mile radius of the plant. No milk-producing animals were identified within 5 miles of the plant. There were no new locations of gardens that would call for a change in the monitoring program. The results of the 2021 land use census are presented in Appendix G.

Sample Collection and Analysis

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 in sectors with the higher predicted D/Qs, where available. Types of foods may vary from year to year as a result of changes in the local vegetable gardens. Samples of apples, cabbage, corn, green beans, carrots, and tomatoes were collected from local gardens in 2021. Samples of these same food crops were purchased from area produce markets or private gardens to serve as control samples. The edible portion of each sample is analyzed by gamma spectroscopy.

There are no milk producing animals within 5 miles of the facility, so no milk samples were obtained in 2021.

Results

The only fission or activation product identified, above nominal LLD, in soil samples was Cs-137 and Sr-90. The average concentration measured in samples from indicator locations was 143 pCi/kg. The average concentration for control locations was 113 pCi/kg. One indicator location was positive for Sr-90, with a value of 151 pCi/kg. These concentrations are consistent with levels previously reported from fallout. All other radionuclides reported were naturally occurring isotopes.

The results of the analysis of soil samples are reported in Table H-4. A plot of the annual average Cs-137 concentrations in soil is presented in Figure H-2. The concentration of Cs-137 in soil is steadily decreasing due to the cessation of weapons testing in the atmosphere, the 30-year half-life of Cs-137 and transport through the environment.

Analyses of food samples indicated no contribution from plant activities. The results are reported in Table H-5.

LIQUID PATHWAY MONITORING

Potential exposures from the liquid pathway can occur from drinking water, ingestion of fish, and direct radiation exposure to radioactive materials deposited in shoreline sediment. The liquid pathway monitoring program conducted during 2021 included the collection of samples of surface (river/reservoir) water, groundwater, drinking water, fish, and shoreline sediment. Samples from the reservoir are collected both upstream and downstream from the plant. Results from the analysis of aquatic samples are presented in Table H-6 through Table H-10.

Sample Collection and Analysis

Samples of surface water are collected from the Tennessee River using automatic sampling systems from one downstream station and one upstream station. The upstream sample is collected from the raw water intake at the Decatur, Alabama water plant (TRM 306) and is utilized as a control sampling location for both surface and drinking water. A timer turns on the system at least once every two hours. The line is flushed, and a sample collected into a collection container. A one-gallon sample is removed from the container every month and the remaining water in the jug is discarded. The monthly composite sample is analyzed by gamma spectroscopy and gross beta analysis. A quarterly composite sample is analyzed for tritium by liquid scintillation counting.

Samples are also collected by an automatic sampling system at the first downstream drinking water intake, West Morgan - East Lawrence Water Authority (TRM 286.5). This sample of raw untreated water is collected at the intake from the water plant. These samples are collected in the same manner as the surface water samples. These monthly samples are analyzed by gamma spectroscopy and gross beta analysis. A quarterly composite is analyzed for tritium.

At other selected locations, grab samples are collected from drinking water systems, which use the Tennessee River as their source. These samples are analyzed every month by gamma spectroscopy and gross beta analysis. A quarterly composite sample from each station is analyzed for tritium.

A groundwater well onsite is equipped with an automatic water sampler. Water is also collected from a private well in an area unaffected by BFN. Samples from the wells are collected every month and a composite sample is analyzed quarterly by gamma spectroscopy and tritium.

Samples of commercial and game fish species are collected semiannually from each of the two reservoirs: the reservoir on which the plant is located (Wheeler Reservoir) and the upstream reservoir (Guntersville Reservoir). The samples are collected using a combination of netting techniques and electrofishing. To sample edible portions of the fish, the fish are filleted. After drying and grinding, the samples are analyzed by gamma spectroscopy.

Shoreline sediment is collected from two downstream recreational use areas and one upstream location. The samples are collected at the normal water level shoreline and analyzed by gamma spectroscopy.

Results

Only naturally occurring isotopes were identified by gamma spectral analysis of surface water. Although tritium is occasionally detected in surface water samples, it was not detected in any control or indicator

surface water samples in 2021. A summary table of the results for this reporting period is shown in Table H-6.

No fission or activation products were detected by the gamma or tritium analysis of public drinking water. Positive gross beta results were identified in four samples from two (of four) indicator locations, averaging 3.57 pCi/L. One positive gross beta result was identified in a control location sample at 3.11 pCi/L. These results are consistent with previous monitoring results. Like surface water, tritium is occasionally identified in drinking water samples, but was not detected in any control or indicator drinking water samples in 2021. The results are shown in Table H-7.

No fission or activation products were detected by gamma spectroscopy in REMP groundwater samples from BFN REMP monitoring locations. Tritium was not detected in any REMP well water samples in 2021. Results from the analysis of groundwater samples are presented in Table H-8.

In 2021, game fish (largemouth bass) and commercial fish (channel or flathead 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-9.

Shoreline sediment was sampled from three locations, two indicator and one control. One indicator sample of shoreline sediment was positive for Cs-137, at a level of 57 pCi/kg, and a control sample measured 63 pCi/kg. This is similar to other low level positive results in the past, and not indicative of a new or on-going release from the facility. The results of the analysis of shoreline sediment are provided in Table H-10.

ASSESSMENT AND EVALUATION

Results

As stated earlier in the report, the estimated increase in radiation dose equivalent to the public resulting from the operation of BFN is negligible 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 reporting period, Cs-137 was identified above the nominal LLD in soil and shoreline sediment samples. The Cs-137 detected in these samples was consistent with levels generally found in the environment as the result of past nuclear weapons testing. The low levels of gross beta activity measured in some water samples represent concentrations that are attributed to natural radioactivity.

Conclusions

The 2021 radiological environmental monitoring program results demonstrate that exposure to members of the general public, which may have been attributable to BFN, is a small fraction of regulatory limits and essentially indistinguishable from the natural background radiation. The levels of radioactivity reported herein are 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 - Browns Ferry Radiological Environmental Monitoring Program

<u>Exposure Pathway and/or Sample</u>	<u>Number of Samples and Locations^a</u>	<u>Sampling and Collection Frequency</u>	<u>Type and Frequency of Analysis</u>
1. AIRBORNE			
a. Particulates	<p>6 samples from locations (in different sectors) at or near the site boundary (LM-1, LM-2, LM-3, LM-4, LM-6 and LM-7)</p> <p>3 samples from communities approximately 10 miles from plant (PM-1, PM-2 and PM-3)</p> <p>2 samples from control locations > 10 miles from the plant (RM-1 and RM-6)</p>	<p>Continuous sampler operation with sample collection at least once per 7 days (more frequently if required by dust loading).</p>	<p>Analyze for gross beta radioactivity \geq 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.</p>
b. Radioiodine	<p>Samples from same locations as air particulates</p>	<p>Continuous sample operation with filter collection at least once per 7 days.</p>	<p>I-131 by gamma scan on each sample.</p>
c. Soil	<p>Samples from same location as air particulates</p>	<p>Once every year</p>	<p>Gamma scan, Sr-89, Sr-90 once per year</p>
2. DIRECT			
a. Dosimeters	<p>2 or more dosimeters placed at or near the site boundary in each of the 16 sectors.</p> <p>2 or more dosimeters placed at stations located approximately 5 miles from the plant in each of the 16 sectors.</p> <p>2 or more dosimeters in at least 8 additional locations of special interest, including at least 2 control stations.</p>	<p>At least once per 92 days</p>	<p>Gamma dose once per 92 days</p>

Table A-1 - Browns Ferry Radiological Environmental Monitoring Program (Continued)

<u>Exposure Pathway and/or Sample</u>	<u>Number of Samples and Locations^a</u>	<u>Sampling and Collection Frequency</u>	<u>Type and Frequency of Analysis</u>
3. WATERBORNE			
a. Surface Water	<p>1 sample downstream from plant discharge (TRM 293.5)</p> <p>1 sample at a control location upstream from the plant discharge (TRM 306)</p>	<p>Collected by automatic sequential-type sampler^b with composite samples collected over a period of approximately 31 days.</p>	<p>Gamma scan at least once per 31 days. Composite for tritium at least once per 92 days.</p>
b. Drinking Water	<p>1 sample at the first potable surface water supply downstream from the plant (TRM 286.5)</p> <p>1 sample at a control location (TRM 306)</p> <p>3 additional samples of potable surface water downstream from the plant (TRM 274.9, TRM 259.8 and TRM 259.6)</p>	<p>Collected by automatic sequential-type sampler^b with composite sample collected at least once per 31 days.</p> <p>Grab sample taken from the water supply at a facility using water from the public supply being monitored. Sample collected at least once per 31 days.</p>	<p>Gross beta and gamma scan at least once per 31 days. Composite for tritium analysis at least once per 92 days.</p>
c. Ground water	<p>1 sample adjacent to the plant (Well 6R)</p> <p>1 sample at a control location up gradient from the plant (Farm B)</p>	<p>Collected by automatic sequential-type sampler^b with composite samples collected over a period of approximately 31 days.</p> <p>Grab sample taken at least once per 31 days.</p>	<p>Composite for gamma scan and tritium at least once per 92 days.</p>

Table A-1 - Browns Ferry Radiological Environmental Monitoring Program (Continued)

<u>Exposure Pathway and/or Sample</u>	<u>Number of Samples and Locations^a</u>	<u>Sampling and Collection Frequency</u>	<u>Type and Frequency of Analysis</u>
d. Shoreline Sediment	1 sample from each of at least two downstream locations with recreational use. (TRM 293 and TRM 279.5) 1 sample from a control location upstream from plant discharge (TRM 305)	At least once per 184 days	Gamma scan of each sample
4. INGESTION			
a. Milk	Samples from milking animals within 8 km. One sample from milking animal at control location 15-30 km. (See ODCM for more details on milk sampling requirements)	At least once per 15 days when animals are on pasture; at least once per 31 days at other times	Gamma scan and I-131 on each sample. Sr-89 and Sr-90 at least once per 92 days
b. Fish	2 samples representing commercial and game species in Gunter'sville Reservoir above the plant. 2 samples representing commercial and game species in Wheeler Reservoir near the plant.	Semi-Annually (at least once per 184 days)	Gamma scan on edible portions
c. Food Products	Samples of food crops such as greens, corn, green beans, tomatoes and potatoes grown at private gardens and/or farms in the immediate vicinity of the plant. 1 sample of each of the same foods grown at greater than 10 miles from the plant.	At least once per year at time of harvest.	Gamma scan on edible portions

^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

Table A-2 - Browns Ferry REMP Sampling Locations

Map Station Number ^a	Station	Sector	Approximate Distance (miles)	Indicator (I) or Control (C)	Samples Collected ^b
1	PM-1	NW	13.8	I	AP,CF,S
2	PM-2	NE	10.9	I	AP,CF,S
3	PM-3	SSE	7.5	I	AP,CF,S
4	LM-7	W	2.1	I	AP,CF,S
5	RM-1	W	31.0	C	AP,CF,S
6	RM-6	E	23.4	C	AP,CF,S
7	LM-1	NNW	1.0	I	AP,CF,S
8	LM-2	NNE	0.9	I	AP,CF,S
9	LM-3	ENE	0.9	I	AP,CF,S
10	LM-4	NNW	1.7	I	AP,CF,S
11	LM-6	SSW	3.0	I	AP,CF,S
12	Farm B	NNW	6.8	C	W
24	TRM ^c 306	-	12.0 ^d	C	PW, SW
25	TRM 259.6	-	34.4 ^d	I	PW
26	TRM 274.9	-	19.1 ^d	I	PW
28	TRM 293.5	-	0.5 ^d	I	SW
70	TRM 259.8	-	34.2 ^d	I	PW
71	TRM 286.5	-	7.5 ^d	I	PW
72	TRM 305	-	11.0 ^d	C	SS
73	TRM 293	-	1.0 ^d	I	SS
74	TRM 279.5	-	14.5 ^d	I	SS
76	Well 6R	NW	0.12	I	W
	Wheeler Reservoir (TRM 275 – 349)	-	-	I	F
	Guntersville Reservoir (TRM 349 – 424)	-	-	C	F

^a See Figure A-1 through Figure A-3

^b Sample Codes:

AP = Air particulate filter
 F = Fish
 M = Milk
 CF = Charcoal Filter

PW = Public water
 V = Vegetation
 S = Soil

SS = Shoreline sediment
 SW = Surface water
 W = Well water

^c TRM = Tennessee River Mile

^d Distance from plant discharge at Tennessee River Mile (TRM) 294

Table A-3 - Browns Ferry Environmental Dosimeter Locations

	<u>Station</u>	<u>Sector</u>	<u>Distance (miles)</u>	<u>Indicator or Control</u>
1	NW-3	NW	13.8	Off
2	NE-3	NE	10.9	Off
3	SSE-2	SSE	7.5	Off
5	W-3	W	31.0	Off
6	E-3	E	23.1	Off
7	N-1	NNW	1.0	On
8	NNE-1	NNE	0.9	On
9	ENE-1	ENE	0.9	On
10	NNW-2	NNW	1.7	On
38	N-2	N	5.0	Off
39	NNE-2	NNE	0.7	On
40	NNE-3	NNE	5.2	Off
41	NE-1	NE	0.8	On
42	NE-2	NE	5.0	Off
43	ENE-2	ENE	6.2	Off
44	E-1	E	0.8	On
45	E-2	E	5.2	Off
46	ESE-1	ESE	0.9	On
47	ESE-2	ESE	3.0	Off
48	SE-1	SE	0.5	On
49	SE-2	SE	5.4	Off
50	SSE-1	SSE	5.1	Off
51	S-1	S	3.1	Off
52	S-2	S	4.8	Off
53	SSW-1	SSW	3.0	Off
54	SSW-2	SSW	4.4	Off
55	SW-1	SW	1.9	On
56	SW-2	SW	4.7	Off
58	WSW-1	WSW	2.7	Off
59	WSW-2	WSW	5.1	Off
60	WSW-3	WSW	10.5	Off
61	W-1	W	1.9	On
62	W-2	W	4.7	Off
64	WNW-1	WNW	3.3	Off
65	WNW-2	WNW	4.4	Off
66	NW-1	NW	2.2	Off
67	NW-2	NW	5.3	Off
68	NNW-1	NNW	1.0	On
69	NNW-3	NNW	5.2	Off
75	N-1A	N	1.0	On

Figure A-1 - Radiological Environmental Monitoring Locations within 1 mile of Plant

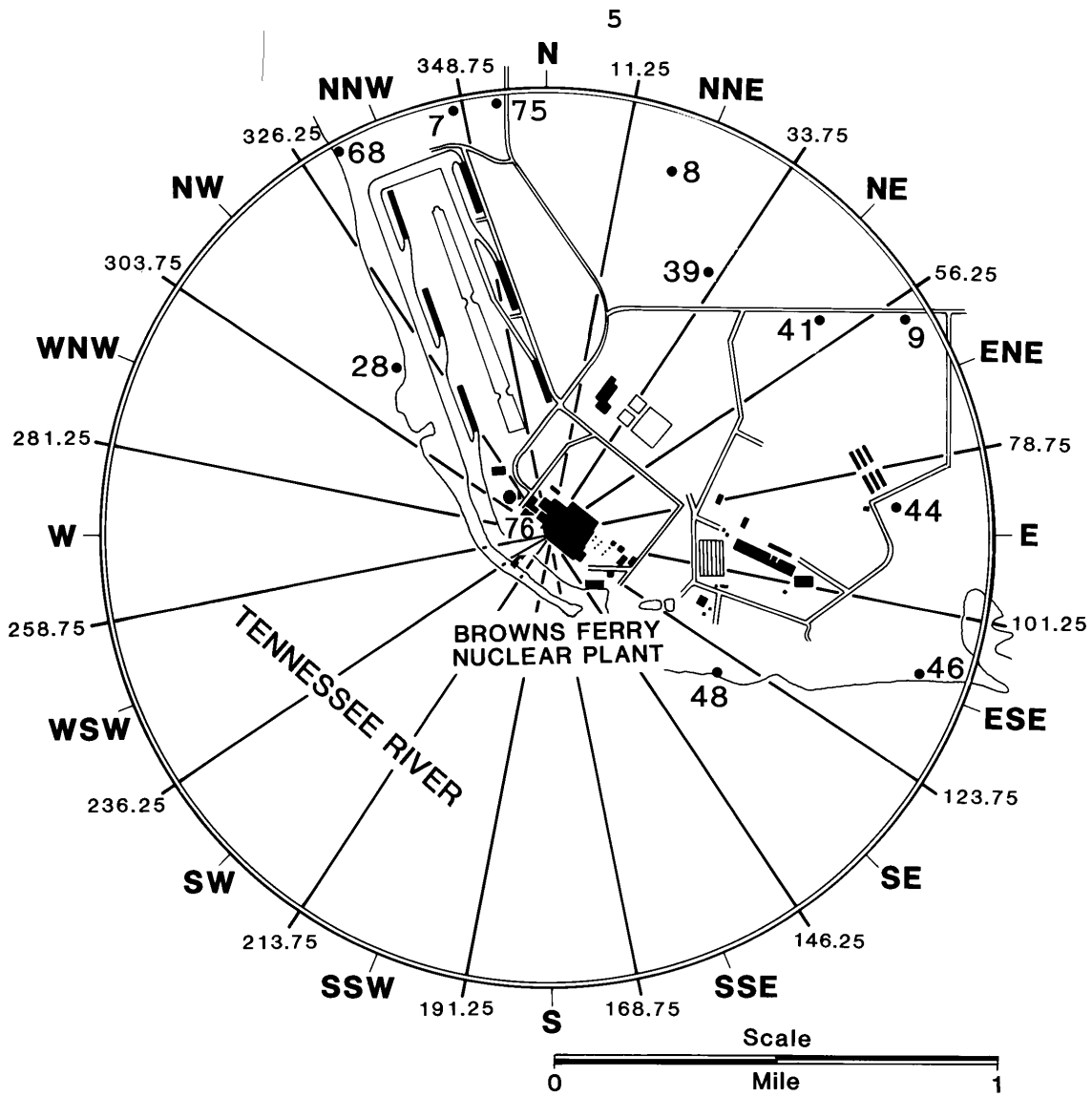


Figure A-2 - Radiological Environmental Monitoring Locations 1 - 5 miles from Plant

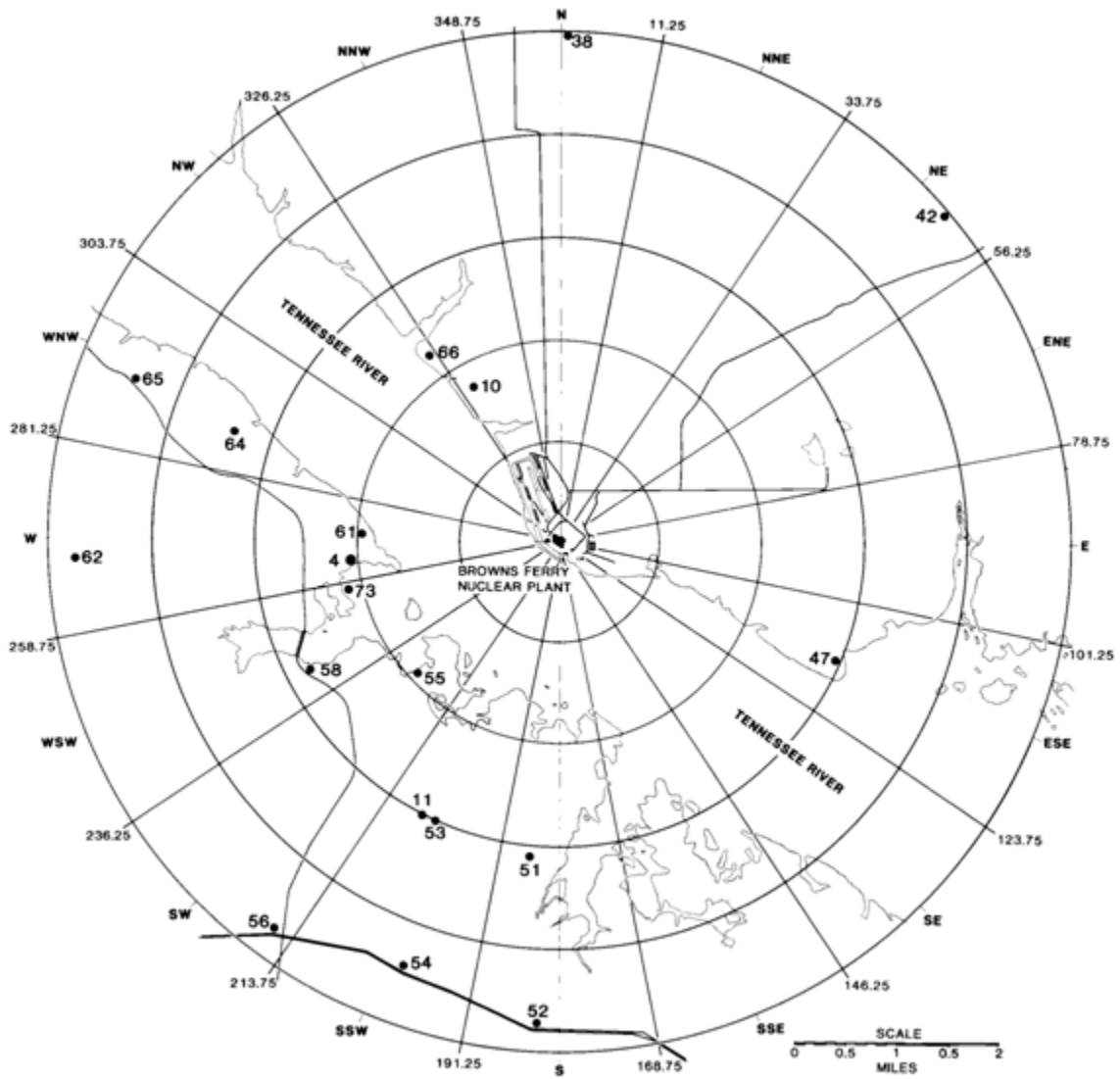
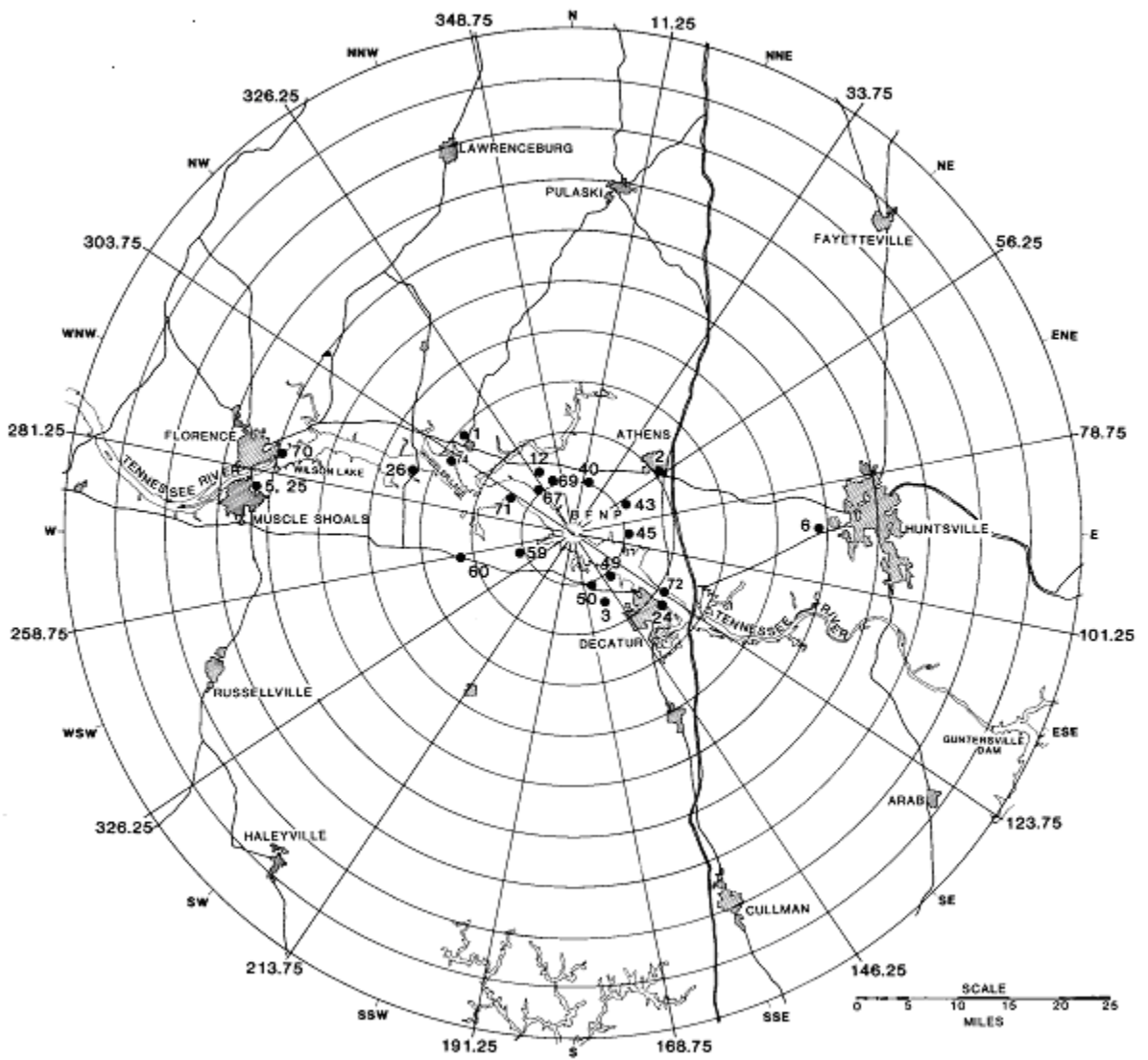


Figure A-3 - Radiological Environmental Sampling Locations Greater than 5 miles from Plant



APPENDIX B PROGRAM MODIFICATIONS

Radiological Environmental Monitoring Program Modifications

In 2021, there were no modifications to the Browns Ferry Nuclear Power Plant Radiological Environmental Monitoring Program sampling locations, analysis types, or frequency.

APPENDIX C PROGRAM DEVIATIONS

Program Deviations

Media	Location	Date	CR	Issue
Air Filter	All	2/16/2021	1671805	Week 8 samples were not obtained within the 7-day ODCM REMP requirement due to hazardous weather conditions.
Charcoal Filter		2/19/2021	1672886	
				Week 9 samples were not placed in the field due to hazardous weather conditions.
Air Filter	LM-2	7/20/2021	1708729	Low sample volume due to pump breaker trip.
Charcoal Filter				
Direct Radiation	N-1 18A and B	3 rd Quarter	1728340	Dosimeters not found during Q3 changeout.

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

Analysis	Concentrations in Water (pCi/Liter)			Concentrations in Air (pCi/m ³)		
	10 CFR 20 Effluent Concentration Limit ^a	Reporting Level ^{b, c}	Nominal Lower Limit of Detection ^d	10 CFR 20 Effluent Concentration Limit ^a	Reporting Level ^{b, c}	Nominal Lower Limit of Detection ^d
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	--	0.005
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	0.005
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: BFN Offsite Dose Calculation Manual, Table 2.3-3

^d Source: Table E-2 and Table E-3 of this report.

Table E-2 - Nominal LLD Values - Radiochemical

Analysis	Airborne		Milk (pCi/L)	Wet Vegetation (pCi/kg, wet)	Sediment and Soil (pCi/kg, dry)
	Particulate or Gases (pCi/m ³)	Water (pCi/L)			
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	Charcoal	Water and	Wet	Sediment	Fish	Food
	Particulate (pCi/m ³)	Filter (pCi/m ³)	Milk (pCi/L)	Vegetation (pCi/kg, wet)	and Soil (pCi/kg, dry)	(pCi/kg, wet)	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)

<u>Analysis</u>	<u>Airborne Particulate</u> (pCi/m ³)	<u>Charcoal Filter</u> (pCi/m ³)	<u>Water and Milk</u> (pCi/L)	<u>Wet Vegetation</u> (pCi/kg, wet)	<u>Sediment and Soil</u> (pCi/kg, dry)	<u>Fish</u> (pCi/kg, wet)	<u>Food Products</u> (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)

<u>Analysis</u>	<u>Water</u> (pCi/L)	<u>Airborne Particulate or Gases</u> (pCi/m ³)	<u>Fish</u> (pCi/kg, wet)	<u>Milk</u> (pCi/L)	<u>Food Products</u> (pCi/kg, wet)	<u>Sediment</u> (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

- If no drinking water pathway exists, a value of 3000 pCi/L may be used
- 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 or no activity 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.

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 is cross-check samples. 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 true value of the activity 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 2021.

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 2021 Annual Environmental Quality Assurance (QA) Report (GEL, 2022), 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 2021. Of the four hundred thirty-three (433) total results, 96.51% (418 of 433) 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 ninety-one (91) 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 2021 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 (50 m²) 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 also identifies all gardens of greater than 500 square feet producing fresh leafy vegetables within a distance of 3 miles (5 km) from the plant.

The land use census was conducted during the growing season in June 2021 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. Sectors and distances were determined using a global positioning system (GPS).

The location of the nearest resident was unchanged in all sectors in 2021.

The location of the nearest garden greater than 500 ft² was changed or updated in four sectors. These updated locations did not result in any changes in the required sampling locations or sampling media; new locations are summarized below:

Table G-1 - 2021 Updated Nearest Garden

Sector	2020 Nearest Garden (meters)	2021 Nearest Garden (meters)
NNE	6150	4250
ENE	7680	4700
S	4540	5700
W	8020	7450

In 2021 no milk locations were identified within an 8-km (5 miles) radius of the plant site. Browns Ferry gaseous effluents are characterized as an elevated release. As a result, BFN is required to identify all qualifying gardens out to 3 miles, in accordance with regulatory requirements and the Browns Ferry ODCM (Tennessee Valley Authority, 2019). The 2021 land use census identified a total of four additional gardens within 3 miles that are not the nearest gardens to the site, in their sector.

Results of the 2021 Land Use Census did not identify the need for any changes to the sampling locations or sampling media as currently required by the BFN REMP.

Table G-2 - Browns Ferry Land Use Census Results

Meteorological Sector	Nearest Resident (meters)	Nearest Garden (meters)	Nearest Milk Production (meters)	Additional Gardens (meters)
N	2440	6200	-	-
NNE	2620	4250	-	-
NE	2020	4290	-	4540
ENE	2510	4700	-	5010
E	1410	1530	-	4240
ESE	1750	2070	-	4500
SE	-	-	-	-
SSE	-	-	-	-
S	4540	5700	-	-
SSW	4160	4880	-	-
SW	4940	4940	-	-
WSW	4040	4330	-	-
W	2660	7450	-	-
WNW	5280	-	-	-
NW	3150	-	-	-
NNW	1650	4350	-	-

APPENDIX H DATA TABLES AND FIGURES

Table H-1 - 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/m ³)	Gross Beta 561	0.01	0.037 (459/459) (0.018 – 0.080)	PM-2, 10.9 Mi. NE	0.038 (51/51) (0.020 – 0.069)	0.037 (102/102) (0.017 – 0.079)	0

NOTES

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

Figure H-1 - Average Beta Activity in Air Filters

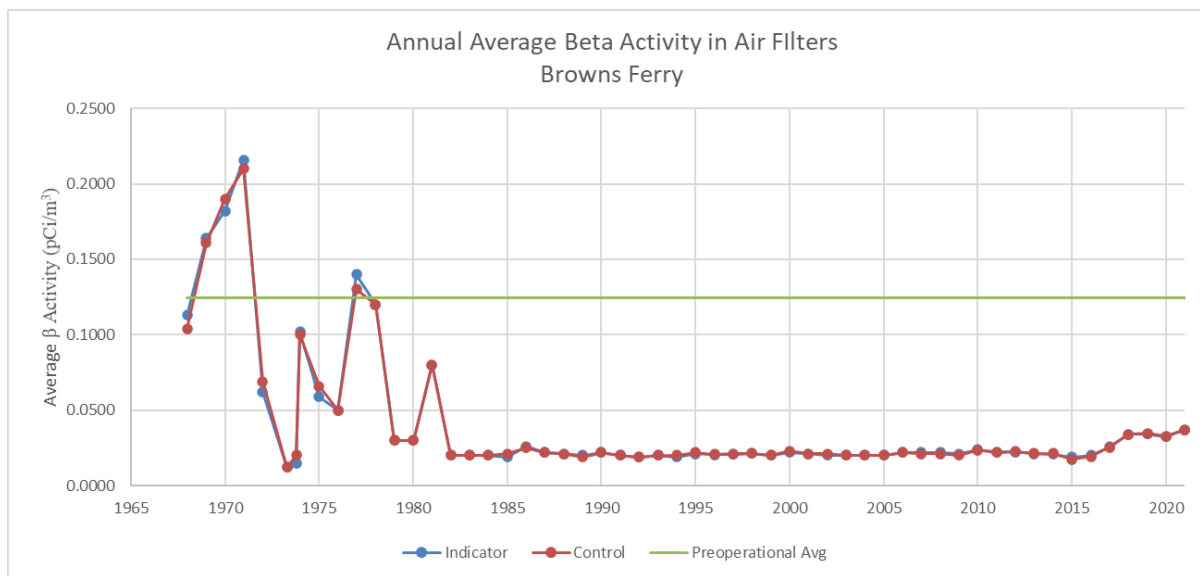


Table H-2 - Weekly Airborne Iodine-131 Radioactivity

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)		
Activated Charcoal Inhalation (pCi/m ³)	I-131 561	0.07	< LLD ^a (0/459)	< LLD	< LLD	< LLD (0/102)	0

NOTES

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

Table H-3 - Monthly Composite Airborne 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/m ³)	Gamma Isotopic ^a 143	Various ^b	< LLD (0/117)	< LLD	< LLD	< LLD (0/26)	0

NOTES

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

Table H-4 - 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 11	Various ^c	< LLD (0/9)	< LLD	< LLD	< LLD (0/2)	0
	Cs-137 ^b 11	180	158 (5/9) 82 - 264	PM-2, 10.9 Mi. NE	264 (1/1) 264 - 264	113 (1/2) 113 - 113	0
	Sr-89 11	1.6	< LLD (0/9)	< LLD	< LLD	< LLD (0/2)	0
	Sr-90 11	0.4	151 (1/9) 151 - 151	LM-3, 0.9 Mi. ENE	151 (1/1) 151 - 151	< LLD (0/2)	0

NOTES

- a. Natural occurring radionuclides were observed in soil samples.
- b. Cs-137 is the only non-natural radionuclide positively identified as part of the gamma isotopic analysis
- c. See Table E-1 through Table E-4 for the required and nominal LLDs for individual radionuclides via gamma isotopic analysis.

Figure H-2 - Average Cs-137 Radioactivity in Soil

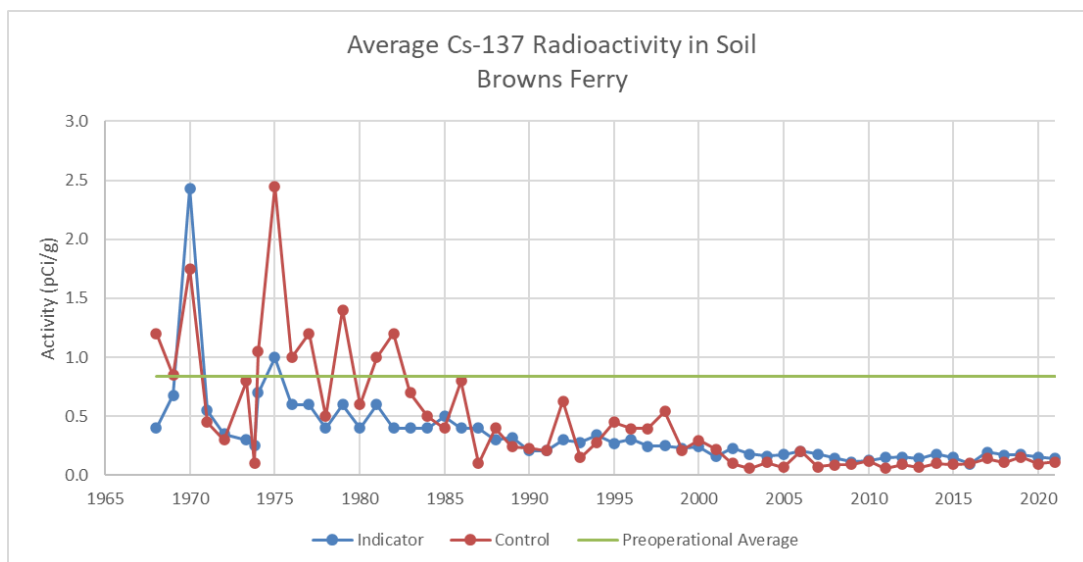


Table H-5 - Annual Local Crop Radioactivity

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)		
Apples Ingestion (pCi/kg)	Gamma Isotopic ^a	2	Various ^b	< LLD (0/1)	< LLD	< LLD	< LLD (0/1)	0
Cabbage Ingestion (pCi/kg)	Gamma Isotopic ^a	2	Various ^b	< LLD (0/1)	< LLD	< LLD	< LLD (0/1)	0
Corn Ingestion (pCi/kg)	Gamma Isotopic ^a	2	Various ^b	< LLD (0/1)	< LLD	< LLD	< LLD (0/1)	0
Carrots Ingestion (pCi/kg)	Gamma Isotopic ^a	2	Various ^b	< LLD (0/1)	< LLD	< LLD	< LLD (0/1)	0
Green Beans Ingestion (pCi/kg)	Gamma Isotopic ^a	2	Various ^b	< LLD (0/1)	< LLD	< LLD	< LLD (0/1)	0
Tomatoes Ingestion (pCi/kg)	Gamma Isotopic ^a	2	Various ^b	< LLD (0/1)	< LLD	< LLD	< LLD (0/1)	0

NOTES

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

Table H-6 - 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	26	Various ^c	< LLD (0/13)	< LLD	< LLD	< LLD (0/13)	0
	Tritium ^b	8	2000	< LLD (0/4)	< LLD	< LLD	< LLD (0/4)	0

NOTES

- Natural occurring radionuclides were observed in surface water samples.
- Tritium analysis of surface water is required quarterly per the BFN ODCM.
- See Table E-1 through Table E-4 for the required and nominal LLDs for individual radionuclides via gamma isotopic analysis.

Table H-7 - 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 65	4.0	3.57 (4/52) 2.75 – 4.23	TRM 259.6	3.96 (2/13) 3.68 – 4.23	< LLD (0/13)	0
	Gamma Isotopic ^a 65	Various ^b	< LLD (0/52)	< LLD	< LLD	< LLD (0/13)	0
	Tritium ^c 20	2000	< LLD (0/16)	< LLD	< LLD	< LLD (0/4)	0

NOTES

- Natural occurring radionuclides were observed in drinking water samples.
- See Table E-1 through Table E-4 for the required and nominal LLDs for individual radionuclides via gamma isotopic analysis.
- Tritium analysis of drinking water is required quarterly per the BFN ODCM.

Table H-8 - Quarterly 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)	Gamma Isotopic ^a 8	Various ^b	< LLD (0/4)	< LLD	< LLD	< LLD (0/4)	0
	Tritium 8	2000	< LLD (0/4)	< LLD	< LLD	< LLD (0/4)	0

NOTES

- Natural occurring radionuclides were observed in ground water samples.
- See Table E-1 through Table E-4 for the required and nominal LLDs for individual radionuclides via gamma isotopic analysis.

Table H-9 - 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 4	Various ^b	< LLD (0/2)	< LLD	< LLD	< LLD (0/2)	0
Commercial Fish - Channel Catfish Ingestion (pCi/kg)	Gamma Isotopic ^a 4	Various ^b	< LLD (0/2)	< LLD	< LLD	< LLD (0/2)	0

NOTES

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

Table H-10 - 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 6	Various ^b	< LLD (0/4)	< LLD	< LLD	< LLD (0/2)	0

NOTES

- Natural occurring radionuclides were observed in shoreline sediment samples.
- See Table E-1 through Table E-4 for the required and nominal LLDs for individual radionuclides via gamma isotopic analysis.

APPENDIX I ERRATA TO PREVIOUS ANNUAL ENVIRONMENTAL
OPERATING REPORTS

Errata to Previous AREORs

No errata to previous AREORs have been identified in 2021.