May 8, 2024

NG-24-0004
DQAP

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

Duane Arnold Energy Center
Docket No. 50-331
Renewed Op. License No. DPR-49

Subject: 2023 Annual Radiological Environmental Operating Report

Please find as Enclosure 1 to this letter, a copy of NextEra Energy Duane Arnold, LLC's 2023 Annual Radiological Environmental Operating Report for the Duane Arnold Energy Center, pursuant to the requirements of DODAM Section 8.2.2 and DQAP Appendix F.

This letter contains no new commitments and does not revise any existing commitments.

Should you have any questions regarding this matter, please contact Michael Casey at (319) 851-7606.

Justin Both

Justin Both
Decommissioning Director
NextEra Energy Duane Arnold, LLC

Enclosure

cc: Regional Administrator, USNRC, Region III
Inspector, USNRC, Duane Arnold Energy Center
Project Manager, USNRC, Duane Arnold Energy Center

IE25
NRR

Enclosure to
NG-24-0004

Duane Arnold Energy Center

2023 Annual Radiological Environmental Operating Report

78 pages follow

NEXTera ENERGY
DUANE ARNOLD

2023
Annual Radiological Environmental Operating Report

Duane Arnold Energy Center
Cedar Rapids, Iowa
Docket No. 50-331

January 1, 2023 through December 31, 2023

Prepared By: _____ Date: 5/7/24
Michael Casey, Radiation Protection and Environmental Manager

Reviewed By: _____ Date: 5/7/24
Lonnie Helms, Radiation Protection Project Manager

Approved By: _____ Date: 5/7/24
Justin Both, Site Decommissioning Director

MICROBAC®

700 Landwehr Road • Northbrook, IL 60062-2310
phone (847) 564-0700 • fax (847) 564-4517

DUANE ARNOLD ENERGY CENTER
CEDAR RAPIDS, IOWA
DOCKET NO. 50-331

REPORT

to the

UNITED STATES
NUCLEAR REGULATORY COMMISSION

Annual Radiological Environmental Operating Report

January 1 to December 31, 2023

Prepared by

Microbac Laboratories - Northbrook

Project No. 8001

Approved: _____

Ashok Banavali, Ph.D.
Laboratory Director

PREFACE

Staff members of the Microbac Laboratories - Northbrook were responsible for the acquisition of data presented in this report, with the exception of Appendices D and E which were completed by DAEC personnel. All environmental samples, with the exception of aquatic, were collected by personnel of DAEC. Aquatic samples were collected by the University of Iowa Hygienic Laboratory.

The report was prepared by Microbac Laboratories - Northbrook.

TABLE OF CONTENTS

PART I

APPENDICES

TABLE OF CONTENTS (continued)

PART II Page

LIST OF TABLES

In addition, the following tables are included in the Appendices:

Appendix A

Appendix C

LIST OF FIGURES

1.0 INTRODUCTION

This report summarizes and interprets results of the Radiological Environmental Monitoring Program (REMP) conducted by Environmental, Inc., Midwest Laboratory at the Duane Arnold Energy Center, Palo, Iowa, during the period January - December 2023. This Program monitors the levels of radioactivity in the air, terrestrial, and aquatic environments in order to assess the impact of the plant on its surroundings.

The REMP fulfills the requirements of Sections IV.B.2 and IV.B.3 of Appendix I to 10 CFR 50 for the operation of the plant. The REMP also fulfills the requirements of 10 CFR 72.44(d)(2) for operation of the ISFSI.

Tabulations of individual analyses made during the year are included in Part II of this report.

The Duane Arnold Energy Center (DAEC) is a boiling water reactor, located in Linn County, Iowa, on the Cedar River, and owned and operated by NextEra Energy Resources. Initial criticality was attained on March 23, 1974. The reactor reached 100% power on August 12, 1974. Commercial operation began on February 1, 1975.

The DAEC permanently shut down on August 10, 2020. NextEra Energy Duane Arnold (NEDA) informed the NRC by letter dated August 27, 2020 (Accession No. ML20240A067); certifying the permanent cessation of power operations at the DAEC.

In October 2020 NEDA certified by letter (ML20286A317) the permanent defueling of the reactor at DAEC. Therefore, as specified in 10 CFR 50.82(a)(2), the 10 CFR Part 50 license for DAEC no longer authorizes operations of the reactor or emplacement or retention of fuel into the reactor vessel. In April 2022 all the nuclear fuel had been removed from the fuel pool and placed in dry cask storage at the site Independent Spent Fuel Storage Installation (ISFSI). There are no effluents from the ISFSI based on the design of the casks.

By December 2022 the plant was in SAFSTOR (a long-term storage condition for a permanently shutdown nuclear power plant). During SAFSTOR, radioactive contamination decreases substantially, making subsequent decontamination and demolition easier and reducing the amount of low level radioactive waste requiring disposal. All radioactive and service water systems were drained or placed in a stable condition. Plant systems are monitored, and adverse conditions are documented and addressed as needed.

The contribution of dose to a member of the public is most likely to be exposed from liquid and gaseous effluent releases. Calculation methods in the Defueled Offsite Dose Assessment Manual (DODAM) follow those prescribed by Regulatory Guide 1.109, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I".

2.0 SUMMARY

The Radiological Environmental Monitoring Program, as required by the U.S. Nuclear Regulatory Commission (NRC) Technical Specifications for the Duane Arnold Energy Center, is herein described. Results for the year 2023 are summarized and discussed. Information regarding DAEC effluents and the Defueled Offsite Dose Assessment Manual (DODAM) can be found in the 2023 DAEC Annual Radiological Material Release Report (ARMRR).

Program findings show only background levels of radioactivity in the environmental samples collected in the vicinity of the Duane Arnold Energy Center.

No effect on the environment is indicated in the areas surrounding the site of the Duane Arnold Energy Center.

3.0 RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

3.1 Program Design and Data Interpretation

The purpose of the Radiological Environmental Monitoring Program at the Duane Arnold Energy Center (DAEC) is to assess the impact of the plant on its environment. For this purpose, samples are collected from the air, terrestrial, and aquatic environments and analyzed for radioactive content. In addition, ambient gamma radiation levels are monitored by thermoluminescent dosimeters (TLDs).

Sources of environmental radiation include the following:

(1) Natural background radiation arising from cosmic rays and primordial radionuclides;
(2) Fallout from atmospheric nuclear detonations;
(3) Releases from nuclear power plants; and
(4) Industrial and medical radioactive waste.

In interpreting the data, effects due to the DAEC operation must be distinguished from those due to other sources.

A major interpretive aid in assessment of these effects is the design of the monitoring program at the DAEC which is based on the indicator-control concept. Most types of samples are collected both at indicator locations (nearby, downwind, or downstream) and at control locations (distant, upwind, or upstream). A station effect would be indicated if the radiation level at an indicator location was significantly larger than that at the control location. The difference would have to be greater than could be accounted for by typical fluctuations in radiation levels arising from other sources.

An additional interpretive technique involves analyses for specific radionuclides present in the environmental samples collected from the DAEC site. The DAEC's monitoring program includes analyses for strontium-90 which are fission products, and tritium, which is produced by cosmic rays, atmospheric nuclear detonations, and also by nuclear power plants. Most samples are also analyzed for gamma-emitting isotopes with results for the following groups quantified: zirconium-95, cesium-137, and cerium-144. These three gamma-emitting isotopes were selected as radiological impact indicators because of the different characteristic proportions in which they appear in the fission product mix produced by a nuclear reactor and that produced by a nuclear detonation. Each of the three isotopes is produced in roughly equivalent amounts by a reactor: each constitutes about 10% of the total activity of fission products ten (10) days after reactor shutdown. Alternatively, ten (10) days after a nuclear explosion, the contributions of zirconium-95, cerium-144, and cesium-137 to the activity of the resulting debris are in the approximate ratio 4:1:0.03 (Eisenbud,1963). The other group quantified consists of niobium-95, ruthenium-103 and -106, cesium-134, barium-lanthanum-140, and cerium-141. These isotopes are released in small quantities by nuclear power plants, but to date their major source of injection into the general environment has been atmospheric nuclear testing. Nuclides of the next group, manganese-54, cobalt-58 and-60, and zinc-65, are activation products and arise from activation of corrosion products. They are typical components of nuclear power plant effluents, but are not produced in significant quantities by nuclear detonations. Nuclides of the final group, beryllium-7, which is of cosmogenic origin, and potassium-40, a naturally-occurring isotope, were chosen as calibration monitors and provide a comparison between levels of naturally occurring radionuclides and radionuclides that could be attributed to the operation of the plant.

Characteristic properties of isotopes quantified in gamma-spectroscopic analysis are presented in Table 5.1. Other means of distinguishing sources of environmental radiation can be employed in interpreting the data. Current radiation levels can be compared with previous levels, including those measured before the plant became operational. Results of the DAEC's Monitoring Program

can be related to those obtained in other parts of the world. Finally, results can be related to events known to cause elevated levels of radiation in the environment, e.g., atmospheric nuclear detonations.

3.2 Program Description

3.2.1 Environmental Monitoring

The sampling and analysis schedule for the Radiological Environmental Monitoring Program (REMP) at the DAEC is summarized in Table 5.2 and is briefly reviewed below. Table 5.3 defines the sampling location codes used in Table 5.2 and specifies for each location its distance, direction, and sector relative to the reactor site. The types of samples collected at each location and the frequency of collections are presented in Table 5.4 using codes defined in Table 5.5.

To monitor the air environment, a continuous air sampler is employed. Airborne particulates at the remaining locations are indicators: D-15 and D-16. Filters are changed and counted bi-weekly. Particulate filters are analyzed for gross beta activity. If gross beta activity exceeds ten times the yearly mean of the control samples, gamma isotopic analysis is performed. Quarterly composites of airborne particulates from each location are analyzed for gamma emitting isotopes.

Ambient gamma radiation is monitored at a total of 22 locations. A TLD is placed at each location and exchanged and analyzed quarterly.

Surface water is collected monthly from two total locations: D-49 and D-61. The monthly samples are analyzed for tritium and gamma-emitting isotopes.

The aquatic environment is also monitored at D-49 and D-61 with semiannual fish collection.

Cedar River bottom sediment is collected semiannually at the D-49 and D-51. The samples are analyzed for gamma-emitting isotopes.

Drinking water is collected monthly from D-52 and D-53. The samples are analyzed for tritium and gamma emitting isotopes. Any positive identification of a reactor by-product material initiates analyses for hard to detect isotopes of Ni-63, Sr-89, Sr-90, Fe-55 and gross alpha.

Milk sampling was discontinued in November of 2020.

Additional monitoring of the terrestrial environment, grain, forage and broadleaf vegetation samples are collected annually, as available, from two indicators locations D-015 and D-016. Grain, forage and broadleaf (green leafy) vegetation samples are analyzed for gamma-emitting isotopes and at least two broad leaf vegetation samples are analyzed for iodine-131.

If any of the cattle grazing on-site are slaughtered for home use, a meat sample is collected. The sample is analyzed for gamma-emitting isotopes.

3.2.2 Groundwater Protection Program

The Duane Arnold Energy Center has committed to the Nuclear Energy Institute's Industry Groundwater Protection Initiative – NEI 07-07. The Groundwater Protection Plan (GWPP) is a component of the Duane Arnold Energy Center's Radiological Environmental Monitoring Program (REMP). As such, REMP and GWPP sampling and analysis except for sewage effluent results can be found in the Duane Arnold Energy Center 2023 Annual Radiological Environmental Operating Report.

In 2016, a tritium plume was discovered as part of the GWPP inside the owner controlled area / directly adjacent to the turbine building. A professional engineering firm was hired to model the soil type, groundwater flow and location of groundwater extraction wells. Three extraction wells and twenty additional monitoring wells were installed in the SSE direction / within the site conceptual flow toward the Cedar River (to the Southeast of the turbine building). Samples of

thirty-one monitoring wells in and around the area of the plume are sent to Microbac Laboratories, Inc. in Northbrook, IL for additional confirmatory analysis. In 2023, all thirty-one sample results were <1000 pCi/L.

The sampling and collection schedule can be found in DODAM Table 6.3-2, and the sampling locations are shown in Figure 5-1 and Figure 5-2.

Sewage effluent

Samples were collected during operation of the sewage treatment plant bi-weekly; there were no plant by-products identified in the samples. The maximum value for the lower limit of detection (LLD) for environmental sample analysis are noted in the DODAM Table 6.3-3 Maximum Values of the Lower Limit of Detection for Environmental Sample Analysis.

The sewage treatment facility has been shut down; the Iowa Department of Natural Resources in Manchester, Iowa was informed in May of 2023. The influent pipes from the plant sources outside the security building was cut and plugged, the influent pumps were shut off, the discharge pipe was plugged, and the system was emptied.

3.3 Program Execution

The program was executed as described in the preceding section with the following exceptions:

- The second quarter TLD for location D-31 was missing in the field.

3.4 Laboratory Procedures

Levels of iodine-131 in vegetation and concentrations of airborne iodine-131 were determined by gamma spectroscopy.

Gamma-spectroscopic analyses are performed using high-purity germanium (HPGe) detectors. The gamma isotopic analysis provides a spectrum with an energy range from 80 to 2048 KeV. Specific isotopes included in the gamma library are Mn-54, Fe-59, Co-58, Co-60, Zn-65, Zr-95, Nb-95, Ru-103, Ru-106, I-131, Ba-La-140, Cs-134, Cs-137, Ce-141, and Ce-144. Naturally occurring gamma-emitters, such as Be-7, K-40 and Ra daughters, are frequently detected but may not be listed.

Tritium was measured by liquid scintillation spectrometry.

Analytical Procedures used by Environmental, Inc. are on file and are available for inspection. Procedures are based on those prescribed by the Health and Safety Laboratory of the U.S. Dep't of Energy, Edition 28, 1997, U.S. Environmental Protection Agency for Measurement of Radioactivity in Drinking Water, 1980, and the U.S. Environmental Protection Agency, EERF, Radiochemical Procedures Manual, 1984.

Microbac Laboratories – Northbrook (previously Environmental Inc. Midwest laboratory) has a comprehensive quality control/quality assurance program designed to assure the reliability of data obtained. Details of the QA Program are presented elsewhere (Microbac Laboratories Inc - Northbrook, 2023). The QA Program includes participation in Interlaboratory Comparison (crosscheck) Programs. Results obtained in crosscheck programs are presented in Appendix A.

3.5 Program Modifications

A new well was added to the program in the second quarter of 2023. (See table 5 location D-55). This location ultimately did replace the well at location D-52.

Eight temporary TLD sampling locations were added to the program for the third and fourth quarter of 2023.

4.0 RESULTS AND DISCUSSION

All collections and analyses were made as scheduled, except for those listed in Table 5.6.

Results are summarized in Table 5.7 as recommended by the Nuclear Regulatory Commission. For each type of analysis and sample medium, the table lists the mean and range of all indicator and control locations, as well as that location with the highest mean and range.

Tabulated results of measurements are not included in this section, although reference to these results will be made in discussion. A complete tabulation of results for 2023 is contained in Part II of the Annual Report on the Radiological Environmental Monitoring Program for the Duane Arnold Energy Center.

4.1 Atmospheric Nuclear Detonations and Nuclear Accidents

There were no reported accidents involving significant release to the environment at nuclear reactor facilities in 2023. The Fukushima Daiichi nuclear accident occurred March 11, 2011.

There were no reported atmospheric nuclear tests in 2023. The last reported test was conducted on October 16, 1980 by the People's Republic of China.

4.2 Program Findings

Results obtained show background levels of radioactivity in the environmental samples collected outside of the Owner Controlled Area in 2023.

Airborne Particulates

The average annual gross beta concentrations in airborne particulates were 0.030 pCi/m3 at the indicator locations. Sampling has been discontinued at the control location. The results are consistent with levels observed from 2000 through 2022. The historical results are tabulated below.

Year	Indicators	Controls		Year	Indicators	Controls
Concentration (pCi/m^3)				Concentration (pCi/m^3)		
2000	0.026	0.027		2012	0.030	0.029
2001	0.026	0.026		2013	0.028	0.025
2002	0.027	0.027		2014	0.026	0.025
2003	0.029	0.029		2015	0.027	0.024
2004	0.028	0.028		2016	0.027	0.023
2005	0.031	0.031		2017	0.028	0.025
2006	0.029	0.027		2018	0.028	0.026
2007	0.031	0.031		2019	0.026	0.025
2008	0.029	0.029		2020	0.026	0.026
2009	0.031	0.030		2021	0.031	0.028
2010	0.028	0.028		2022	0.030	0.053
2011	0.030	0.029		2023	0.030	NA

Average annual gross beta concentrations in airborne particulates.

NA – Not analyzed. Sampling has been discontinued at the control location.

4.2 Program Findings, Airborne Particulates (continued)

Gamma spectroscopic analysis of quarterly composites of air particulate filters yielded Beryllium-7 results for the indicator locations similar to last year's results. Sampling has been discontinued at the control location. Beryllium-7,produced continuously in the upper atmosphere by cosmic radiation (Arnold and Al-Salih, 1955), is typically detected in quarterly air samples. No reactor by-product radionuclides were identified in any of the air samples analyzed. All samples met required lower limits of detection as specified in the ODAM.

Airborne Iodine

All iodine sampling has been discontinued.

Ambient Radiation (TLDs)

103 TLDs were collected and analyzed in 2023. At the control location, D-4, thermoluminescent dosimeter (TLD) readings averaged 16.8 mR/quarter. At locations within a half mile, one mile and three mile radius of the stack, the measurements averaged 16.9, 18.6 and 15.3 mR/quarter, respectively. The on-site location D-15 averaged 14.5 mR/quarter. These average measurements are similar to the estimated average natural background radiation for Middle America, 19.5 mR/quarter, which is based on data on Pages 71 and 108 of the report, "Natural Background Radiation in the United States" (National Council on Radiation Protection and Measurements, 1975). The terrestrial absorbed dose (uncorrected for structural and body shielding) ranges from 8.8 to 18.8 mrad/quarter and averages 11.5 mrad/quarter for Middle America. Cosmic radiation and cosmogenic radionuclides contribute 8.0 mrad/quarter for a total average of 19.5 mrad/quarter. No plant effect is indicated.

ISFSI Facility Operations Monitoring

Four TLDs, placed directionally along the ISFSI fence line, averaged 62.4 mR/quarter. Eight temporary TLD locations were added for the third and fourth quarter of 2023. These TLD's averaged 42.7 mR/quarter.

Calculations performed using thermoluminescent dosimeters (TLDs) data has determined that radiation within 300 feet of the ISFSI is statistically higher than background. There is direct radiation for members of the public that are on site and close (within 300 feet) of the ISFSI. For members of the public who traverse the road adjacent to the ISFSI the residency time is considered negligible and hence the dose is "0".

Groundwater (drinking water-potable)

The location designation D-55 was used to document the analysis of a new drinking water well for the site Security Building. Once the permitting was complete the new drinking water well was submitted with the D-52 Plant Potable water.

28 drinking water samples from three locations were collected in 2023. Tritium concentrations in ground water samples were less than the MDC of 172 pCi/L in all samples analyzed. I-131 and other gamma-emitting isotopes were below detection limits.

No reactor by-product radionuclides could be identified. All samples met required lower limits of detection as specified in the ODAM.

4.2 Program Findings (continued)

Vegetation

Six vegetation samples from two locations were collected in 2023 consisting of green leafy vegetation, forage and grain samples. Iodine-131 concentrations in vegetation samples were less than the LLD level of 0.043 pCi/g wet weight in the two green leafy vegetation samples and less 0.054 pCi/g wet in the four grain and forage samples analyzed.

Naturally occurring potassium-40 was the only other gamma-emitting isotope observed in all vegetation samples, all other gamma-emitting isotopes were below detection limits. All samples met required lower limits of detection as specified in the ODAM.

Surface Water

24 surface water samples were collected from two locations in 2023. No tritium was detected above an LLD of 172 pCi/L. No gamma emitting isotopes were measured above their respective LLD's in any of the samples tested.

Fish

Seven fish samples from three sport fish species were collected in April and November, 2023, and analyzed for gamma-emitting isotopes. With the exception of naturally-occurring potassium-40, no gamma-emitting isotopes were identified in edible portions of fish. The potassium-40 level was similar at both the indicator and control locations (3.92 and 3.96 pCi/g wet, respectively).

No reactor by-product radionuclides were identified. All samples met required lower limits of detection as specified in the ODAM.

River Sediments

Four river sediment samples from two locations were collected in 2023 during the months of April and November, and analyzed for gamma-emitting isotopes. Potassium-40 activity ranged from 7.73 to 10.18 pCi/g dry weight at the indicator locations and between 7.21 and 9.97 pCi/g dry weight at the control location.

All samples met required lower limits of detection as specified in the ODAM-DODAM.

4.3 Ground Water Protection Program Findings

Microbac Laboratories - Northbrook provides laboratory services for the Duane Arnold Energy Center Ground Water Protection Program except for sewage effluent results.

Groundwater

31 groundwater samples (non-potable water) were collected from 31 permitted monitoring wells 2023. Tritium was the only plant by-product identified. Concentrations of tritium ranged from less than 157 pCi/L to 964 pCi/L at D-132A, monitoring well MW-12A. Tritium was not identified in any drinking water well on-site or at off-site wells or Cedar Rapids municipal drinking water samples. Lastly, the monitoring well farthest down gradient prior to the boundary of the owner-controlled area and the Cedar River, MW-33A, no tritium was detected above an MDC of 167 pCi/L.

5.0 TABLES AND FIGURES

Table 5.1 Characteristic properties of isotopes quantified in gamma-spectroscopic analyses.

Designation	Comment	Isotope	Half-life [a]
Naturally Occurring			
A. Cosmogenic	Produced by interaction of cosmic rays with atmosphere	Be-7	53.2 d
B. Terrestrial	Primordial	K-40	1.26×10^9 y
II. Fission Products [b]	Nuclear accidents and detonations constitute the major environmental source.		
A. Short-lived		I-131	8.04 d
		Ba-140	12.8 d
B. Other than Short-lived		Nb-95	35.15 d
		Zr-95	65 d
		Ru-103	39.35 d
		Ru-106	368.2 d
		Cs-134	2.061 y
		Cs-137	30.174 y
		Ce-141	32.5 d
		Ce-144	284.31 d
III. Activation Products	Typically found in nuclear power plant effluents	Mn-54	312.5 d
		Fe-59	45.0 d
		Co-58	70.78 d
		Co-60	5.26 y
		Zn-65	245 d

[a] Half-lives are taken from Appendix E of Environmental Quarterly, 1 January 1978, EML-334 (U. S. Department of Energy, 1978).

[b] Includes fission-product daughters.

Table 5.2 Sample collection and analysis program.

Sampling Location [a]				
Exposure Pathway and/or Sample Type	Sample Point	Description	Sampling and Collection Frequency	Type and Frequency of Analysis [b]
Airborne Particulates	15 16	On-site North On-site South	Continuous operation of sampler with sample collection at least once monthly or as required by dust loading	Analyze for gross beta activity more than 72 hours after filter change. Perform gamma isotopic analysis on each sample having gross beta activity greater than ten times the yearly mean of the control samples. Composite weekly samples to form a quarterly composite (by location). Analyze quarterly composite for gamma isotopic.
Ambient Radiation	4 15,17,18, 20,22,29, 31, 83, 85 33,35,37, 39,42 43,46,48 161-164	(Controls) (Indicators) Within 0.5 mile of Stack Within 3.0 miles of Stack Within 1.0 mile of Stack ISFSI Fence line	One dosimeter continuously at each location. Dosimeters are changed at least quarterly.	Read gamma radiation dose quarterly.
Surface Water	49 61	Lewis Access (C) Plant Discharge ~ ½ mi. downstream from Plant Discharge	Once per month.	Gamma isotopic and tritium analysis for each sample (by location).

Table 5.2 Sample collection and analysis program, (continued).

Sampling Location [a]				
Exposure Pathway and/or Sample Type	Sample Point	Description	Sampling and Collection Frequency	Type and Frequency of Analysis [b]
Ground Water	52 53	Plant potable water Treated Municipal Water	Grab sample at least once per quarter	Analysis gamma emitting isotopes, and tritium on quarterly samples. If reactor by-product gamma emitters are identified, or if tritium concentrations measure > MDA, then analyze for Ni-63, Sr-89, Sr-90 and alpha emitters.
River Sediment	49 51	Lewis Access Plant Discharge	At least once every six months.	Gamma isotopic analysis of each sample
Vegetation	15,16	Farms raising food crops	Annually at harvest time. Two samples of each: grain, green leafy, and forage.	Gamma isotopic analysis, of each sample.
Fish	49 61	Cedar River upstream of DAEC not influenced by effluent (C) Downstream of DAEC in influence of effluent	One sample per 6 months (once during January through June and once during July through December).	Gamma isotopic analysis on edible portions.

[a] (C) denotes control location. All other locations are indicators.
[b] Gamma isotopic analysis and analysis for gamma-emitting nuclides refer to high resolution gamma ray spectrum analysis.
[c] Sample collection discontinued after 01-08-22 collection period

Table 5.3 Sampling locations, Duane Arnold Energy Center.

Sampling Location		
Code	Location Description	Distance and Direction from Site Stack
D-4	Pleasant Creek SRA	4,960 meters NW
D-15	On-site, North-Northwest	1,050 meters NNW
D-16	On-site, SSE	520 meters SSE
D-17	On-site, N	1,050 meters N
D-18	On-site, NNE	630 meters NNE
D-20	On-site, ENE	550 meters ENE
D-22	On-site, ESE	535 meters ESE
D-29	On-site, W	630 meters W
D-31	On-site, NW	1,020 meters NW
D-33	3 mile ring	4,340 meters N
D-35	3 mile ring	2,800 meters NE
D-37	3 mile ring	2,960 meters E
D-39	3 mile ring	2,510 meters SE
D-42	3 mile ring	4,380 meters SSE
D-43	1 mile ring	1,590 meters SSW
D-46	1 mile ring	1,580 meters WNW
D-48	1 mile ring	1,680 meters NNW

Table 5.3 Sampling locations, Duane Arnold Energy Center (continued).

Sampling Location		
Code	Location Description	Distance and Direction from Site Stack
D-49	Lewis Access, upstream of DAEC	6,750 meters NNW
D-51	Plant Discharge	600 meters SE
D-52	Plant potable water	On-site
D-53	Treated Municipal Water	13,900 meters SE
D-61	Downstream of plant discharge	670 meters SSE
D-83	On-site, SSE	620 meters SSE
D-85	On-site, SSW	660 meters SSW
D-161	ISFSI Fence East	On-site
D-162	ISFSI Fence South	On-site
D-163	ISFSI Fence West	On-site
D-164	ISFSI Fence North	On-site

Table 5.4 Type and Frequency of collections.

Location	Monthly	Quarterly	Semiannually	Annually
D-4		TLD		
D-15	AP	TLD		G
D-16	AP			G
D-17		TLD		
D-18		TLD		
D-20		TLD		
D-22		TLD		
D-29		TLD		
D-31		TLD		
D-33		TLD		
D-35		TLD		
D-37		TLD		
D-39		TLD		
D-42		TLD		
D-43		TLD		
D-46		TLD		
D-48		TLD		
D-49	SW		BS, F	
D-51			BS	
D-52	WW			
D-53	WW			
D-61	SW		F	
D-83, D-85		TLD		
D-161 to D-164		TLD		

Table 5.5. Sample codes used in Table 5.4 and Table 5.6.

Code	Description
AP	Airborne Particulates
AI	Airborne Iodine
TLD	Thermoluminescent Dosimeter
MI	Milk
WW	Well Water
G	Vegetation
ME	Meat
SW	Surface Water
F	Fish
BS	River Sediment
SO	Soil

Table 5.6. Program Deviations, Duane Arnold Energy Center.

Sample Type	Analysis	Location(s)	Collection Date or Period	Comments
TLD	Direct Radiation	D-31	2nd Qtr '23	TLD missing in field

Table 5.7 Radiological Environmental Monitoring Program Summary.

Name of Facility	Duane Arnold Energy Center	Docket No.	50-331
Location of Facility	Linn, Iowa	Reporting Period	January-December, 2023

Sample Type (Units)	Type and Number of Analyses [a]	LLD [b]	Indicator Locations Mean (F) [c] Range [c]	Location with Highest Annual Mean		Control Locations Mean (F) [c] Range [c]	Number Non-Routine Results [e]
				Location [d]	Mean (F) [c] Range [c]		
Airborne Pathway							
Airborne Particulates (pCi/m^3)	GB 101	0.003	0.030 (101/101) (0.013-0.073)	D-16	0.032 (1/50) (0.017-0.070)	-	0
	GS 7						
	Be-7	0.146	0.060 (8/8) (0.050-0.070)	D-16	0.063 (4/4) (0.050-0.070)	< LLD	0
	Mn-54	0.0011	< LLD	-	-	< LLD	0
	Fe-59	0.0035	< LLD	-	-	< LLD	0
	Co-58	0.0012	< LLD	-	-	< LLD	0
	Co-60	0.0018	< LLD	-	-	< LLD	0
	Zn-65	0.0021	< LLD	-	-	< LLD	0
	Nb-95	0.0016	< LLD	-	-	< LLD	0
	Zr-95	0.0019	< LLD	-	-	< LLD	0
	Ru-103	0.0015	< LLD	-	-	< LLD	0
	Ru-106	0.0094	< LLD	-	-	< LLD	0
	Cs-134	0.0014	< LLD	-	-	< LLD	0
	Cs-137	0.0013	< LLD	-	-	< LLD	0
	Ce-141	0.0028	< LLD	-	-	< LLD	0
	Ce-144	0.0058	< LLD	-	-	< LLD	0
Direct Radiation							
TLDs (mR/quarter) Control Locations	Gamma 4	1.0	None	D-4	16.8 (4/4) (16.1-17.7)	16.8 (4/4) (16.1-17.7)	0
Within 0.5 mi. of Stack	Gamma 35	1.0	15.1 (35/35) (11.7-19.5)	D-29 / D-31	16.9 (4/4)/(4/4) (15.1-17.6)/ (16.0-18.1)	None	0
Within 1.0 mi. of Stack	Gamma 12	1.0	16.7 (12/12) (12.7-20.6)	D-42	18 6 (4/4) (17.7-19.6)	None	0
Within 3.0 mi.of Stack	Gamma 20	1.0	13.9 (20/20) (10.4-17.6)	D-42	15.3 (4/4) (14.4-17.6)	None	0
ISFSI border	Gamma 32	1.0	52.5 (32/32) (18.3-96.1)	D-161 to D-164	90.5 (4/4) (84.8-96.1)	None	0

Table 5.7 Radiological Environmental Monitoring Program Summary.

Name of Facility	Duane Arnold Energy Center	Docket No.	50-331
Location of Facility	Linn, Iowa	Reporting Period	January-December, 2023

Sample Type (Units)	Type and Number of Analyses [a]	LLD [b]	Indicator Locations Mean (F) [c] Range [c]	Location with Highest Annual Mean		Control Locations Mean (F) [c] Range [c]	Number Non-Routine Results [e]
				Location [d]	Mean (F) [c] Range [c]		
Waterborne Pathway							
Surface Water (pCi/L)	H-3 24	172	< LLD	D-49	-	< LLD	0
	GS 24						
	Mn-54	8.1	< LLD	-	-	< LLD	0
	Fe-59	20.0	< LLD	-	-	< LLD	0
	Co-58	8.3	< LLD	-	-	< LLD	0
	Co-60	8.9	< LLD	-	-	< LLD	0
	Zn-65	14.3	< LLD	-	-	< LLD	0
	Nb-95	9.5	< LLD	-	-	< LLD	0
	Zr-95	14.0	< LLD	-	-	< LLD	0
	I-131	12.1	< LLD	-	-	< LLD	0
	Cs-134	9.7	< LLD	-	-	< LLD	0
	Cs-137	8.5	< LLD	-	-	< LLD	0
	Ba-140	39.7	< LLD	-	-	< LLD	0
	La-140	10.8	< LLD	-	-	< LLD	0
Sediments Ci/g dry)	GS 4						
	K-40	1.0	8.75 (2/2) (7.33-10.18)	D-51	8.75 (2/2) (7.73-10.18)	8.59 (2/2) (7.21-9.97)	0
	Mn-54	0.0381	< LLD	-	-	< LLD	0
	Fe-59	0.112	< LLD	-	-	< LLD	0
	Co-58	0.045	< LLD	-	-	< LLD	0
	Co-60	0.029	< LLD	-	-	< LLD	0
	Zn-65	0.062	< LLD	-	-	< LLD	0
	Nb-95	0.079	< LLD	-	-	< LLD	0
	Zr-95	0.083	< LLD	-	-	< LLD	0
	Ru-103	0.052	< LLD	-	-	< LLD	0
	Ru-106	0.180	< LLD	-	-	< LLD	0
	Cs-134	0.022	< LLD	-	-	< LLD	0
	Cs-137	0.016	0.07 (1/2)	D-49	0.08 (1/2)	0.08 (1/2)	0
	Ce-141	0.113	< LLD	-	-	< LLD	0
	Ce-144	0.212	< LLD	-	-	< LLD	0

Table 5.7 Radiological Environmental Monitoring Program Summary.

Name of Facility	Duane Arnold Energy Center	Docket No.	50-331
Location of Facility	Linn, Iowa	Reporting Period	January-December, 2023

Sample Type (Units)	Type and Number of Analyses [a]	LLD [b]	Indicator Locations Mean (F) [c] Range [c]	Location with Highest Annual Mean		Control Locations Mean (F) [c] Range [c]	Number Non-Routine Results [e]
				Location [d]	Mean (F) [c] Range [c]		
Waterborne Pathway							
Ground Water, potable (pCi/L)							
	H-3 28	172	< LLD	-	-	< LLD	0
	GS 28						
	Mn-54	7.4	< LLD	-	-	< LLD	0
	Fe-59	13.4	< LLD	-	-	< LLD	0
	Co-58	8.9	< LLD	-	-	< LLD	0
	Co-60	9.1	< LLD	-	-	< LLD	0
	Zn-65	7.8	< LLD	-	-	< LLD	0
	Nb-95	8.1	< LLD	-	-	< LLD	0
	Zr-95	15.0	< LLD	-	-	< LLD	0
	I-131	14.6	< LLD	-	-	< LLD	0
	Cs-134	8.5	< LLD	-	-	< LLD	0
	Cs-137	8.3	< LLD	-	-	< LLD	0
	Ba-140	38.3	< LLD	-	-	< LLD	0
	La-140	13.7	< LLD	-	-	< LLD	0
Ingestion Pathway							
Broadleaf Vegetation (pCi/g wet)	GS 2						
	K-40	0.05	4.63 (2/2) (3.40-5.86)	D-16	8.86 (1/1)	None	0
	Mn-54	0.026	< LLD	-	-	-	0
	Fe-59	0.056	< LLD	-	-	-	0
	Co-58	0.028	< LLD	-	-	-	0
	Co-60	0.062	< LLD	-	-	-	0
	Zn-65	0.052	< LLD	-	-	-	0
	Nb-95	0.027	< LLD	-	-	-	0
	Zr-95	0.041	< LLD	-	-	-	0
	Ru-103	0.032	< LLD	-	-	-	0
	Ru-106	0.188	< LLD	-	-	-	0
	I-131	0.043	< LLD	-	-	-	0
	Cs-134	0.032	< LLD	-	-	-	0
	Cs-137	0.050	< LLD	-	-	-	0
	Ce-141	0.056	< LLD	-	-	-	0
	Ce-144	0.258	<LLD	-	-	-	0

Table 5.7 Radiological Environmental Monitoring Program Summary.

Name of Facility	Duane Arnold Energy Center	Docket No.	50-331
Location of Facility	Linn, Iowa (County, State)	Reporting Period	January-December, 2023

Sample Type (Units)	Type and Number of Analyses [a]	LLD [b]	Indicator Locations Mean (F) [c] Range [c]	Location with Highest Annual Mean		Control Locations Mean (F) [c] Range [c]	Number Non-Routine Results [e]
				Location [d]	Mean (F) [c] Range [c]		
Ingestion Pathway (cont.)							
Vegetation (Grain and Forage) (pCi/g wet)	GS 4						
	K-40	0.05	3.92 (4/4) (2.30-5.46)	D-16	3.96 (2/2) (3.56-4.37)	None	0
	Mn-54	0.025	< LLD	-	-		0
	Fe-59	0.064	< LLD	-	-		0
	Co-58	0.023	< LLD	-	-		0
	Co-60	0.049	< LLD	-	-		0
	Zn-65	0.056	< LLD	-	-		0
	Nb-95	0.032	< LLD	-	-		0
	Zr-95	0.051	< LLD	-	-		0
	Ru-103	0.024	< LLD	-	-		0
	Ru-106	0.274	< LLD	-	-		0
	I-131	0.054	< LLD	-	-		0
	Cs-134	0.029	< LLD	-	-		0
	Cs-137	0.041	< LLD	-	-		0
	Ce-141	0.065	< LLD	-	-		0
	Ce-144	0.172	< LLD	-	-		0
Fish (pCi/g wet)	GS	7					
	K-40	1.0	3.92 (4/4) (3.61-4.30)	D-61	3.92 (4/4) (3.61-4.30)	3.54 (3/3) (3.44-3.65)	0 0
	Mn-54	0.019	< LLD	-	-	< LLD	0
	Fe-59	0.053	< LLD	-	-	< LLD	0
	Co-58	0.023	< LLD	-	-	< LLD	0
	Co-60	0.026	< LLD	-	-	< LLD	0
	Zn-65	0.065	< LLD	-	-	< LLD	0
	Nb-95	0.045	< LLD	-	-	< LLD	0
	Zr-95	0.049	< LLD	-	-	< LLD	0
	Ru-103	0.035	< LLD	-	-	< LLD	0
	Ru-106	0.175	< LLD	-	-	< LLD	0
	Cs-134	0.023	< LLD	-	-	< LLD	0
	Cs-137	0.025	< LLD	-	-	< LLD	0
	Ce-141	0.055	< LLD	-	-	< LLD	0
	Ce-144	0.151	< LLD	-	-	< LLD	0

[a] GB = Gross beta; GS = Gamma spectroscopy

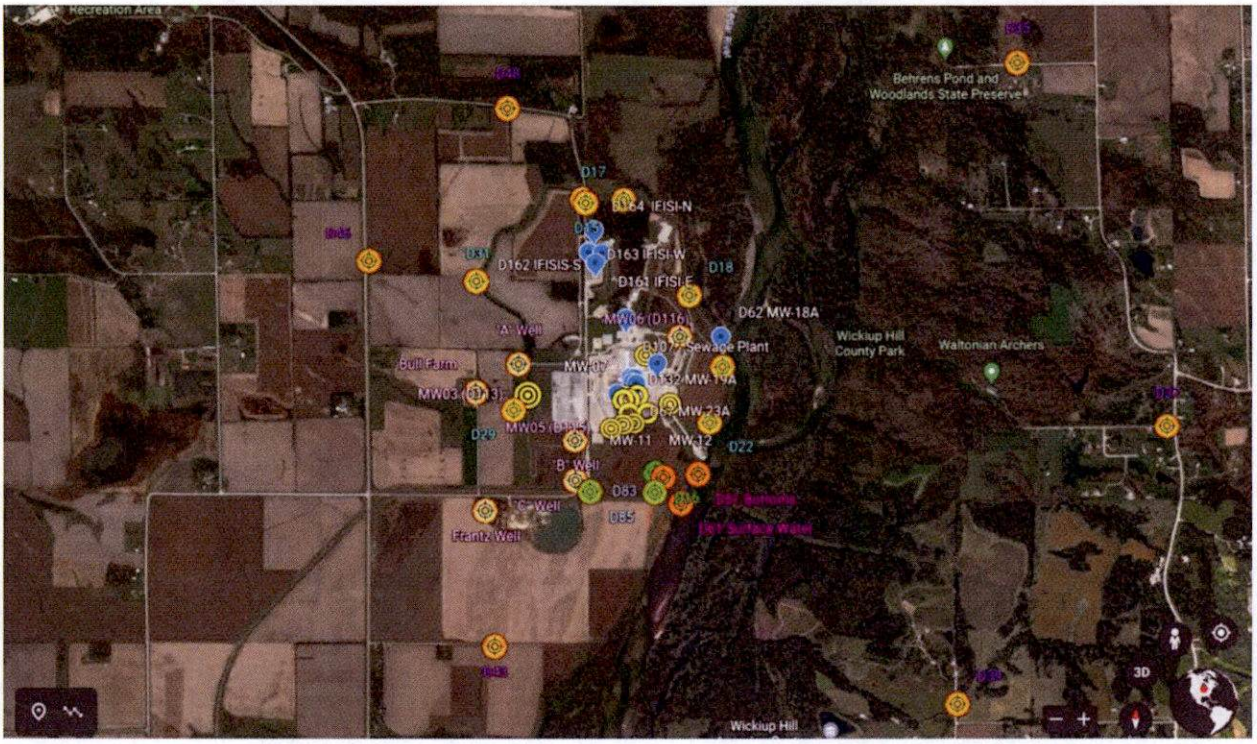
[b] LLD = Nominal lower limit of detection based on 4.66 sigma counting error for the background sample.

[c] Mean and range based upon detectable measurements only. Fraction of detectable measurements at specified locations is indicated in parentheses (F).

[d] Locations are specified by: (1) Name and code (Table 5.3); and (2) distance, direction and sector relative to reactor site.

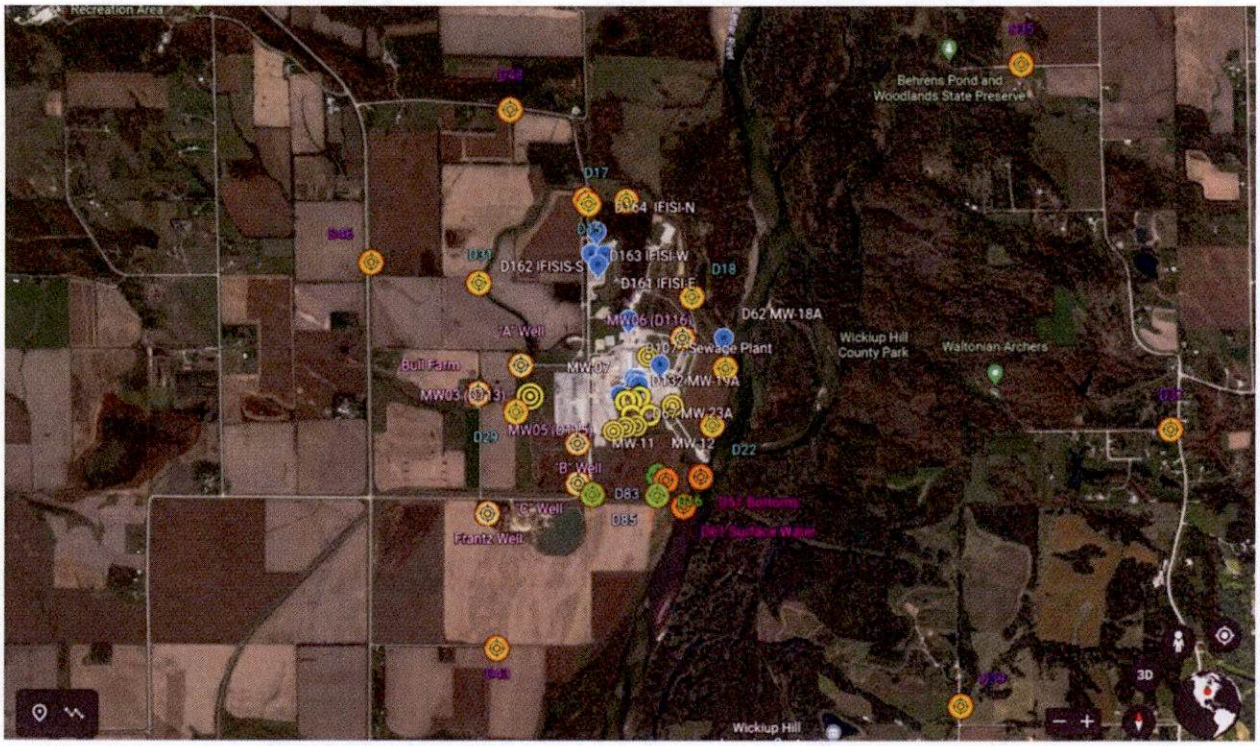
[e] Non-routine results are those which exceed ten times the control station value for the location. If a control station value is not available, the result is considered non-routine if it exceeds ten times the preoperational value for the location.

Figure 5-1
Environmental Monitoring Programs
Sampling Near the Duane Arnold Energy Center
Small Area



See Table 5.3 for sampling locations and Table 5.4 for Type and Frequency of collection.

Figure 5-2
Radiological Environmental Monitoring Program
Sampling Stations Outside 0.5 Miles from DAEC
Large Area



See Table 5.3 for sampling locations and Table 5.4 for Type and Frequency of collection.

6.0 REFERENCES CITED

Arnold, J. R. and H. A. Al-Salih. 1955. Beryllium-7 Produced by Cosmic Rays. Science 121: 451-453.

Eisenbud, M. 1963. Environmental Radioactivity, McGraw-Hill, New York, New York, pp. 213, 275-276.

Environmental, Inc., Midwest Laboratory.

_____2015 Study Plan, SP-DAEC-8001, revision 24 February 12, 2015, The Operational Radiological Environmental Monitoring Program for the Duane Arnold Energy Center, Cedar Rapids, Iowa

_____2001 through 2022. Environmental Radiological Monitoring Program for the Duane Arnold Energy Center, Annual Report - Part II, Data Tabulations and Analyses, January - December, 2001 – 2019.

_____1984 to 2000. (formerly Teledyne Brown Engineering, Environmental Services, Midwest Laboratory) Environmental Radiological Monitoring Program for the Duane Arnold Energy Center, Annual Report - Part II, Data Tabulations and Analyses, January - December, 1983 - 1999.

_____1982 to 1984. (formerly Hazleton Environmental Sciences Corporation) Environmental Radiation Monitoring for the Duane Arnold Energy Center, Annual Report - Part II, Data Tabulations and Analyses, January - December 1981 - 1983.

_____2022. Quality Manual, Rev. 8, 17 October 2022.

_____2012. Quality Assurance Program Manual, Rev. 3, 14 November 2012.

_____2022. Quality Control Procedures Manual, Rev. 5, 9 May 2022.

_____2009. Quality Control Program, Rev. 2, 12 November 2009.

Microbac Laboratories-Northbrook (Before June 1, 2023 Environmental Inc.)

_____2023. Quality Manual, Rev. 9, 25 August 2023.

Gold, S., H. W. Barkhau, B. Shlein, and B. Kahn, 1964. Measurement of Naturally Occurring Radionuclides in Air, in the Natural Environment, University of Chicago Press, Chicago, Illinois, 369-382.

National Center for Radiological Health, 1968. Radiological Health and Data Reports, Vol. 9, Number 12, 730-746.

U. S. Department of Energy. 1978. Environmental Quarterly, Appendix E. Half-Life Tables, 1 January 1978, EML-334.

U. S. Nuclear Regulatory Commission. 1977. Regulatory Guide 1.109, Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10CFR Part 50, Appendix I.

Wilson, D. W., G. M. Ward and J. E. Johnson. 1969. In Environmental Contamination by Radioactive Materials, International Atomic Energy Agency. p.125.

MICROBAC®
700 Landwehr Road • Northbrook, IL 60062-2310
phone (847) 564-0700 • fax (847) 564-4517

APPENDIX A

INTERLABORATORY AND INTRALABORATORY COMPARISON PROGRAM RESULTS

NOTE: Appendix A is updated four times a year. The complete appendix is included in March, June, September and December monthly progress reports only.

January, 2023 through December, 2023

Appendix A

Interlaboratory/ Intralaboratory Comparison Program Results

Microbac Laboratories - Northbrook (previously Environmental Inc.) has participated in interlaboratory comparison (crosscheck) programs since the formulation of its quality program in December 1971. These programs are operated by agencies and/or companies which supply environmental sample types containing concentrations of radionuclides known to the issuing entity but not to participant laboratories. The purpose of such a program is to provide an independent check on a laboratory's analytical procedures and to alert it of any possible problems.

Participant laboratories measure the concentration of specified radionuclides and report them to the issuing agency. Several months later, the agency reports the known values to the participant laboratories and specifies control limits. Results consistently higher or lower than the known values or outside the control limits indicate a need to check the instruments or procedures used.

Results in Table A-1 were obtained through participation in the RAD PT Study Proficiency Testing Program administered by Environmental Resource Associates, serving as a replacement for studies conducted previously by the U.S. EPA Environmental Monitoring Systems Laboratory, Las Vegas, Nevada.

Table A-2 lists results for thermoluminescent dosimeters (TLDs), via irradiation and evaluation by the University of Wisconsin-Madison Radiation Calibration Laboratory at the University of Wisconsin Medical Radiation Research Center.

Table A-3 lists results of the analyses on intralaboratory "spiked" samples for the past twelve months. All samples are prepared using NIST traceable sources. Data for previous years available upon request.

Table A-4 lists results of the analyses on intralaboratory "blank" samples for the past twelve months. Data for previous years available upon request.

Table A-5 lists analytical results from the intralaboratory "duplicate" program for the past twelve months. Acceptance is based on each result being within 25% of the mean of the two results or the two sigma uncertainties of each result overlap.

The results in Table A-6 were obtained through participation in the Mixed Analyte Performance Evaluation Program.

Results in Table A-7 were obtained through participation in the MRAD PT Study Proficiency Testing Program administered by Environmental Resource Associates, serving as a replacement for studies conducted previously by the Environmental Measurement Laboratory Quality Assessment Program (EML).

Attachment A lists the laboratory acceptance criteria for various analyses.

Out-of-limit results are explained directly below the result.

Attachment A

ACCEPTANCE CRITERIA FOR INTRALABORATORY "SPIKED" SAMPLES

Analysis	Ratio of lab result to known value.
Gamma Emitters	0.8 to 1.2
Strontium-89, Strontium-90	0.8 to 1.2
Potassium-40	0.8 to 1.2
Gross alpha	0.5 to 1.5
Gross beta	0.8 to 1.2
Tritium	0.8 to 1.2
Radium-226, Radium-228	0.7 to 1.3
Plutonium	0.8 to 1.2
Iodine-129, Iodine-131	0.8 to 1.2
Nickel-63, Technetium-99, Uranium-238	0.7 to 1.3
Iron-55	0.8 to 1.2
Other Analyses	0.8 to 1.2

TABLE A-1. Interlaboratory Comparison Crosscheck program, Environmental Resource Associates (ERA)[a].

RAD study

Lab Code	Date	Analysis	Concentration (pCi/L) Laboratory Result	ERA Value	Acceptance Limits	Acceptance
RAD-132 Study						
ERDW-162	2/23/2023	Ba-133	33.0 ± 3.5	30.5	24.2 - 34.6	Pass
ERDW-162	2/23/2023	Cs-134	30.7 ± 3.0	28.2	21.9 - 31.1	Pass
ERDW-162	2/23/2023	Cs-137	191 ± 7	190	171 - 211	Pass
ERDW-162	2/23/2023	Co-60	110 ± 4	110	99.0 - 123	Pass
ERDW-162	2/23/2023	Zn-65	109 ± 8	105	94.5 - 125	Pass
ERDW-162	2/23/2023	Gr. Alpha	25.3 ± 0.2	30.0	15.3 - 39.2	Pass
ERDW-162	2/23/2023	G. Beta	15.0 ± 0.1	16.5	9.25 - 24.8	Pass
ERDW-162	2/23/2023	Ra-226	7.58 ± 0.52	8.26	6.21 - 9.71	Pass
ERDW-162	2/23/2023	Ra-228	7.44 ± 1.53	7.17	4.51 - 9.20	Pass
ERDW-162	2/23/2023	H-3	22,600 ± 467	21,600	18,900 - 23,800	Pass
RAD-134 Study						
ERDW-1956	7/10/2023	Ba-133	64.1 ± 4.7	66.5	55.4 - 73.2	Pass
ERDW-1956	7/10/2023	Cs-134	97.0 ± 4.8	90.8	74.5 - 99.9	Pass
ERDW-1956	7/10/2023	Cs-137	179 ± 8	163	147 - 181	Pass
ERDW-1956	7/10/2023	Co-60	26.6 ± 2.9	20.7	17.5 - 25.6	Fail [b]
ERDW-1956	7/10/2023	Zn-65	318 ± 12	290	261 - 339	Pass
ERDW-50167	7/10/2023	Gr. Alpha	34.3 ± 1.9	47.9	24.9 - 60.3	Pass
ERDW-50167	7/10/2023	G. Beta	27.4 ± 1.2	28.6	18.2 - 36.4	Pass
ERDW-50171	7/10/2023	Ra-226	19.3 ± 0.9	17.4	12.9 - 19.9	Pass
ERDW-50171	7/10/2023	Ra-228	7.11 ± 1.59	7.16	4.50 - 9.18	Pass
ERDW-50173	7/10/2023	H-3	10,500 ± 326	9,860	8,570 - 10,800	Pass
ERDW-50169	7/10/2023	I-131	23.9 ± 1.2	24.4	20.2 - 28.9	Pass

[a] Results obtained by Microbac Laboratories Inc. - Northbrook as a participant in the crosscheck program for proficiency testing in drinking water conducted by Environmental Resource Associates (ERA).

[b] The Cobalt-60 result did not meet ERA acceptance criteria. The sample was reanalyzed and passed for all analytes. (Co-60 reanalysis result was 21.2 ± 3.0 pCi/L). No cause for the earlier failure could be determined.

TABLE A-2. Thermoluminescent Dosimetry, (TLD, $CaSO_4$: Dy Cards).[a]

Lab Code	Irradiation Date	Description	Delivered Dose (mrem)	Reported[b] Dose (mrem)	Performance[c] Quotient (P)	
Environmental, Inc.		Group 1				
2022-23-3	11/29/2023	Spike 1	93.0	90.0	-0.03	
2022-23-3	11/29/2023	Spike 2	93.0	88.5	-0.05	
2022-23-3	11/29/2023	Spike 3	93.0	89.0	-0.04	
2022-23-3	11/29/2023	Spike 4	93.0	89.5	-0.04	
2022-23-3	11/29/2023	Spike 5	93.0	88.1	-0.05	
2022-23-3	11/29/2023	Spike 6	93.0	95.1	0.02	
2022-23-3	11/29/2023	Spike 7	93.0	90.8	-0.02	
2022-23-3	11/29/2023	Spike 8	93.0	90.8	-0.02	
2022-23-3	11/29/2023	Spike 9	93.0	92.3	-0.01	
2022-23-3	11/29/2023	Spike 10	93.0	89.0	-0.04	
2022-23-3	11/29/2023	Spike 11	93.0	84.9	-0.09	
2022-23-3	11/29/2023	Spike 12	93.0	90.8	-0.02	
2022-23-3	11/29/2023	Spike 13	93.0	92.0	-0.01	
2022-23-3	11/29/2023	Spike 14	93.0	87.7	-0.06	
2022-23-3	11/29/2023	Spike 15	93.0	88.8	-0.05	
2022-23-3	11/29/2023	Spike 16	93.0	88.6	-0.05	
2022-23-3	11/29/2023	Spike 17	93.0	84.2	-0.09	
2022-23-3	11/29/2023	Spike 18	93.0	88.6	-0.05	
2022-23-3	11/29/2023	Spike 19	93.0	86.4	-0.07	
2022-23-3	11/29/2023	Spike 20	93.0	88.3	-0.05	
Mean (Spike 1-20)				89.2	-0.04	Pass[d]
Standard Deviation (Spike 1-20)				2.5	0.03	Pass[d]

a TLD's were irradiated by the University of Wisconsin-Madison Radiation Calibration Laboratory following ANSI N13.37 protocol from a known air kerma rate. TLD's were read and the results were submitted by Microbac Laboratories - Northbrook to the University of Wisconsin-Madison Radiation Calibration Laboratory for comparison to the delivered dose.

b Reported dose was converted from exposure (R) to Air Kerma (cGy) using a conversion of 0.876. Conversion from air kerma to ambient dose equivalent for Cs-137 at the reference dose point $H^*(10)K_a = 1.20$. mrem/cGy = 1000.

c Performance Quotient (P) is calculated as ((reported dose - conventionally true value) ÷ conventionally true value) where the conventionally true value is the delivered dose.

d Acceptance is achieved when neither the absolute value of the mean of the P values, nor the standard deviation of the P values exceed 0.15.

TABLE A-2. Thermoluminescent Dosimetry, (TLD, $CaSO_4$: Dy Cards).[a]

Lab Code	Irradiation Date	Description	Delivered Dose (mrem)	Reported[b] Dose (mrem)	Performance[c] Quotient (P)	
Environmental, Inc.		Group 2				
2022-23-4	11/29/2023	Spike 21	176.0	170.1	-0.03	
2022-23-4	11/29/2023	Spike 22	176.0	166.8	-0.05	
2022-23-4	11/29/2023	Spike 23	176.0	156.3	-0.11	
2022-23-4	11/29/2023	Spike 24	176.0	163.1	-0.07	
2022-23-4	11/29/2023	Spike 25	176.0	166.8	-0.05	
2022-23-4	11/29/2023	Spike 26	176.0	168.0	-0.05	
2022-23-4	11/29/2023	Spike 27	176.0	159.8	-0.09	
2022-23-4	11/29/2023	Spike 28	176.0	160.4	-0.09	
2022-23-4	11/29/2023	Spike 29	176.0	165.4	-0.06	
2022-23-4	11/29/2023	Spike 30	176.0	166.2	-0.06	
2022-23-4	11/29/2023	Spike 31	176.0	159.9	-0.09	
2022-23-4	11/29/2023	Spike 32	176.0	161.4	-0.08	
2022-23-4	11/29/2023	Spike 33	176.0	165.8	-0.06	
2022-23-4	11/29/2023	Spike 34	176.0	163.9	-0.07	
2022-23-4	11/29/2023	Spike 35	176.0	167.9	-0.05	
2022-23-4	11/29/2023	Spike 36	176.0	157.4	-0.11	
2022-23-4	11/29/2023	Spike 37	176.0	165.6	-0.06	
2022-23-4	11/29/2023	Spike 38	176.0	161.3	-0.08	
2022-23-4	11/29/2023	Spike 39	176.0	165.9	-0.06	
2022-23-4	11/29/2023	Spike 40	176.0	159.4	-0.09	
Mean (Spike 21-40)				163.6	-0.07	Pass[d]
Standard Deviation (Spike 21-40)				3.9	0.02	Pass[d]

a TLD's were irradiated by the University of Wisconsin-Madison Radiation Calibration Laboratory following ANSI N13.37 protocol from a known air kerma rate. TLD's were read and the results were submitted by Microbac Laboratories - Northbrook to the University of Wisconsin-Madison Radiation Calibration Laboratory for comparison to the delivered dose.

b Reported dose was converted from exposure (R) to Air Kerma (cGy) using a conversion of 0.876. Conversion from air kerma to ambient dose equivalent for Cs-137 at the reference dose point $H^*(10)K_a = 1.20$. mrem/cGy = 1000.

c Performance Quotient (P) is calculated as ((reported dose - conventionally true value) ÷ conventionally true value) where the conventionally true value is the delivered dose.

d Acceptance is achieved when neither the absolute value of the mean of the P values, nor the standard deviation of the P values exceed 0.15.

TABLE A-3. Intralaboratory "Spiked" Samples

Lab Code[b]	Date	Concentration[a] Analysis	Laboratory results 2s, n=1[c]	Known Activity	Control Limits[d]	Acceptance	Ratio Lab/Known
SPDW-26	1/5/2023	Ra-228	11.8 ± 1.9	13.4	9.4 - 17.4	Pass	0.88
SPDW-50002	1/11/2023	H-3	21,747 ± 452	22,100	17,680 - 26,520	Pass	0.98
SPDW-50004	1/20/2023	H-3	21,861 ± 458	22,100	17,680 - 26,520	Pass	0.99
SPDW-50006	1/5/2023	Ra-226	11.3 ± 0.3	12.3	8.6 - 16.0	Pass	0.92
SPDW-50034	1/27/2023	Ra-226	12.6 ± 0.4	12.3	8.6 - 16.0	Pass	1.02
LCS-SO-012723	8/1/2020	Cs-134	17.1 ± 0.2	19.2	15.4 - 23.0	Pass	0.89
LCS-SO-012723	8/1/2020	Zn-65	13.8 ± 1.7	14.1	11.3 - 16.9	Pass	0.98
LCS-SO-012723	8/1/2020	Co-60	26.4 ± 0.2	27.0	21.6 - 32.4	Pass	0.98
LCS-SO-012723	8/1/2020	Co-57	30.7 ± 0.1	30.9	24.7 - 37.1	Pass	0.99
LCS-SO-012723	8/1/2020	Mn-54	17.7 ± 0.8	16.5	13.2 - 19.8	Pass	1.07
LCS-SO-012723	8/1/2020	K-40	18.4 ± 0.7	16.8	13.4 - 20.2	Pass	1.10
SPDW-50010	1/31/2023	Ra-228	9.7 ± 1.3	13.4	9.4 - 17.4	Pass	0.72
SPDW-50008	2/3/2023	H-3	21,961 ± 459	22,100	17,680 - 26,520	Pass	0.99
SPDW-50016	2/10/2023	H-3	22,137 ± 462	22,100	17,680 - 26,520	Pass	1.00
SPDW-50012	2/24/2023	Sr-90	18.6 ± 1.2	17.1	13.7 - 20.5	Pass	1.09
SPDW-50032	2/16/2023	Ra-228	13.1 ± 1.9	13.4	9.4 - 17.4	Pass	0.98
SPDW-50018	2/16/2023	Gr. Alpha	19.1 ± 1.3	23.5	11.8 - 28.2	Pass	0.81
SPDW-50018	2/16/2023	Gr. Beta	133 ± 2	141	112 - 169	Pass	0.94
SPDW-50021	2/17/2023	H-3	21,843 ± 459	22,100	17,680 - 26,520	Pass	0.99
SPDW-50047	2/24/2023	Ra-226	12.8 ± 0.4	12.3	8.6 - 16.0	Pass	1.04
SPDW-50049	3/17/2023	H-3	22,120 ± 465	22,100	17,680 - 26,520	Pass	1.00
SPDW-50056	3/24/2023	H-3	21,911 ± 463	22,100	17,680 - 26,520	Pass	0.99
SPDW-50060	3/16/2023	Ra-226	12.9 ± 0.4	12.3	8.6 - 16.0	Pass	1.05
SPDW-50097	4/13/2023	Ra-226	11.7 ± 0.5	12.3	8.6 - 16.0	Pass	0.95
SPDW-50068	4/14/2023	H-3	22,656 ± 482	22,100	17,680 - 26,520	Pass	1.03
SPDW-50081	4/25/2023	H-3	21,594 ± 461	22,100	17,680 - 26,520	Pass	0.98
SPDW-50131	5/3/2023	Ra-226	11.4 ± 0.3	12.3	8.6 - 16.0	Pass	0.93
SPDW-50104	5/12/2023	H-3	21,513 462	22,100	17,680 - 26,520	Pass	0.97
SPDW-50117	5/26/2023	H-3	22,069 468	22,100	17,680 - 26,520	Pass	1.00
SPDW-50182	6/8/2023	Ra-226	10.4 ± 0.3	12.3	8.6 - 16.0	Pass	0.85
SPDW-50137	6/12/2023	H-3	21,898 ± 456	22,100	17,680 - 26,520	Pass	0.99
SPDW-50138	6/12/2023	H-3	21,898 ± 456	22,100	17,680 - 26,520	Pass	0.99
SPDW-50153	6/26/2023	H-3	21,672 ± 456	22,100	17,680 - 26,520	Pass	0.98
SPDW-50153	6/26/2023	H-3	21,672 ± 456	22,100	17,680 - 26,520	Pass	0.98
SPDW-50259	7/19/2023	Ra-226	10.5 ± 0.3	12.3	8.6 - 16.0	Pass	0.85
SPDW-50219	8/15/2023	Sr-90	17.5 ± 1.1	17.1	13.7 - 20.5	Pass	1.02
SPDW-50291	8/28/2023	Ra-226	11.0 ± 0.3	12.3	8.6 - 16.0	Pass	0.89
SPDW-50249	8/22/2023	Gr. Alpha	16.7 ± 1.4	23.5	11.8 - 28.2	Pass	0.71
SPDW-50249	8/22/2023	Gr. Beta	128 ± 2	141	112 - 169	Pass	0.91
SPDW-50252	8/18/2023	H-3	21,628 ± 459	22,100	17,680 - 26,520	Pass	0.98
SPDW-50257	8/25/2023	H-3	22,152 ± 469	22,100	17,680 - 26,520	Pass	1.00

[a] Liquid sample results are reported in pCi/Liter, air filters (pCi/m3), charcoal (pCi/charcoal canister), and solid samples (pCi/kg).
[b] Laboratory codes : W & SPW (Water), MI (milk), AP (air filter), SO (soil), VE (vegetation), CH (charcoal canister), F (fish), U (urine).
[c] Results are based on single determinations.
[d] Acceptance criteria are listed in Attachment A of this report.

TABLE A-3. Intralaboratory "Spiked" Samples

Lab Code[b]	Date	Concentration[a] Analysis	Laboratory results 2s, n=1[c]	Known Activity	Control Limits[d]	Acceptance	Ratio Lab/Known
LCS-09/12/23	8/1/2020	Cs-134	17,533 ± 346	19,170	15,336 - 23,004	Pass	0.91
LCS-09/12/23	8/1/2020	Co-60	27,480 ± 347	26,055	20,844 - 31,266	Pass	1.05
LCS-09/12/23	8/1/2020	K-40	20,183 1268	18,468	14,774 - 22,162	Pass	1.09
SPDW-50270	9/6/2023	H-3	22,287 ± 469	22,100	17,680 - 26,520	Pass	1.01
SPDW-50283	9/25/2023	H-3	21,062 ± 444	22,100	17,680 - 26,520	Pass	0.95
SPDW-50291	8/28/2023	Ra-226	11.0 ± 0	12.3	8.6 - 16.0	Pass	0.89
SPDW-50316	10/3/2023	H-3	21,406 ± 454	22,100	17,680 - 26,520	Pass	0.97
SPW-50330	11/17/2023	H-3	21,143 ± 543	22,100	17,680 - 26,520	Pass	0.96
LCS-SO-112823	8/1/2020	Cs-134	17.2 ± 0.2	19.2	15.4 - 23.0	Pass	0.90
LCS-SO-112823	8/1/2020	Zn-65	14.9 ± 3.1	14.1	11.3 - 16.9	Pass	1.06
LCS-SO-112823	8/1/2020	Co-60	26.0 ± 0.3	27.0	21.6 - 32.4	Pass	0.96
LCS-SO-112823	8/1/2020	Co-57	29.3 ± 0.9	30.9	24.7 - 37.1	Pass	0.95
LCS-SO-112823	8/1/2020	Mn-54	17.5 ± 1.3	16.5	13.2 - 19.8	Pass	1.06
LCS-SO-112823	8/1/2020	K-40	18.0 ± 0.7	16.8	13.4 - 20.2	Pass	1.07
SPW-3908	12/18/2023	NI-63	2,032 ± 27	1,788	1,430 - 2,146	Pass	1.14
SPW-3910	12/18/2023	Fe-55	269 ± 24	232	186 - 278	Pass	1.16
SPDW-50378	12/19/2023	H-3	21,102 ± 452	22,100	17,680 - 26,520	Pass	0.95
SPDW-50388	12/28/2023	H-3	20,540 ± 445	22,100	17,680 - 26,520	Pass	0.93
SPDW-50393	12/19/2023	Ra-226	11.6 ± 0.3	12.3	8.6 - 16.0	Pass	0.94

[a] Liquid sample results are reported in pCi/Liter, air filters (pCi/m3), charcoal (pCi/charcoal canister), and solid samples (pCi/kg).
[b] Laboratory codes : W & SPW (Water), MI (milk), AP (air filter), SO (soil), VE (vegetation), CH (charcoal canister), F (fish), U (urine).
[c] Results are based on single determinations.
[d] Acceptance criteria are listed in Attachment A of this report.

TABLE A-4. Intralaboratory "Blank" Samples

Lab Code[b]	Sample Type	Date	Analysis[c]	Concentration[a]		
				Laboratory results (4.66σ)		Acceptance
				LLD	Activity[d]	Criteria (4.66 σ)
SPW-25	Water	1/5/2023	Ra-228	0.98	0.74 ± 0.54	2
SPDW-50000	Water	1/6/2023	I-131	0.36	-0.10 ± 0.16	1
SPDW-50001	Water	1/11/2023	H-3	157	13 ± 74	200
SPDW-50003	Water	1/20/2023	H-3	161	98 ± 85	200
SPDW-50005	Water	1/5/2023	Ra-226	0.02	0.00 ± 0.03	2
SPDW-50033	Water	1/27/2023	Ra-226	0.03	-0.01 ± 0.03	2
SPDW-50009	Water	1/31/2023	Ra-228	1.40	0.69 ± 0.75	2
SPDW-50007	Water	2/3/2023	H-3	160	17 ± 80	200
SPDW-50015	Water	2/10/2023	H-3	159	91 ± 84	200
SPDW-50011	Water	2/9/2023	Sr-89	0.62	0.24 ± 0.49	5
SPDW-50011	Water	2/9/2023	Sr-90	0.66	-0.02 ± 0.30	1
SPDW-50018	Water	2/16/2023	Gr. Alpha	0.62	0.01 ± 0.44	2
SPDW-50018	Water	2/16/2023	Gr. Beta	0.78	-0.10 ± 0.54	4
SPDW-50020	Water	2/17/2023	H-3	154	122 ± 80	200
SPDW-50031	Water	2/16/2023	Ra-228	0.82	0.42 ± 0.43	2
SPDW-50046	Water	2/24/2023	Ra-226	0.03	0.05 ± 0.04	2
SPDW-50044	Water	3/13/2023	I-131	0.15	-0.06 ± 0.08	1
SPDW-50048	Water	3/17/2023	H-3	163	80 ± 80	200
SPDW-50055	Water	3/24/2023	H-3	169	63 ± 82	200
SPDW-50059	Water	3/16/2023	Ra-226	0.04	-0.02 ± 0.03	2
SPDW-50063	Water	3/28/2023	Ra-226	0.06	-0.01 ± 0.05	2
SPDW-50067	Water	4/14/2023	H-3	173	92 ± 87	200
SPDW-50069	Water	4/17/2023	I-131	0.11	-0.05 ± 0.08	1
SPDW-50102	Water	5/15/2023	I-131	0.15	-0.01 ± 0.08	1
SPDW-50103	Water	5/12/2023	H-3	161	67 ± 80	200
SPDW-50116	Water	5/26/2023	H-3	161	122 ± 87	200
SPDW-50137	Water	6/12/2023	H-3	157	125 ± 80	200
SPDW-50154	Water	6/26/2023	H-3	157	105 ± 80	200
SPDW-50181	Water	6/8/2023	Ra-226	0.04	-0.07 ± 0.03	2
SPDW-50218	Water	8/15/2023	Sr-89	0.66	-0.07 ± 0.48	5
SPDW-50218	Water	8/15/2023	Sr-90	0.55	0.02 ± 0.26	1
SPDW-50248	Water	8/22/2024	Gr. Alpha	0.57	-0.03 ± 0.40	2
SPDW-50248	Water	8/22/2024	Gr. Beta	0.70	0.28 ± 0.50	4
SPDW-50256	Water	8/25/2023	H-3	161	75 ± 84	200
SPDW-50258	Water	7/19/2023	Ra-226	0.06	-0.25 ± 0.04	2
SPDW-50270	Water	9/6/2023	H-3	160	90 ± 81	200
SPDW-50282	Water	9/25/2023	H-3	163	53 ± 79	200
SPDW-50290	Water	8/28/2023	Ra-226	0.05	0.00 ± 0.04	2

[a] Liquid sample results are reported in pCi/Liter, air filters (pCi/m^3), charcoal (pCi/charcoal canister), and solid samples (pCi/g).

[b] Laboratory codes : W & SPW (Water), MI (milk), AP (air filter), SO (soil), VE (vegetation), CH (charcoal canister), F (fish), U (urine).

[c] I-131(G); iodine-131 as analyzed by gamma spectroscopy.

[d] Activity reported is a net activity result.

TABLE A-4. Intralaboratory "Blank" Samples

Lab Code[b]	Sample Type	Date	Analysis[c]	Concentration[a]		
				Laboratory results (4.66σ)		Acceptance
				LLD	Activity[d]	Criteria (4.66 σ)
SPDW-50311	Water	10/16/2023	I-131	0.25	0.06 ± 0.14	1
SPDW-50312	Water	10/3/2023	Ra-226	0.04	0.06 ± 0.09	2
SPDW-50315	Water	10/27/2023	H-3	169	5 ± 79	200
SPDW-50329	Water	11/17/2023	H-3	170	51 ± 82	200
SPDW-50379	Water	11/17/2023	Ra-226	0.05	0.09 ± 0.04	2
SPDW-50346	Water	12/5/2023	H-3	0.10	-0.12 ± 0.07	1
SPDW-50347	Water	12/5/2023	Ra-228	1.27	-0.07 ± 0.62	2
SPW-3907	Water	12/18/2023	Ni-63	149	0 ± 91	200
SPW-3909	Water	12/18/2023	Fe-55	435	7 ± 265	2000
SPDW-50377	Water	12/19/2023	H-3	173	-42 ± 78	200
SPDW-50387	Water	12/28/2023	H-3	171	-21 ± 79	200

[a] Liquid sample results are reported in pCi/Liter, air filters (pCi/m^3), charcoal (pCi/charcoal canister), and solid samples (pCi/g).

[b] Laboratory codes : W & SPW (Water), MI (milk), AP (air filter), SO (soil), VE (vegetation), CH (charcoal canister), F (fish), U (urine).

[c] I-131(G); iodine-131 as analyzed by gamma spectroscopy.

[d] Activity reported is a net activity result.

TABLE A-5. Intralaboratory "Duplicate" Samples

			Concentration[a]			
Lab Codeb	Date	Analysis	First Result	Second Result	Averaged Result	Acceptance
WW-65,66	1/10/2023	Gr. Beta	15.4 ± 2.0	17.2 ± 2.1	16.3 ± 1.5	Pass
WW-107,108	1/18/2023	H-3	153 ± 88	132 ± 87	143 ± 62	Pass
SG-187,188	1/30/2023	Gr. Alpha	28.1 ± 3.9	22.0 ± 3.5	25.1 ± 2.6	Pass
SG-187,188	1/30/2023	Gr. Beta	22.3 ± 1.8	22.2 ± 1.8	22.3 ± 1.3	Pass
SG-187,188	1/30/2023	Pb-214	4.08 ± 0.16	3.38 ± 0.09	3.73 ± 0.09	Pass
SG-187,188	1/30/2023	Ac-228	3.88 ± 0.28	3.98 ± 0.14	3.93 ± 0.16	Pass
SWU-201,202	1/31/2023	H-3	171 ± 89	234 ± 92	203 ± 64	Pass
SW-243,244	2/7/2023	H-3	358 ± 98	262 ± 93	310 ± 68	Pass
PW-266,267	2/6/2023	Ra-226	0.61 ± 0.18	0.37 ± 0.20	0.49 ± 0.13	Pass
DW-50028.50029	2/27/2023	Ra-226	0.68 ± 0.13	0.76 ± 0.13	0.72 ± 0.09	Pass
DW-50028.50029	2/27/2023	Ra-228	2.26 ± 0.65	1.20 ± 0.65	1.73 ± 0.46	Pass
DW-50052,50053	2/27/2023	Ra-228	0.48 ± 0.57	1.19 ± 0.65	0.84 ± 0.43	Pass
DW-50035,50036	2/28/2023	Gr. Alpha	3.68 ± 1.42	4.00 ± 1.29	3.84 ± 0.96	Pass
DW-50035,50036	2/28/2023	Gr. Beta	2.50 ± 0.64	1.99 ± 0.64	2.25 ± 0.45	Pass
LW-518,519	3/8/2023	Gr. Beta	1.71 ± 0.64	1.38 ± 0.64	1.55 ± 0.45	Pass
SG-571,572	3/8/2023	Pb-214	7.80 ± 0.46	8.20 ± 0.35	8.00 ± 0.29	Pass
SG-571,572	3/8/2023	Ac-228	11.9 ± 0.8	11.4 ± 0.6	11.7 ± 0.5	Pass
SG-571.572	3/8/2023	Gr. Alpha	86.5 ± 10.6	89.6 ± 11.0	88.1 ± 7.6	Pass
DW-50052,50053	3/17/2023	Gr. Alpha	9.16 ± 1.02	14.7 ± 1.2	11.9 ± 0.8	Pass
DW-50052,50053	3/17/2023	Gr. Beta	6.03 ± 0.71	7.58 ± 0.75	6.81 ± 0.52	Pass
CF-700,701	3/22/2023	K-40	2.91 ± 0.32	3.30 ± 0.36	3.11 ± 0.24	Pass
SW-679,680	3/27/2023	H-3	14,480 ± 389	14,487 ± 389	14,484 ± 275	Pass
SG-974,975	4/4/2023	Gr. Alpha	12.0 ± 2.1	12.1 ± 2.1	12.1 ± 1.5	Pass
DW-50074,50075	4/21/2023	Ra-226	1.63 ± 0.22	1.56 ± 0.28	1.60 ± 0.18	Pass
DW-50074,50075	4/21/2023	Ra-228	3.41 ± 0.98	2.14 ± 0.80	2.78 ± 0.63	Pass
U-1038,1039	4/20/2023	Gr. Beta	6.14 ± 1.71	6.46 ± 2.19	6.30 ± 1.39	Pass
WW-1101,1102	4/25/2023	H-3	358 ± 96	334 ± 95	346 ± 68	Pass
DW-50092,50093	5/1/2023	Ra-226	1.00 ± 0.22	1.46 ± 0.19	1.23 ± 0.15	Pass
DW-50092,50093	5/1/2023	Ra-228	1.11 ± 0.73	1.57 ± 0.82	1.34 ± 0.55	Pass
WW-1122,1123	5/2/2023	H-3	307 ± 93	229 ± 89	268 ± 64	Pass
WW-1269,1270	5/17/2023	H-3	366 ± 100	214 ± 92	290 ± 68	Pass
DW-50110,50111	5/29/2023	Ra-226	6.27 ± 0.40	4.77 ± 0.26	5.52 ± 0.24	Pass
DW-50110,50111	5/29/2023	Ra-228	2.81 ± 0.97	3.53 ± 0.98	3.17 ± 0.69	Pass
SW-1356,1357	5/30/2023	H-3	380 ± 94	257 ± 88	319 ± 64	Pass
WW-1398,1399	5/24/2023	H-3	571 ± 103	613 ± 105	592 ± 74	Pass
SG-1377,1378	5/30/2023	Pb-214	1.07 ± 0.14	1.19 ± 0.15	1.13 ± 0.10	Pass
SG-1377,1378	5/30/2023	Ac-228	1.23 ± 0.28	1.11 ± 0.23	1.17 ± 0.18	Pass

TABLE A-5. Intralaboratory "Duplicate" Samples

			Concentration[a]			
Lab Codeb	Date	Analysis	First Result	Second Result	Averaged Result	Acceptance
DW-50124,50125	6/5/2023	Ra-226	0.25 ± 0.08	0.24 ± 0.09	0.25 ± 0.06	Pass
AP-060523A/B	6/5/2023	Gr. Beta	0.023 ± 0.003	0.0236 ± 0.003	0.023 ± 0.002	Pass
DW-50126,50127	6/5/2023	Gr. Alpha	2.50 ± 1.17	3.87 ± 1.39	3.19 ± 0.91	Pass
WW-1441,1442	6/6/2023	Gr. Beta	2.55 ± 0.64	1.91 ± 0.67	2.23 ± 0.46	Pass
SW-1483,1484	6/8/2023	H-3	281 ± 90	281 ± 90	281 ± 64	Pass
CF-1546,1547	6/12/2023	K-40	7.77 ± 0.34	7.48 ± 0.48	7.63 ± 0.29	Pass
AP-061223A/B	6/12/2023	Gr. Beta	0.031 ± 0.005	0.030 ± 0.005	0.031 ± 0.004	Pass
S-1567,1568	6/14/2023	K-40	9.75 ± 0.71	9.80 ± 0.77	9.78 ± 0.52	Pass
WW-1630,1631	6/6/2023	H-3	319 ± 93	236 ± 89	278 ± 64	Pass
F-1945,1946	6/26/2023	K-40	3.81 ± 0.34	3.22 ± 0.54	3.52 ± 0.32	Pass
DW-50157,50158	6/26/2023	Gr. Beta	0.93 ± 0.59	1.09 ± 0.06	1.01 ± 0.30	Pass
AP-062823A/B	6/28/2023	Gr. Beta	0.026 ± 0.004	0.021 ± 0.003	0.024 ± 0.003	Pass
AP-070323A/B	7/3/2023	Gr. Beta	0.028 ± 0.003	0.026 ± 0.003	0.027 ± 0.002	Pass
DW-50160,50161	7/5/2023	Ra-226	2.63 ± 0.32	2.77 ± 0.27	2.70 ± 0.21	Pass
DW-50160,50161	7/5/2023	Ra-228	2.46 ± 0.78	2.51 ± 0.81	2.49 ± 0.56	Pass
AP-071123A/B	7/11/2023	Gr. Beta	0.025 ± 0.003	0.027 ± 0.003	0.026 ± 0.002	Pass
DW-50188,50189	7/21/2023	Ra-226	3.07 ± 0.30	2.63 ± 0.20	2.85 ± 0.18	Pass
DW-50188,50189	7/21/2023	Ra-228	5.28 ± 0.92	5.08 ± 0.90	5.18 ± 0.64	Pass
DW-50197,50198	7/24/2023	Gr. Alpha	5.82 ± 1.50	5.78 ± 1.30	5.80 ± 0.99	Pass
DW-50200,50201	7/24/2023	Ra-226	2.51 ± 0.24	4.07 ± 0.29	3.29 ± 0.19	Pass
DW-50200,50201	7/24/2023	Ra-228	7.04 ± 1.13	6.55 ± 1.09	6.80 ± 0.79	Pass
SG-2199,2200	7/25/2023	Pb-214	1.18 ± 0.22	1.03 ± 0.19	1.11 ± 0.15	Pass
SG-2199,2200	7/25/2023	Ac-228	1.74 ± 0.32	1.86 ± 0.42	1.80 ± 0.26	Pass
AP-072623A/B	7/26/2023	Gr. Beta	0.021 ± 0.003	0.021 ± 0.003	0.021 ± 0.002	Pass
AP-080223A/B	8/2/2023	Gr. Beta	0.015 ± 0.003	0.016 ± 0.003	0.016 ± 0.002	Pass
SG-2315,2316	8/3/2023	Gr. Alpha	59.5 ± 6.7	48.2 ± 6.1	53.9 ± 4.5	Pass
SG-2315,2316	8/3/2023	Gr. Beta	39.8 ± 2.9	34.4 ± 2.6	37.1 ± 1.9	Pass
AP-080723A/B	8/7/2024	Gr. Beta	0.025 ± 0.005	0.025 ± 0.005	0.025 ± 0.004	Pass
DW-50200,50201	8/9/2023	Ra-228	1.88 ± 0.71	1.29 ± 0.70	1.59 ± 0.50	Pass
AP-081423A/B	8/14/2023	Gr. Beta	0.030 ± 0.003	0.028 ± 0.003	0.029 ± 0.002	Pass
AP-082123A/B	8/21/2023	Gr. Beta	0.020 ± 0.003	0.022 ± 0.003	0.021 ± 0.002	Pass
DW-50262,50263	8/24/2023	Ra-228	2.62 ± 0.87	1.46 ± 0.52	2.04 ± 0.51	Pass
DW-50262,50263	8/24/2023	Ra-228	2.62 ± 0.87	2.80 ± 0.67	2.71 ± 0.55	Pass
AP-082823A/B	8/28/2023	Gr. Beta	0.023 ± 0.003	0.028 ± 0.003	0.026 ± 0.002	Pass
DW-50268,50269	8/29/2023	Gr. Alpha	0.87 ± 0.69	0.97 ± 0.81	0.92 ± 0.53	Pass
SG-2660,2661	9/4/2023	Gr. Alpha	68.5 ± 7.1	51.0 ± 6.3	59.8 ± 4.7	Pass
SG-2660,2661	9/4/2023	Pb-214	13.7 ± 0.5	14.2 ± 0.5	14.0 ± 0.4	Pass
SG-2660,2661	9/4/2023	Ac-228	14.4 ± 0.8	14.3 ± 0.9	14.4 ± 0.6	Pass
AP-090523A/B	9/5/2023	Gr. Beta	0.023 ± 0.003	0.023 ± 0.003	0.023 ± 0.002	Pass
AP-091223A/B	9/12/2023	Gr. Beta	0.024 ± 0.002	0.025 ± 0.002	0.025 ± 0.001	Pass

TABLE A-5. Intralaboratory "Duplicate" Samples

			Concentration[a]			
Lab Codeb	Date	Analysis	First Result	Second Result	Averaged Result	Acceptance
W-2776,2777	9/18/2023	Gr. Alpha	1.86 ± 1.73	0.99 ± 1.64	1.43 ± 1.19	Pass
W-2776,2777	9/18/2023	Ra-226	0.43 ± 0.10	0.55 ± 0.27	0.49 ± 0.14	Pass
W-2776,2777	9/18/2023	Ra-228	1.71 ± 1.07	3.33 ± 1.12	2.52 ± 0.77	Pass
AP-092023A/B	9/20/2023	Gr. Beta	0.039 ± 0.004	0.042 ± 0.004	0.041 ± 0.003	Pass
DW-50296,50297	9/27/2023	Ra-226	0.51 ± 0.09	0.54 ± 0.20	0.53 ± 0.11	Pass
AP-092823A/B	9/28/2023	Gr. Beta	0.030 ± 0.004	0.034 ± 0.004	0.032 ± 0.003	Pass
S-3136,3137	10/11/2023	Pb-214	1.93 ± 0.06	1.84 ± 0.08	1.89 ± 0.05	Pass
S-3135,3136	10/11/2023	Ac-228	4.06 ± 0.17	3.84 ± 0.19	3.95 ± 0.13	Pass
SG-3511,3512	10/10/2023	Gr. Alpha	59.0 ± 6.2	68.5 ± 6.6	63.8 ± 4.5	Pass
SG-3511,3512	10/10/2023	Gr. Beta	52.1 ± 2.9	54.6 ± 3.0	53.4 ± 2.1	Pass
SG-3511,3512	10/10/2023	Pb-214	9.67 ± 0.25	9.57 ± 0.29	9.62 ± 0.19	Pass
SG-3511,3512	10/10/2023	Ac-228	8.99 ± 0.43	8.79 ± 0.53	8.89 ± 0.34	Pass
SG-3521,3522	11/8/2023	Gr. Alpha	57.3 ± 7.3	70.9 ± 7.6	64.1 ± 5.3	Pass
SG-3521,3522	11/8/2023	Pb-214	11.2 ± 0.2	11.7 ± 0.2	11.5 ± 0.1	Pass
SG-3521,3522	11/8/2023	Ac-228	13.0 ± 0.4	13.4 ± 0.5	13.2 ± 0.3	Pass
DW-50335,50336	11/17/2023	Gr. Alpha	3.70 ± 1.00	3.46 ± 0.90	3.58 ± 0.67	Pass
DW-50335,50336	11/17/2023	Gr. Beta	1.73 ± 0.63	2.07 ± 0.06	1.90 ± 0.32	Pass
W-3647,3648	11/20/2023	H-3	2,815 ± 181	2,829 ± 182	2,822 ± 128	Pass
DW-50358,50359	12/4/2023	Gr. Beta	2.53 ± 0.61	1.66 ± 0.62	2.10 ± 0.43	Pass
DW-50349,50350	12/4/2023	Ra-226	0.04 ± 0.11	0.32 ± 0.10	0.18 ± 0.07	Pass
DW-50349,50350	12/4/2023	Ra-228	1.37 ± 0.48	1.57 ± 0.47	1.47 ± 0.34	Pass
DW-50365,50366	12/11/2023	Gr. Alpha	1.4 ± 0.79	1.95 ± 0.91	1.675 ± 0.60	Pass
DW-50365,50366	12/11/2023	Gr. Beta	3.18 ± 0.62	3.18 ± 0.66	3.18 ± 0.45	Pass
DW-50374,50375	12/13/2023	Gr. Alpha	0.89 ± 0.60	0.54 ± 0.67	0.715 ± 0.45	Pass
W-4035.4036	12/31/2023	H-3	157,638 ± 1,218	159,848 ± 1,227	158,743 ± 864	Pass
W-4035.4036	12/31/2023	Ni-63	2,410 ± 78	2,337 ± 78	2,373 ± 55	Pass
W-4035.4036	12/31/2023	Sr-90	49.8 ± 5.2	42.7 ± 4.8	46.3 ± 3.5	Pass

TABLE A-6. Department of Energy's Mixed Analyte Performance Evaluation Program (MAPEP).

			Concentration[a]			
Lab Code [b]	Reference Date	Analysis	Laboratory result	Known Activity	Acceptance Range [c]	Acceptance
MAAP-544	2/1/2023	Gross Alpha	1.23 ± 0.10	0.97	0.29 - 1.65	Pass
MAAP-544	2/1/2023	Gross Beta	1.67 ± 0.06	1.49	0.75 - 2.24	Pass
MADW-543	2/1/2023	Gross Alpha	0.843 ± 0.074	1.19	0.36 - 2.02	Pass
MADW-543	2/1/2023	Gross Beta	0.578 ± 0.093	5.94	2.97 - 8.91	Fail [d]
MASO-540	2/1/2023	Cs-134	2.33 ± 2.77	0	NA [c]	Pass
MASO-540	2/1/2023	Cs-137	1.22 ± 2.41	0	NA [c]	Pass
MASO-540	2/1/2023	Co-57	585 ± 4	698	489 - 907	Pass
MASO-540	2/1/2023	Co-60	727 ± 8	795	557 - 1034	Pass
MASO-540	2/1/2023	Mn-54	1180 ± 10	1230	861 - 1599	Pass
MASO-540	2/1/2023	Zn-65	846 ± 11	990	693 - 1287	Pass
MASO-540	2/1/2023	K-40	526 ± 23	574	402 - 746	Pass
MADW-545	2/1/2023	Cs-134	9.17 ± 0.17	9.6	6.7 - 12.5	Pass
MADW-545	2/1/2023	Cs-137	9.38 ± 0.29	8.7	6.1 - 11.3	Pass
MADW-545	2/1/2023	Co-57	-0.01 ± 0.08	0.0	NA [c]	Pass
MADW-545	2/1/2023	Co-60	7.47 ± 0.18	7.24	5.07 - 9.41	Pass
MADW-545	2/1/2023	Mn-54	12.3 ± 0.3	11.3	7.9 - 14.7	Pass
MADW-545	2/1/2023	Zn-65	15.7 ± 0.5	15.3	10.7 - 19.9	Pass
MADW-545	2/1/2023	K-40	1.23 ± 1.52	0	NA [c]	Pass
MADW-545	2/1/2023	Sr-90	-0.0035 ± 0.0172	0	NA [c]	Pass
MAAP-538	2/1/2023	Cs-134	1.12 ± 0.04	1.52	1.06 - 1.98	Pass
MAAP-538	2/1/2023	Cs-137	0.56 ± 0.07	0.630	0.441 - 0.819	Pass
MAAP-538	2/1/2023	Co-57	0.62 ± 0.30	0.661	0.463 - 0.859	Pass
MAAP-538	2/1/2023	Co-60	0.89 ± 0.07	1.05	0.74 - 1.37	Pass
MAAP-538	2/1/2023	Mn-54	2.02 ± 0.09	2.14	1.50 - 2.78	Pass
MAAP-538	2/1/2023	Zn-65	2.13 ± 0.14	2.25	1.58 - 2.93	Pass
MAAP-538	2/1/2023	Sr-90	0.004 ± 0.061	0	NA [c]	Pass
MASO-540	2/1/2023	Cs-134	2.33 ± 2.77	0	NA [c]	Pass
MASO-540	2/1/2023	Cs-137	1.22 ± 2.41	0	NA [c]	Pass
MASO-540	2/1/2023	Co-57	585 ± 4	698	489 - 907	Pass
MASO-540	2/1/2023	Co-60	727 ± 8	795	557 - 1034	Pass
MASO-540	2/1/2023	Mn-54	1180 ± 10	1230	861 - 1599	Pass
MASO-540	2/1/2023	Zn-65	846 ± 11	990	693 - 1287	Pass
MASO-540	2/1/2023	K-40	526 ± 23	574	402 - 746	Pass

TABLE A-6. Department of Energy's Mixed Analyte Performance Evaluation Program (MAPEP).

			Concentration[a]			
Lab Code [b]	Reference Date	Analysis	Laboratory result	Known Activity	Acceptance Range [c]	Acceptance
MADW-545	2/1/2023	Cs-134	9.17 ± 0.17	9.6	6.7 - 12.5	Pass
MADW-545	2/1/2023	Cs-137	9.38 ± 0.29	8.7	6.1 - 11.3	Pass
MADW-545	2/1/2023	Co-57	-0.01 ± 0.08	0.0	NA [c]	Pass
MADW-545	2/1/2023	Co-60	7.47 ± 0.18	7.24	5.07 - 9.41	Pass
MADW-545	2/1/2023	Mn-54	12.3 ± 0.3	11.3	7.9 - 14.7	Pass
MADW-545	2/1/2023	Zn-65	15.7 ± 0.5	15.3	10.7 - 19.9	Pass
MADW-545	2/1/2023	K-40	1.23 ± 1.52	0	NA [c]	Pass
MADW-545	2/1/2023	Sr-90	-0.0035 ± 0.0172	0	NA [c]	Pass
MAAP-538	2/1/2023	Cs-134	1.12 ± 0.04	1.52	1.06 - 1.98	Pass
MAAP-538	2/1/2023	Cs-137	0.56 ± 0.07	0.630	0.441 - 0.819	Pass
MAAP-538	2/1/2023	Co-57	0.62 ± 0.30	0.661	0.463 - 0.859	Pass
MAAP-538	2/1/2023	Co-60	0.89 ± 0.07	1.05	0.74 - 1.37	Pass
MAAP-538	2/1/2023	Mn-54	2.02 ± 0.09	2.14	1.50 - 2.78	Pass
MAAP-538	2/1/2023	Zn-65	2.13 ± 0.14	2.25	1.58 - 2.93	Pass
MAAP-538	2/1/2023	Sr-90	0.004 ± 0.061	0	NA [c]	Pass
MAVE-545	2/1/2023	Cs-134	7.45 ± 0.39	7.60	5.32 - 9.88	Pass
MAVE-545	2/1/2023	Cs-137	0.010 ± 0.084	0	NA [c]	Pass
MAVE-545	2/1/2023	Co-57	6.83 ± 0.17	6.93	4.85 - 9.01	Pass
MAVE-545	2/1/2023	Co-60	6.89 ± 0.17	6.51	4.56 - 8.46	Pass
MAVE-545	2/1/2023	Mn-54	9.08 ± 0.28	8.03	5.62 - 10.44	Pass
MAVE-545	2/1/2023	Zn-65	7.83 ± 0.39	7.43	5.20 - 9.66	Pass
MAAP-2761	8/1/2023	Gross Alpha	0.16 ± 0.04	0.255	0.077 - 0.434	Pass
MAAP-2761	8/1/2023	Gross Beta	1.16 ± 0.07	0.927	0.464 - 1.391	Pass
MADW-2753	8/1/2023	Gross Alpha	1.20 ± 0.06	1.59	0.48 - 2.70	Pass
MADW-2753	8/1/2023	Gross Beta	14.7 ± 0.1	16.27	8.14 - 24.41	Pass
MASO-2757	8/1/2023	Cs-134	612 ± 8	693	485 - 901	Pass
MASO-2757	8/1/2023	Cs-137	1900 ± 20	1810	1267 - 2353	Pass
MASO-2757	8/1/2023	Co-57	1020 ± 20	1060	742 - 1378	Pass
MASO-2757	8/1/2023	Co-60	901 ± 10	898	629 - 1167	Pass
MASO-2757	8/1/2023	Mn-54	6.53 ± 3.22	0	NA [c]	Pass
MASO-2757	8/1/2023	Zn-65	1270 ± 30	1160	812 - 1508	Pass
MASO-2757	8/1/2023	K-40	702 ± 54	574	402 - 746	Pass

TABLE A-6. Department of Energy's Mixed Analyte Performance Evaluation Program (MAPEP).

			Concentration[a]			
Lab Code [b]	Reference Date	Analysis	Laboratory result	Known Activity	Acceptance Range [c]	Acceptance
MADW-2751	8/1/2023	Cs-134	8.88 ± 0.18	11.3	7.9 - 14.7	Pass
MADW-2751	8/1/2023	Cs-137	7.95 ± 0.30	8.7	6.1 - 11.3	Pass
MADW-2751	8/1/2023	Co-57	16.5 ± 0.3	19.3	13.5 - 25.1	Pass
MADW-2751	8/1/2023	Co-60	0.09 ± 0.06	0	NA [c]	Pass
MADW-2751	8/1/2023	Mn-54	11.6 ± 0.3	12.7	8.9 - 16.5	Pass
MADW-2751	8/1/2023	Zn-65	17.9 ± 0.6	19.1	13.4 - 24.8	Pass
MADW-2751	8/1/2023	K-40	1.56 ± 1.60	0	NA [c]	Pass
MAAP-2755	8/1/2023	Cs-134	1.30 ± 0.10	1.60	1.12 - 2.08	Pass
MAAP-2755	8/1/2023	Cs-137	0.04 ± 0.03	0	NA [c]	Pass
MAAP-2755	8/1/2023	Co-57	1.47 ± 0.05	1.63	1.14 - 2.12	Pass
MAAP-2755	8/1/2023	Co-60	0.04 ± 0.09	0	NA [c]	Pass
MAAP-2755	8/1/2023	Mn-54	1.59 ± 0.09	1.57	1.10 - 2.04	Pass
MAAP-2755	8/1/2023	Zn-65	1.71 ± 0.14	1.89	1.32 - 2.46	Pass
MAAP-2755	8/1/2023	Sr-90	0.533 ± 0.040	0.614	0.430 - 0.796	Pass
MAVE-2759	8/1/2023	Cs-134	4.25 ± 0.14	4.96	3.49 - 6.47	Pass
MAVE-2759	8/1/2023	Cs-137	0.025 ± 0.050	0	NA [c]	Pass
MAVE-2759	8/1/2023	Co-57	4.28 ± 0.13	4.24	2.97 - 5.51	Pass
MAVE-2759	8/1/2023	Co-60	2.49 ± 0.11	2.79	1.95 - 3.63	Pass
MAVE-2759	8/1/2023	Mn-54	2.45 ± 0.16	2.6	1.8 - 3.3	Pass
MAVE-2759	8/1/2023	Zn-65	0.058 - 0.107	0	NA [c]	Pass

[a] Results are reported in units of Bq/kg (soil), Bq/L (water) or Bq/total sample (filters, vegetation).

[b] Laboratory codes as follows: MAW (water), MADW (water), MAAP (air filter), MASO (soil) and MAVE (vegetation).

[c] MAPEP results are presented as the known values and expected laboratory precision (1 sigma, 1 determination) and control limits as defined by the MAPEP. A known value of "zero" indicates an analysis was included in the testing series as a "false positive". MAPEP does not provide an acceptance range.

[d] A decimal point was misplaced in a unit conversion. If the conversion was was done properly the result: 5.78 ± 0.93 Bq/L woud have been within MAPEP's acceptance range.

TABLE A-7. Interlaboratory Comparison Crosscheck Program, Environmental Resource Associates (ERA)[a].

MRAD-38 Study

Lab Code [b]	Date	Analysis	Concentration [a] Laboratory Result	ERA Value [c]	Acceptance Limits [d]	Acceptance
ERAP-599	3/20/2023	Cs-134	139	153	99 - 188	Pass
ERAP-599	3/20/2023	Cs-137	970	892	733 - 1170	Pass
ERAP-599	3/20/2023	Co-60	474	467	397 - 593	Pass
ERAP-599	3/20/2023	Mn-54	< 3.3	< 35.0	0.00 - 35.0	Pass
ERAP-599	3/20/2023	Zn-65	1280	1110	910 - 1700	Pass
ERAP-599	3/20/2023	Sr-90	143	137	87 - 187	Pass
ERAP-598	3/20/2023	Gross Alpha	72.7	76.8	40.1 - 127	Pass
ERAP-598	3/20/2023	Gross Beta	35.0	32.8	19.9 - 49.6	Pass

[a] Results obtained by Microbac Laboratories - Northbrook as a participant in the crosscheck program for proficiency testing administered by Environmental Resource Associates, serving as a replacement for studies conducted previously by the Environmental Measurements Laboratory Quality Assessment Program (EML).

[b] Laboratory code ERAP (air filter). Results are reported in units of (pCi/Filter).

[c] The ERA Assigned values for the air filter standards are equal to 100% of the parameter present in the standard as determined by the gravimetric and/or volumetric measurements made during standard preparation as applicable.

[d] The acceptance limits are established per the guidelines contained in the Department of Energy (DOE) report EML-564, Analysis of Environmental Measurements Laboratory (EML) Quality Assessment Program (QAP) Data Determination of Operational Criteria and Control Limits for Performance Evaluation Purposes or ERA's SOP for the generation of Performance Acceptance Limits.

MICROBAC®
700 Landwehr Road • Northbrook, IL 60062-2310
phone (847) 564-0700 • fax (847) 564-4517

Appendix B

Data Reporting Conventions

APPENDIX B. DATA REPORTING CONVENTIONS

Data Reporting Conventions

1.0. All activities, except gross alpha and gross beta, are decay corrected to collection time or the end of the collection period.

2.0. Single Measurements

Each single measurement is reported as follows: $x \pm s$

where: x = value of the measurement;

$s = 2\sigma$ counting uncertainty (corresponding to the 95% confidence level).

In cases where the activity is less than the lower limit of detection L, it is reported as: < L, where L = the lower limit of detection based on 4.66σ uncertainty for a background sample.

3.0. Duplicate analyses

If duplicate analyses are reported, the convention is as follows. :

3.1 Individual results: For two analysis results; $x_1 \pm s_1$ and $x_2 \pm s_2$

Reported result: $x \pm s$; where $x = (1/2)(x_1 + x_2)$ and $s = (1/2)\sqrt{s_1^2 + s_2^2}$

3.2. Individual results: $< L_1$, $< L_2$ Reported result: < L, where L = lower of L_1 and L_2

3.3. Individual results: $x \pm s$, < L Reported result: $x \pm s$ if $x \geq L$; < L otherwise.

4.0. Computation of Averages and Standard Deviations

4.1 Averages and standard deviations listed in the tables are computed from all of the individual measurements over the period averaged; for example, an annual standard deviation would not be the average of quarterly standard deviations. The average $\bar{x}$ and standard deviation "s" of a set of n numbers $x_1, x_2 \ldots x_n$ are defined as follows:

$$\bar{x} = \frac{1}{n} \sum x \qquad s = \sqrt{\frac{\sum (x - \bar{x})^2}{n-1}}$$

4.2 Values below the highest lower limit of detection are not included in the average.

4.3 If all values in the averaging group are less than the highest LLD, the highest LLD is reported.

4.4 If all but one of the values are less than the highest LLD, the single value x and associated two sigma error is reported.

4.5 In rounding off, the following rules are followed:

4.5.1. If the number following those to be retained is less than 5, the number is dropped, and the retained numbers are kept unchanged. As an example, 11.443 is rounded off to 11.44.

4.5.2. If the number following those to be retained is equal to or greater than 5, the number is dropped and the last retained number is raised by 1. As an example, 11.445 is rounded off to 11.45.

MICROBAC®
700 Landwehr Road • Northbrook, IL 60062-2310
phone (847) 564-0700 • fax (847) 564-4517

Appendix C

Maximum permissible concentrations of radioactivity
in air and water above natural background in unrestricted areas

APPENDIX C

Table C-1. Maximum permissible concentrations of radioactivity in air and water above natural background in unrestricted areas[a].

	Air (pCi/m^3)		Water (pCi/L)
Gross alpha	1×10^{-3}	Strontium-89	8,000
Gross beta	1	Strontium-90	500
Iodine-131[b]	2.8×10^{-1}	Cesium-137	1,000
		Barium-140	8,000
		Iodine-131	1,000
		Potassium-40 [c]	4,000
		Gross alpha	2
		Gross beta	10
		Tritium	1×10^6

[a] Taken from Table 2 of Appendix B to Code of Federal Regulations Title 10, Part 20, and appropriate footnotes. Concentrations may be averaged over a period not greater than one year.

[b] Value adjusted by a factor of 700 to reduce the dose resulting from the air-grass-cow-milk-child pathway.

[c] A natural radionuclide.

MICROBAC®

700 Landwehr Road • Northbrook, IL 60062-2310
phone (847) 564-0700 • fax (847) 564-4517

DUANE ARNOLD ENERGY CENTER
CEDAR RAPIDS, IOWA
Docket No. 50-331

RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM (REMP)

ANNUAL REPORT - PART II
DATA TABULATIONS AND ANALYSES

January 1 to December 31, 2023

Prepared by

Microbac Laboratories Inc. - Northbrook

Project No. 8001

Reviewed and
Approved

Ashok Banavali, Ph.D.
Laboratory Director

TABLE OF CONTENTS

LIST OF TABLES

1.0 INTRODUCTION

The following constitutes a supplement to the Annual Report for the Radiological Environmental Monitoring Program conducted at the Duane Arnold Energy Center, Palo, Iowa in 2023. Results of completed analyses are presented in the attached tables.

For information regarding sampling locations, type and frequency of collection, and sample codes, please refer to Part I, Tables 5.3 - 5.5 and Figures 5.1 and 5.2.

All concentrations, except gross beta and airborne iodine, are decay corrected to the time of collection. Airborne I-131 is decayed to the midpoint of the collection period.

The required values for lower limits of detection (LLD) for gamma emitting isotopes are established through the Defueled Offsite Dose Assessment Manual (DODAM). Naturally occurring radioisotopes, such as Be-7, K-40 and Ra daughters, are frequently detected, but may not be listed for every sample medium.

2.0 PROGRAM DEVIATIONS

Sample Type	Analysis	Location(s)	Collection Date or Period	Comments
TLD	Gamma	D-31	2nd Qtr '23	TLD missing in field.

3.0 DATA TABLES

Table 1. Airborne particulates, analyses for gross beta.

Location: D-15 (On-site, north)

Units: pCi/m^3

Collection: Monthly requirement.

Date Collected	Volume (m^3)	Gross Beta	Date Collected	Volume (m^3)	Gross Beta
Required LLD		0.010	Required LLD		0.010
01-06-23	286	0.046 ± 0.005	07-06-23	291	0.030 ± 0.004
01-13-23	291	0.066 ± 0.005	07-13-23	288	0.017 ± 0.003
01-20-23	288	0.036 ± 0.004	07-20-23	285	0.019 ± 0.003
01-27-23	288	0.033 ± 0.004	07-27-23	289	0.029 ± 0.004
02-03-23	288	0.040 ± 0.004	08-03-23	277	0.029 ± 0.004
02-10-23	286	0.027 ± 0.004	08-10-23	285	0.029 ± 0.004
02-17-23	291	0.021 ± 0.004	08-17-23	300	0.020 ± 0.003
02-24-23	286	0.021 ± 0.004	08-24-23	285	0.042 ± 0.005
03-03-23	288	0.027 ± 0.004	08-31-23	293	0.029 ± 0.004
03-10-23	291	0.020 ± 0.004	09-07-23	282	0.029 ± 0.004
03-17-23	284	0.022 ± 0.004	09-14-23	286	0.016 ± 0.004
03-24-23	291	0.031 ± 0.004	09-21-23	293	0.029 ± 0.004
03-31-23	285	0.044 ± 0.005	09-28-23	283	0.030 ± 0.004
1st Quarter Mean ± s.d.		0.033 ± 0.013	3rd Quarter Mean ± s.d.		0.027 ± 0.007
04-06-23	250	0.023 ± 0.004	10-05-23	290	0.043 ± 0.005
04-14-23	328	0.027 ± 0.004	10-12-23	287	0.018 ± 0.003
04-21-23	287	0.016 ± 0.003	10-19-23	288	0.024 ± 0.004
04-28-23	288	0.013 ± 0.003	10-26-23	290	0.028 ± 0.004
			11-02-23	286	0.024 ± 0.004
05-05-23	288	0.013 ± 0.003			
05-12-23		ND[a]	11-09-23	290	0.038 ± 0.004
05-19-23	327	0.023 ± 0.004	11-16-23	291	0.027 ± 0.004
05-26-23	286	0.018 ± 0.003	11-22-23	247	0.023 ± 0.004
06-02-23	296	0.028 ± 0.004	11-30-23		NS[b]
06-08-23	240	0.023 ± 0.004	12-07-23	287	0.073 ± 0.006
06-15-23	285	0.018 ± 0.003	12-14-23	325	0.025 ± 0.004
06-22-23	288	0.026 ± 0.004	12-21-23	325	0.032 ± 0.004
06-29-23	289	0.024 ± 0.004	12-29-23	374	0.032 ± 0.004
2nd Quarter Mean ± s.d.		0.021 ± 0.005	4th Quarter Mean ± s.d.		0.032 ± 0.015
			Cumulative Average		0.028

[a] "ND" = No data; sample lost in transit.

[b] "NS" = No sample. Sample holder found detached. Filter appeared blank.

Table 2. Airborne particulates, analyses for gross beta.

Location: D-16 (On-site)

Units: pCi/m^3

Collection: Monthly requirement.

Date Collected	Volume (m^3)	Gross Beta	Date Collected	Volume (m^3)	Gross Beta
Required LLD		0.010	Required LLD		0.010
01-06-23	272	0.051 ± 0.005	07-06-23	276	0.031 ± 0.004
01-13-23	277	0.070 ± 0.006	07-13-23	272	0.021 ± 0.004
01-20-23	273	0.034 ± 0.004	07-20-23	273	0.021 ± 0.004
01-27-23	274	0.036 ± 0.005	07-27-23	274	0.034 ± 0.004
02-03-23	274	0.035 ± 0.004	08-03-23	290	0.025 ± 0.004
02-10-23	272	0.039 ± 0.004	08-10-23	183 [b]	0.034 ± 0.006
02-17-23	276	0.021 ± 0.004	08-17-23	277	0.027 ± 0.004
02-24-23	272	0.028 ± 0.004	08-24-23	266	0.044 ± 0.005
03-03-23	274	0.033 ± 0.004	08-31-23	279	0.037 ± 0.004
03-10-23	276	0.026 ± 0.004	09-07-23	272	0.032 ± 0.004
03-17-23	270	0.023 ± 0.004	09-14-23	272	0.027 ± 0.004
03-24-23	276	0.027 ± 0.004	09-21-23	279	0.038 ± 0.004
03-31-23	269	0.044 ± 0.005	09-28-23	270	0.041 ± 0.005
1st Quarter Mean ± s.d.		0.036 ± 0.013	3rd Quarter Mean ± s.d.		0.032 ± 0.007
04-06-23	237	0.023 ± 0.005	10-05-23	276	0.047 ± 0.005
04-14-23	312	0.031 ± 0.004	10-12-23	273	0.023 ± 0.004
04-21-23	273	0.017 ± 0.003	10-19-23	274	0.025 ± 0.004
04-28-23	273	0.020 ± 0.004	10-26-23	275	0.033 ± 0.004
			11-02-23	272	0.026 ± 0.004
05-05-23	274	0.017 ± 0.003			
05-12-23		NS[a]	11-09-23	276	0.047 ± 0.005
05-19-23	311	0.025 ± 0.004	11-16-23	276	0.033 ± 0.004
05-26-23	272	0.020 ± 0.004	11-22-23	234	0.029 ± 0.005
06-02-23	282	0.031 ± 0.004	11-30-23	314	0.035 ± 0.004
06-08-23	228	0.028 ± 0.004	12-07-23	273	0.041 ± 0.005
06-15-23	271	0.020 ± 0.004	12-14-23	351	0.030 ± 0.004
06-22-23	274	0.026 ± 0.004	12-21-23	351	0.039 ± 0.004
06-29-23	275	0.029 ± 0.004	12-29-23	404	0.037 ± 0.004
2nd Quarter Mean ± s.d.		0.024 ± 0.005	4th Quarter Mean ± s.d.		0.034 ± 0.008
			Cumulative Average		0.032

[a] "ND" = No data; sample lost in transit.

[b] Lower volume due to power outage.

Table 3. Airborne particulates, analyses for gamma-emitting isotopes.
Collection: Quarterly Composite Units: pCi/m^3

Location	D-15			
Quarter	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
Lab Code	DAP- 818	DAP- 2040	DAP- 3177	DAP- 4084
Volume (m^3)	3742	3452	3737	3580
Be-7	0.059 ± 0.011	0.065 ± 0.015	0.054 ± 0.015	0.050 ± 0.012
Mn-54	< 0.0007	< 0.0007	< 0.0008	< 0.0007
Fe-59	< 0.0009	< 0.0029	< 0.0023	< 0.0016
Co-58	< 0.0009	< 0.0009	< 0.0007	< 0.0006
Co-60	< 0.0015	< 0.0008	< 0.0011	< 0.0014
Zn-65	< 0.0015	< 0.0009	< 0.0017	< 0.0013
Nb-95	< 0.0013	< 0.0016	< 0.0010	< 0.0007
Zr-95	< 0.0014	< 0.0017	< 0.0014	< 0.0007
Ru-103	< 0.0008	< 0.0015	< 0.0012	< 0.0007
Ru-106	< 0.0055	< 0.0082	< 0.0081	< 0.0042
Cs-134	< 0.0007	< 0.0010	< 0.0010	< 0.0008
Cs-137	< 0.0012	< 0.0008	< 0.0006	< 0.0010
Ce-141	< 0.0014	< 0.0018	< 0.0014	< 0.0011
Ce-144	< 0.0026	< 0.0040	< 0.0039	< 0.0050
Location	D-16			
Quarter	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
Lab Code	DAP- 819	DAP- 2041	DAP- 3179	DAP- 4085
Volume (m^3)	3556	3283	3483	3849
Be-7	0.067 ± 0.017	0.070 ± 0.016	0.065 ± 0.016	0.049 ± 0.012
Mn-54	< 0.0011	< 0.0008	< 0.0008	< 0.0006
Fe-59	< 0.0023	< 0.0035	< 0.0023	< 0.0006
Co-58	< 0.0011	< 0.0012	< 0.0003	< 0.0005
Co-60	< 0.0010	< 0.0006	< 0.0006	< 0.0018
Zn-65	< 0.0021	< 0.0009	< 0.0012	< 0.0016
Nb-95	< 0.0012	< 0.0015	< 0.0009	< 0.0010
Zr-95	< 0.0012	< 0.0019	< 0.0010	< 0.0011
Ru-103	< 0.0012	< 0.0014	< 0.0013	< 0.0010
Ru-106	< 0.0071	< 0.0094	< 0.0094	< 0.0064
Cs-134	< 0.0009	< 0.0007	< 0.0014	< 0.0008
Cs-137	< 0.0009	< 0.0009	< 0.0005	< 0.0013
Ce-141	< 0.0028	< 0.0017	< 0.0014	< 0.0016
Ce-144	< 0.0058	< 0.0036	< 0.0036	< 0.0048

Table 4. Ambient gamma radiation as measured by thermoluminescent dosimeters (TLD).
Quarterly collection. Units: mR/91 days

Control Location	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
D-4	16.6 ± 1.2	16.1 ± 1.8	17.7 ± 1.5	16.7 ± 1.9
Within 0.5 mi. of Stack				
D-15	15.1 ± 0.7	12.9 ± 1.4	15.9 ± 0.9	14.0 ± 1.3
D-17	17.3 ± 1.0	13.9 ± 1.1	19.5 ± 0.9	14.9 ± 1.1
D-18	14.2 ± 0.9	15.2 ± 1.2	15.2 ± 0.9	16.0 ± 1.2
D-20	13.8 ± 0.8	11.7 ± 1.1	15.1 ± 0.9	12.7 ± 1.1
D-22	12.7 ± 0.7	13.6 ± 1.2	13.6 ± 0.7	15.3 ± 1.2
D-29	15.1 ± 1.3	17.4 ± 1.8	17.6 ± 1.0	17.6 ± 1.3
D-31	16.6 ± 1.1	ND[a]	16.0 ± 1.3	18.1 ± 1.1
D-83	13.0 ± 0.9	14.0 ± 1.3	14.1 ± 1.1	14.8 ± 1.1
D-85	15.7 ± 0.5	15.0 ± 1.5	16.8 ± 0.5	15.8 ± 1.4
Mean ± s.d.	14.8 ± 1.6	14.2 ± 1.7	16.0 ± 1.8	15.5 ± 1.7

[a] "ND" = No data; see Table 2.0, Program Deviations.

Table 4. Ambient gamma radiation as measured by thermoluminescent dosimeters (TLD).
Quarterly collection. Units: mR/91 days

Within 1.0 mi. of Stack	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
D-43	13.3 ± 1.1	12.7 ± 1.2	15.5 ± 0.9	13.6 ± 1.1
D-46	17.7 ± 1.0	18.5 ± 2.2	19.6 ± 1.0	18.6 ± 2.2
D-48	17.7 ± 1.3	15.7 ± 1.3	20.6 ± 1.3	16.4 ± 1.5
Mean ± s.d.	16.3 ± 2.5	15.6 ± 2.9	18.5 ± 2.7	16.2 ± 2.5
Within 3.0 mi. of Stack				
D-33	12.3 ± 0.7	12.0 ± 1.1	13.4 ± 0.7	12.6 ± 1.0
D-35	13.0 ± 0.8	10.4 ± 1.1	13.9 ± 0.8	11.4 ± 1.1
D-37	12.6 ± 1.2	13.6 ± 1.2	16.8 ± 0.7	14.1 ± 1.3
D-39	15.4 ± 1.1	13.8 ± 1.2	16.6 ± 1.0	14.7 ± 1.2
D-42	14.4 ± 1.0	14.4 ± 1.1	17.6 ± 1.2	14.7 ± 1.1
Mean ± s.d.	13.5 ± 1.3	12.8 ± 1.6	15.7 ± 1.9	13.5 ± 1.5
ISFSI Fenceline				
D-161	85.4 ± 3.3	77.4 ± 4.5	74.4 ± 5.5	77.7 ± 2.2
D-162	24.5 ± 1.2	24.3 ± 1.7	24.9 ± 1.7	23.6 ± 1.6
D-163	76.0 ± 3.4	78.4 ± 2.1	70.9 ± 1.0	73.5 ± 3.3
D-164	85.3 ± 3.7	70.2 ± 5.8	71.4 ± 4.1	60.1 ± 3.7
D-ISFSI-1			28.1 ± 1.6	23.8 ± 1.1
D-ISFSI-2			96.1 ± 6.4	84.8 ± 6.6
D-ISFSI-3			77.6 ± 4.8	63.0 ± 4.0
D-ISFSI-4			26.8 ± 1.3	22.0 ± 1.0
D-ISFSI-5			34.7 ± 2.2	33.9 ± 1.7
D-ISFSI-6			46.5 ± 2.1	43.0 ± 2.8
D-ISFSI-7			34.8 ± 0.8	30.3 ± 2.1
D-ISFSI-8			19.2 ± 0.9	18.3 ± 1.2
Mean ± s.d.	67.8 ± 29.2	62.6 ± 25.8	50.5 ± 26.0	58.7 ± 24.6

Table 5. Well water samples, analyses for gamma emitting isotopes and tritium.

Collection: Monthly

Units: pCi/L

Location	D-52 Drinking Water			
Lab Code	DWW- 73	DWW- 340	DWW- 575	DWW- 892
Date Collected	01-13-23	02-15-23	03-15-23	04-13-23
H-3	< 161	< 154	< 164	< 161
Mn-54	< 1.3	< 1.9	< 1.3	< 1.6
Fe-59	< 6.3	< 3.1	< 1.7	< 1.9
Co-58	< 2.3	< 1.2	< 0.8	< 1.1
Co-60	< 1.7	< 1.5	< 2.9	< 4.1
Zn-65	< 4.4	< 2.7	< 2.7	< 3.5
Nb-95	< 1.8	< 1.0	< 1.5	< 2.1
Zr-95	< 3.9	< 3.2	< 1.0	< 3.3
I-131	< 2.8	< 1.8	< 2.1	< 3.0
Cs-134	< 2.4	< 1.6	< 1.4	< 2.0
Cs-137	< 2.4	< 1.5	< 2.4	< 3.3
Ba-140	< 10.4	< 6.2	< 7.0	< 11.5
La-140	< 1.7	< 2.5	< 1.5	< 2.9
Lab Code	DWW- 1218	DWW- 1551	DWW- 2022	DWW- 2498
Date Collected	05-15-23	06-12-23	07-17-23	08-16-23
H-3	< 161	< 157	< 162	< 158
Mn-54	< 1.3	< 4.4	< 3.3	< 6.8
Fe-59	< 3.4	< 12.2	< 2.9	< 6.8
Co-58	< 1.3	< 5.0	< 2.2	< 4.2
Co-60	< 1.7	< 3.9	< 5.7	< 5.2
Zn-65	< 2.5	< 4.2	< 5.5	< 4.4
Nb-95	< 2.9	< 4.8	< 3.9	< 4.8
Zr-95	< 4.6	< 7.6	< 5.1	< 8.5
I-131	< 4.8	< 11.9	< 3.7	< 7.0
Cs-134	< 2.1	< 5.1	< 3.2	< 6.7
Cs-137	< 2.6	< 4.1	< 5.5	< 5.1
Ba-140	< 16.4	< 37.2	< 11.2	< 24.4
La-140	< 2.6	< 12.4	< 3.4	< 5.2

Table 5. Well water samples, analyses for gamma emitting isotopes and tritium.

Collection: Monthly

Units: pCi/L

Location	D-52 Drinking Water			
Lab Code	DWW- 2684	DWW- 3189	DWW- 3573	DWW- 3777
Date Collected	09-11-23	10-16-23	11-15-23	12-04-23
H-3	< 163	< 169	< 172	< 171
Mn-54	< 3.7	< 4.7	< 1.8	< 2.4
Fe-59	< 5.3	< 2.9	< 5.2	< 7.6
Co-58	< 3.4	< 5.6	< 2.8	< 2.9
Co-60	< 9.1	< 7.3	< 2.4	< 6.2
Zn-65	< 7.5	< 6.3	< 6.3	< 6.0
Nb-95	< 3.0	< 4.4	< 4.1	< 4.3
Zr-95	< 7.0	< 7.2	< 6.4	< 4.2
I-131	< 11.2	< 6.8	< 7.9	< 4.1
Cs-134	< 5.7	< 4.7	< 3.0	< 4.7
Cs-137	< 7.5	< 8.3	< 3.5	< 6.4
Ba-140	< 23.1	< 17.7	< 21.5	< 14.1
La-140	< 4.0	< 2.9	< 3.5	< 2.0

Table 5. Well water samples, analyses for gamma emitting isotopes and tritium.

Collection: Monthly

Units: pCi/L

Location	D-53 Treated Municipal Water, Drinking Water			
Lab Code	DWW- 74	DWW- 341	DWW- 576	DWW- 893
Date Collected	01-13-23	02-15-23	03-15-23	04-13-23
H-3	< 161	< 154	< 164	< 161
Mn-54	< 1.9	< 1.5	< 2.8	< 3.5
Fe-59	< 2.7	< 3.6	< 2.0	< 2.3
Co-58	< 2.3	< 2.4	< 2.4	< 2.2
Co-60	< 6.1	< 1.9	< 2.1	< 6.1
Zn-65	< 4.3	< 3.6	< 4.3	< 4.3
Nb-95	< 2.6	< 2.3	< 1.7	< 2.5
Zr-95	< 5.3	< 2.1	< 3.7	< 5.1
I-131	< 5.0	< 2.4	< 2.0	< 6.1
Cs-134	< 3.3	< 2.0	< 2.2	< 3.2
Cs-137	< 4.9	< 2.3	< 1.7	< 5.1
Ba-140	< 9.8	< 10.3	< 8.9	< 13.7
La-140	< 2.0	< 1.5	< 1.8	< 2.7
Lab Code	DWW- 1216	DWW- 1552	DWW- 2021	DWW- 2497
Date Collected	05-15-23	06-12-23	07-17-23	08-16-23
H-3	< 161	< 157	< 162	< 158
Mn-54	< 2.4	< 3.5	< 2.0	< 3.2
Fe-59	< 3.0	< 13.4	< 3.9	< 3.7
Co-58	< 1.7	< 4.5	< 2.9	< 3.6
Co-60	< 6.3	< 5.4	< 6.6	< 7.1
Zn-65	< 3.1	< 3.4	< 2.6	< 5.2
Nb-95	< 4.5	< 5.7	< 2.4	< 2.5
Zr-95	< 5.8	< 8.7	< 4.8	< 4.7
I-131	< 14.2	< 14.6	< 5.0	< 5.3
Cs-134	< 3.1	< 6.4	< 3.3	< 3.7
Cs-137	< 5.5	< 4.4	< 5.2	< 7.0
Ba-140	< 14.3	< 38.3	< 13.0	< 19.3
La-140	< 6.1	< 13.7	< 3.7	< 2.0

Table 5. Well water samples, analyses for gamma emitting isotopes and tritium.

Collection: Monthly

Units: pCi/L

Location	D-53 Treated Municipal Water, Drinking Water			
Lab Code	DWW- 2685	DWW- 3190	DWW- 3574	DWW- 3778
Date Collected	09-11-23	10-16-23	11-15-23	12-04-23
H-3	< 163	< 169	< 172	< 171
Mn-54	< 7.4	< 6.3	< 2.5	< 1.7
Fe-59	< 9.1	< 9.8	< 5.4	< 5.2
Co-58	< 8.9	< 4.7	< 2.9	< 3.1
Co-60	< 5.3	< 4.9	< 3.3	< 1.8
Zn-65	< 7.7	< 7.8	< 4.1	< 6.5
Nb-95	< 8.1	< 6.9	< 4.0	< 3.4
Zr-95	< 15.0	< 9.8	< 2.8	< 5.0
I-131	< 10.5	< 5.1	< 6.0	< 5.3
Cs-134	< 8.5	< 8.3	< 3.1	< 4.1
Cs-137	< 6.0	< 7.7	< 2.9	< 3.5
Ba-140	< 24.5	< 23.3	< 16.3	< 15.8
La-140	< 7.8	< 4.8	< 5.3	< 3.5

Table 5. Well water samples, analyses for gamma emitting isotopes and tritium.

Collection: Monthly

Units: pCi/L

Location	D-55 First Interface (New Well)			
Lab Code	DWW- 890	DWW- 1217	DWW- 1553	DWW- 2023
Date Collected	04-12-23	05-15-23	06-12-23	07-17-23
H-3	< 161	< 161	< 157	< 162
Mn-54	< 1.2	< 2.2	< 4.6	< 4.1
Fe-59	< 6.4	< 4.5	< 12.0	< 5.3
Co-58	< 1.5	< 1.9	< 5.0	< 6.2
Co-60	< 1.8	< 2.1	< 4.7	< 4.4
Zn-65	< 3.2	< 2.2	< 8.7	< 10.0
Nb-95	< 2.0	< 2.6	< 6.1	< 3.4
Zr-95	< 4.5	< 4.3	< 9.5	< 8.8
I-131	< 3.1	< 2.6	< 13.8	< 6.5
Cs-134	< 2.5	< 2.3	< 5.9	< 5.1
Cs-137	< 2.9	< 2.2	< 3.4	< 3.4
Ba-140	< 9.8	< 8.1	< 38.0	< 24.7
La-140	< 2.6	< 4.2	< 9.0	< 5.1

Table 6. Vegetation, analyses for iodine-131 and other gamma-emitting isotopes.

Collection: Annually

Units: pCi/g wet

Location	D-015	D-015	D-015
Lab Code	DVE- 2708	DVE- 2709	DVE- 2710
Date Collected	09-12-23	09-12-23	09-12-23
Sample Type	Green Leaves	Forage	Corn
K-40	3.40 ± 0.64	5.46 ± 0.54	2.30 ± 0.19
Mn-54	< 0.022	< 0.021	< 0.006
Fe-59	< 0.051	< 0.040	< 0.028
Co-58	< 0.011	< 0.023	< 0.009
Co-60	< 0.062	< 0.049	< 0.010
Zn-65	< 0.044	< 0.056	< 0.021
Nb-95	< 0.019	< 0.024	< 0.018
Zr-95	< 0.026	< 0.046	< 0.021
Ru-103	< 0.032	< 0.024	< 0.012
Ru-106	< 0.188	< 0.189	< 0.102
I-131	< 0.040	< 0.054	< 0.012
Cs-134	< 0.032	< 0.026	< 0.013
Cs-137	< 0.050	< 0.041	< 0.011
Ce-141	< 0.056	< 0.044	< 0.015
Ce-144	< 0.258	< 0.135	< 0.064

Location	D-016	D-016	D-016
Lab Code	DVE- 2711	DVE- 2712	DVE- 2713
Date Collected	09-12-23	09-12-23	09-12-23
Sample Type	Green Leaves	Forage	Corn
K-40	5.86 ± 0.60	4.37 ± 0.53	3.56 ± 0.23
Mn-54	< 0.026	< 0.025	< 0.006
Fe-59	< 0.056	< 0.064	< 0.018
Co-58	< 0.028	< 0.021	< 0.004
Co-60	< 0.029	< 0.024	< 0.005
Zn-65	< 0.052	< 0.053	< 0.016
Nb-95	< 0.027	< 0.032	< 0.007
Zr-95	< 0.041	< 0.051	< 0.011
Ru-103	< 0.030	< 0.023	< 0.007
Ru-106	< 0.187	< 0.274	< 0.063
I-131	< 0.043	< 0.048	< 0.006
Cs-134	< 0.027	< 0.029	< 0.008
Cs-137	< 0.032	< 0.034	< 0.006
Ce-141	< 0.055	< 0.065	< 0.010
Ce-144	< 0.214	< 0.172	< 0.045

Table 7. Surface water samples, analyses for iodine-131, tritium and gamma-emitting isotopes.

Collection: Monthly
Units: pCi/L
Location: D-49

Lab Code	DSW- 103	DSW- 365	DSW- 596	DSW- 951	DSW- 1290	DSW- 1643
Date Collected	01-18-23	02-20-23	03-20-23	04-18-23	05-18-23	06-19-23
H-3	< 160	< 154	< 164	< 161	< 161	< 162
Mn-54	< 4.4	< 2.0	< 3.7	< 3.8	< 2.7	< 2.5
Fe-59	< 5.9	< 4.5	< 5.2	< 3.7	< 4.2	< 13.4
Co-58	< 2.1	< 2.5	< 2.0	< 3.8	< 2.9	< 4.3
Co-60	< 3.1	< 2.5	< 7.0	< 2.4	< 3.4	< 2.8
Zn-65	< 6.1	< 6.5	< 5.4	< 3.6	< 4.2	< 11.3
Nb-95	< 2.1	< 2.2	< 3.0	< 4.1	< 2.3	< 6.7
Zr-95	< 4.1	< 4.0	< 6.5	< 6.3	< 4.5	< 10.2
I-131	< 4.0	< 2.8	< 5.2	< 3.3	< 4.6	< 12.0
Cs-134	< 3.6	< 2.7	< 3.6	< 3.6	< 2.4	< 7.6
Cs-137	< 3.4	< 3.3	< 6.2	< 2.3	< 2.5	< 6.2
Ba-140	< 10.9	< 9.4	< 12.4	< 8.1	< 12.3	< 30.2
La-140	< 4.1	< 1.9	< 2.8	< 3.0	< 2.2	< 5.4

Lab Code	DSW- 2052	DSW- 2495	DSW- 2771	DSW- 3227	DSW- 3546	DSW- 3929
Date Collected	07-18-23	08-16-23	09-18-23	10-17-23	11-14-23	12-18-23
H-3	< 162	< 161	< 163	< 169	< 172	< 171
Mn-54	< 4.8	< 4.0	< 8.1	< 3.4	< 1.6	< 2.0
Fe-59	< 9.1	< 7.1	< 20.0	< 4.5	< 3.1	< 5.0
Co-58	< 3.4	< 1.7	< 6.3	< 2.3	< 1.2	< 1.8
Co-60	< 4.2	< 8.9	< 7.0	< 8.0	< 3.4	< 0.8
Zn-65	< 10.1	< 5.1	< 14.3	< 4.3	< 3.3	< 4.8
Nb-95	< 4.3	< 4.6	< 7.2	< 4.3	< 2.7	< 2.8
Zr-95	< 7.9	< 7.3	< 13.6	< 4.9	< 3.4	< 3.1
I-131	< 6.8	< 6.6	< 7.2	< 3.6	< 2.4	< 2.2
Cs-134	< 5.6	< 4.9	< 8.6	< 3.9	< 1.9	< 2.7
Cs-137	< 4.2	< 7.2	< 7.7	< 8.5	< 3.3	< 2.5
Ba-140	< 21.4	< 18.6	< 14.0	< 20.9	< 8.6	< 9.4
La-140	< 4.7	< 3.1	< 9.3	< 4.6	< 1.9	< 3.3

Table 7. Surface water samples, analyses for iodine-131, tritium and gamma-emitting isotopes.

Collection: Monthly
Units: pCi/L
Location: D-61

Lab Code	DSW- 104	DSW- 366	DSW- 597	DSW- 952	DSW- 1292	DSW- 1644
Date Collected	01-18-23	02-20-23	03-20-23	04-18-23	05-18-23	06-19-23
H-3	< 160	< 154	< 164	< 161	< 161	< 158
Mn-54	< 2.9	< 2.0	< 2.8	< 1.1	< 1.9	< 4.9
Fe-59	< 5.0	< 5.0	< 4.2	< 2.6	< 2.8	< 14.4
Co-58	< 1.9	< 2.6	< 3.8	< 1.4	< 1.3	< 4.3
Co-60	< 2.7	< 6.6	< 1.6	< 2.8	< 1.5	< 3.4
Zn-65	< 2.9	< 5.4	< 8.1	< 2.1	< 2.7	< 10.1
Nb-95	< 1.9	< 2.0	< 2.6	< 1.6	< 1.7	< 6.9
Zr-95	< 3.9	< 4.7	< 6.1	< 2.3	< 1.9	< 9.5
I-131	< 2.3	< 4.6	< 3.2	< 1.9	< 2.7	< 12.1
Cs-134	< 3.3	< 3.1	< 3.8	< 1.4	< 1.5	< 7.1
Cs-137	< 3.3	< 5.6	< 5.0	< 2.3	< 1.6	< 4.9
Ba-140	< 12.0	< 8.7	< 16.4	< 5.0	< 8.6	< 36.1
La-140	< 3.4	< 1.8	< 3.8	< 1.7	< 2.4	< 10.8

Lab Code	DSW- 2051	DSW- 2496	DSW- 2772	DSW- 3228	DSW- 3547	DSW- 3931
Date Collected	07-18-23	08-16-23	09-18-23	10-17-23	11-14-23	12-18-23
H-3	< 162	< 158	< 163	< 169	< 172	< 171
Mn-54	< 2.7	< 5.4	< 7.5	< 7.7	< 1.7	< 2.4
Fe-59	< 5.1	< 4.4	< 6.5	< 12.3	< 4.1	< 4.0
Co-58	< 2.3	< 6.7	< 5.0	< 8.3	< 3.3	< 3.1
Co-60	< 6.3	< 4.8	< 5.1	< 7.2	< 5.4	< 3.0
Zn-65	< 4.8	< 8.6	< 7.0	< 7.6	< 3.5	< 7.7
Nb-95	< 2.4	< 4.5	< 7.5	< 9.5	< 2.4	< 3.3
Zr-95	< 6.6	< 11.7	< 14.0	< 11.1	< 4.1	< 2.4
I-131	< 5.2	< 4.2	< 7.9	< 5.4	< 11.8	< 2.7
Cs-134	< 3.3	< 7.3	< 9.7	< 9.3	< 3.3	< 2.9
Cs-137	< 5.7	< 7.4	< 4.9	< 6.5	< 5.5	< 2.8
Ba-140	< 14.5	< 13.6	< 39.7	< 19.5	< 18.6	< 11.6
La-140	< 3.1	< 3.6	< 5.3	< 5.7	< 4.8	< 2.8

Table 8. Fish, analyses of edible portion for gamma-emitting isotopes.

Collection: Semiannually

Units: pCi/g wet

Location	Upstream, D-49		
Lab Code	DF- 1021	DF- 1022	DF- 3499
Date Collected	04-27-23	04-27-23	11-07-23
Sample Type	Channel Catfish	Walleye	Walleye
K-40	3.44 ± 0.37	3.53 ± 0.34	3.65 ± 0.57
Mn-54	< 0.014	< 0.011	< 0.014
Fe-59	< 0.051	< 0.025	< 0.033
Co-58	< 0.017	< 0.012	< 0.023
Co-60	< 0.014	< 0.013	< 0.011
Zn-65	< 0.029	< 0.022	< 0.039
Nb-95	< 0.035	< 0.017	< 0.039
Zr-95	< 0.024	< 0.027	< 0.025
Ru-103	< 0.016	< 0.020	< 0.035
Ru-106	< 0.129	< 0.088	< 0.164
Cs-134	< 0.018	< 0.012	< 0.023
Cs-137	< 0.017	< 0.010	< 0.020
Ce-141	< 0.043	< 0.035	< 0.055
Ce-144	< 0.105	< 0.052	< 0.117

Location	Downstream, D-61			
Lab Code	DF- 1023	DF- 1024	DF- 3500	DF- 3502
Date Collected	04-27-23	04-27-23	11-07-23	11-07-23
Sample Type	Channel Catfish	Largemouth Bass	Walleye	Channel Catfish
K-40	3.61 ± 0.35	3.66 ± 0.35	4.30 ± 0.60	4.10 ± 0.60
Mn-54	< 0.010	< 0.011	< 0.019	< 0.019
Fe-59	< 0.025	< 0.043	< 0.047	< 0.053
Co-58	< 0.015	< 0.013	< 0.015	< 0.018
Co-60	< 0.026	< 0.013	< 0.017	< 0.024
Zn-65	< 0.034	< 0.024	< 0.065	< 0.060
Nb-95	< 0.017	< 0.031	< 0.045	< 0.035
Zr-95	< 0.021	< 0.033	< 0.038	< 0.049
Ru-103	< 0.032	< 0.023	< 0.029	< 0.023
Ru-106	< 0.117	< 0.123	< 0.175	< 0.130
Cs-134	< 0.015	< 0.013	< 0.023	< 0.022
Cs-137	< 0.022	< 0.017	< 0.022	< 0.025
Ce-141	< 0.047	< 0.045	< 0.028	< 0.041
Ce-144	< 0.098	< 0.080	< 0.108	< 0.151

Table 9. River sediment, analysis for gamma-emitting isotopes.

Collection: Semiannually

Units: pCi/g dry

Location	D-49 (Control)	
Lab Code	DBS- 1016	DBS- 3413
Date Collected	04-27-23	11-02-23
K-40	9.97 ± 0.69	7.21 ± 0.41
Mn-54	< 0.031	< 0.016
Fe-59	< 0.085	< 0.028
Co-58	< 0.027	< 0.019
Co-60	< 0.022	< 0.009
Zn-65	< 0.062	< 0.024
Nb-95	< 0.041	< 0.020
Zr-95	< 0.050	< 0.021
Ru-103	< 0.035	< 0.022
Ru-106	< 0.180	< 0.135
Cs-134	< 0.019	< 0.011
Cs-137	0.08 ± 0.025	< 0.012
Ce-141	< 0.085	< 0.052
Ce-144	< 0.116	< 0.075

Location	D-51 (Discharge)	
Lab Code	DBS- 1017	DBS- 3414
Date Collected	04-27-23	11-02-23
K-40	10.18 ± 0.76	7.33 ± 0.50
Mn-54	< 0.038	< 0.018
Fe-59	< 0.112	< 0.057
Co-58	< 0.045	< 0.022
Co-60	< 0.029	< 0.014
Zn-65	< 0.052	< 0.041
Nb-95	< 0.079	< 0.037
Zr-95	< 0.083	< 0.035
Ru-103	< 0.052	< 0.020
Ru-106	< 0.135	< 0.127
Cs-134	< 0.022	< 0.011
Cs-137	0.07 ± 0.037	< 0.016
Ce-141	< 0.113	< 0.061
Ce-144	< 0.212	< 0.112

Table 10 Groundwater Protection Program Summary.

Ground water, Monitoring wells, analyses for tritium [a].

Lab Code	Date	H-3 (pCi/L)	
		D-129A	(09A)
DWW- 1455	06/01/23	< 157	
		D-129B	(09B)
DWW- 1478	05/31/23	253 ± 89	
		D-131A	(11A)
DWW- 1469	06/01/23	< 157	
		D-131B	(11B)
DWW- 1470	06/01/23	< 157	
		D-132A	(12A)
DWW- 1471	06/01/23	864 ± 117	
		D-132B	(12B)
DWW- 1473	06/01/23	237 ± 88	
		D-134A	(14A)
DWW- 1459	05/31/23	467 ± 99	
		D-134B	(14B)
DWW- 1554	06/06/23	211 ± 86	
		D-62	(18A)
DWW- 1460	05/31/23	512 ± 101	
		D-64	(20A)
DWW- 1479	05/31/23	223 ± 87	

[a] Analyses for gamma, gross alpha, Sr-89, Sr-90, Fe-55 and Ni-63 will be performed if tritium activity > 1K pCi/L.

Table 18 Groundwater Protection Program Summary.

Ground water, Monitoring wells, analyses for tritium [a].

Lab Code	Date	H-3 (pCi/L)	
		D-65	(21A)
DWW- 1461	05/31/23	< 157	
		D-66	(22A)
DWW- 1458	05/31/23	291 ± 91	
		D-67	(23A)
DWW- 1456	05/31/23	486 ± 100	
		D-165	(24A)
DWW- 1464	06/01/23	< 157	
		D-167	(26A)
DWW- 1472	06/01/23	192 ± 85	
		D-168A	(27A)
DWW- 1465	06/01/23	< 157	
		D-168B	(27B)
DWW- 1466	06/01/23	< 157	
		D-169A	(28A)
DWW- 1474	06/01/23	< 157	
		D-169B	(28B)
DWW- 1451	06/01/23	< 157	

[a] Analyses for gamma, gross alpha, Sr-89, Sr-90, Fe-55 and Ni-63 will be performed if tritium activity > 1K pCi/L .

Table 18 Groundwater Protection Program Summary.

Ground water, Monitoring wells, analyses for tritium [a].

Lab Code	Date	H-3 (pCi/L)	
		D-170A	(29A)
DWW- 1468	06/01/23	183 ± 85	
		D-170B	(29B)
DWW- 1450	06/01/23	< 157	
		D-171A	(30A)
DWW- 1452	06/01/23	< 157	
		D-171B	(30B)
DWW- 1462	06/01/23	< 157	
		D-173A	(32A)
DWW- 1467	06/01/23	< 157	
		D-173B	(32B)
DWW- 1475	06/01/23	169 ± 84	
		D-79	MW-33A
DWW- 1453	06/01/23	< 157	
		D-80	MW-34A
DWW- 1454	06/01/23	232 ± 87	
		D-81	MW-35A
DWW- 1476	06/01/23	< 157	

[a] Analyses for gamma, gross alpha, Sr-89, Sr-90, Fe-55 and Ni-63 will be performed if tritium activity > 1K pCi/L .

Table 18 Groundwater Protection Program Summary.

Ground water, Monitoring wells, analyses for tritium [a].

Lab Code	Date	H-3 (pCi/L)
		EW-01
DWW- 1457	05/31/23	730 ± 111
		EW-02
DWW- 1480	05/31/23	798 ± 114
		EW-03
DWW- 1477	05/31/23	699 ± 110

[a] Analyses for gamma, gross alpha, Sr-89, Sr-90, Fe-55 and Ni-63 will be performed if tritium activity > 1K pCi/L .