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ZION NUCLEAR POWER STATION

Annual Radiological Environmental Operating Report

1 January through 31 December 2019

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Zion, IL 60099

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I. Summary and Conclusions

This report on the Radiological Environmental Monitoring Program (REMP) conducted for the Zion Nuclear Power Station (ZNPS) by ZionSolutions (ZS) covers the period 1 January 2019 through 31 December 2019. During that time period, 1,041 analyses were performed on 1,121 samples. In assessing all the data gathered for this report and comparing these results with preoperational data, it was concluded that the operation of ZNPS had no adverse radiological impact on the environment.

Public water samples were analyzed for concentrations of gross beta, tritium and gamma-emitting nuclides. No fission or activation products were detected. Gross beta activities detected were consistent with those detected in previous years, and with levels of natural radioactivity typically observed in the environment.

Food product samples/vegetation were analyzed for concentrations of gamma-emitting nuclides. No fission or activation products were detected.

Fish (commercially and recreationally important species) and sediment samples were analyzed for concentrations of gamma-emitting nuclides. No Cesium-137 (Cs-137) activity was detected in fish or sediment samples. No plant-produced fission or activation products were found in fish or sediment.

Air particulate samples were analyzed for concentrations of gross beta and gamma-emitting nuclides. No fission or activation products were detected.

Environmental gamma radiation measurements were performed quarterly using thermoluminescent dosimeters.

The RETDAS Computer Model predicts concentrations of activation and fission products in off-site media (fish, vegetation, sediment, air and water) based on measured concentrations of sampled airborne activity. Permitted liquid discharges were terminated in 2018, and no liquid discharges, permitted, planned or unplanned have been performed since.

This is why the concentrations offsite and the resulting dose impact are calculated by computer. The levels predicted are too low to measure off site, as demonstrated by the results of environmental sampling summarized in this report.

Lastly, in Appendix E is the annual groundwater report summarizing the results of groundwater samples collected on site quarterly. In 2018, tritium was identified in groundwater for the first time since the station's 10CFR50 licenses were transferred from Exelon to Zion Solutions on September 1, 2010. One result was just above MDA in well 08S in February 2019, but on two subsequent recounts of the same sample, results were below MDA. No other positive tritium results were identified in any other ground water or surface water results in 2019. This is reviewed and discussed in Appendix E.

II. Introduction

The Zion Nuclear Power Station (ZNPS), consisted of two 1,100 MWt pressurized water reactors, was owned and operated by Exelon Corporation, and is located in Zion, Illinois adjacent to Lake Michigan. Unit No. 1 went critical in December 1973. Unit No. 2 went critical in September 1974. The plant permanently ceased operation in January of 1998 and has been permanently defueled, and except for the Independent Spent Fuel Storage Installation (ISFSI), no above-ground structures remain on site. All structures have been surveyed, characterized, demolished and shipped off site as waste. Some clean construction debris was used as backfill in accordance with the License Termination Plan (LTP). The only remaining sources of radioactive material on site include spent fuel stored in canisters on the ISFSI and trace amounts of radioactive material in backfilled structures and surface soil per the Station's LTP. The site is located in northeast Illinois on the western shore of Lake Michigan, approximately 50 miles north of Chicago, Illinois.

This report covers those analyses performed by Teledyne Brown Engineering (TBE) and Mirion Technologies on samples collected during the period 1 January 2019 through 31 December 2019.

A. Objectives of the REMP

The objectives of the REMP are to:

1. Provide data on measurable levels of radiation and radioactive materials at and beyond the site boundary, in public areas and in the environment.
2. Evaluate the relationship between quantities of radioactive material released from the plant and resultant radiation doses to individuals from principal pathways of exposure
3. Validate the effluent computer model that predicts radioactive material concentrations at populated off-site sample locations.

B. Implementation of the Objectives

The implementation of the objectives is accomplished by:

1. Identifying significant exposure pathways
2. Establishing baseline radiological data of media within those pathways
3. Continuously monitoring those media before, during and after Station operation to assess Station radiological impacts (if any) on man and the environment

III. Program Description

A. Sample Collection

Samples for the ZNPS REMP were collected for Zion Solutions (ZS) by Environmental Inc. (Midwest Labs). This section describes the general collection methods used by Environmental Inc. (Midwest Labs) to obtain environmental samples for the ZNPS REMP in 2019. Sample locations and descriptions can be found in Table B-1 and Figures B-1, B-2 and B-3 in Appendix B. The sampling methods used by Environmental Inc. (Midwest Labs) are listed in Table B-2.

Aquatic Environment

The aquatic environment was evaluated by performing radiological analyses on samples of public water, fish and sediment. Two gallon water samples were collected monthly from four public water locations (Z-14, Z-15, Z-16 and Z-18). Control locations were Z-14 and Z-18. All samples were collected in new unused plastic bottles, which were rinsed at least twice with source water prior to collection. Fish samples comprised of the edible flesh portion of white sucker, largemouth bass, common carp, brown trout, lake trout and burbot were collected semiannually at two locations, Z-26 and Z-27. Sediment samples composed of recently deposited substrate were collected at one location semiannually, Z-25.

Atmospheric Environment

The atmospheric environment was evaluated by performing radiological analyses on samples of air particulates. Airborne particulate samples were collected and analyzed weekly at four land based locations (Z-01, Z-02, Z-03, and Z-13). Locations Z-01 (South), Z-02 (West) and Z-03 (North) surround the power block footprint and are utilized to identify any airborne radioactivity that might leave the site - none was detected. The easterly location is over water (Lake Michigan). The control location was Z-13, located 10 miles northwest of the site. Airborne particulate samples were obtained at each location, using a vacuum pump with glass fiber filters attached. The pumps were run continuously and sampled air at the rate of approximately one cubic foot per minute. The filters were replaced weekly and sent to the laboratory for analysis.

Terrestrial Environment

The terrestrial environment was evaluated by performing radiological analyses on food product samples. Food products were collected annually in August at three locations (Z-Control, Z-Quad 3 and Z-Quad 4). The control location was Z-Control. Various types of samples were collected and placed in new unused plastic bags and sent to the laboratory for analysis.

Ambient Gamma Radiation

Direct radiation measurements were made with Panasonic Environmental TLD type 814 with 3 CaSO₄ elements. Each location consisted of 2 TLD sets. The TLD locations were placed on, around and surrounding the ZNPS site at the following locations:

Inner Ring: Z-01, Z-02, Z-03, Z-101, Z-102, Z-103, Z-104, Z-105, Z-106, Z-107, Z-108, Z-109, Z-121, Z-124, Z-125, Z-129, Z-130, Z-131

Special Interest: Z-112, Z-113, Z-114, Z-115

Outer Ring: Z-209, Z-211, Z-212, Z-213, Z-214, Z-215, Z-216

Control: Z-13

The specific TLD locations were determined by the following criteria:

1. The presence of relatively dense population;
2. Site meteorological data taking into account distance and elevation for each of the sixteen–22 1/2 degree sectors around the site, where estimated annual dose from ZNPS, if any, would be most significant;
3. On hills free from local obstructions and within clear line of sight to construction activities (where practical) and the ISFSI;
4. And near the closest dwelling to the demolition activities in the prevailing downwind direction and the ISFSI.

(Two TLDs – each comprised of three CaSO₄ elements enclosed in plastic – were placed at each location approximately four to eight feet above ground level. The TLDs were exchanged quarterly and sent to Mirion Technologies for analysis.)

B. Sample Analysis

This section describes the general analytical methodologies used by TBE to analyze the environmental samples for radioactivity for the ZNPS REMP in 2019. The analytical procedures used by the laboratories are listed in Table B-2.

In order to achieve the stated objectives, the current program includes the following analyses:

1. Concentrations of beta emitters in public water and air particulates using gross beta analysis with proportional detectors.

2. Concentrations of gamma emitters in public water, air particulates, vegetation, fish, and sediment using high purity germanium (HPGe) gamma spectroscopy.
3. Concentrations of tritium in public water using liquid scintillation analysis (LSC) with the energy window focused on the tritium emission energy.
4. Ambient gamma radiation levels at various locations on and off site up to 10 miles away using multi-chip thermoluminescent dosimeters (TLDs).

C. Data Interpretation

The radiological and direct radiation data collected prior to Zion Nuclear Power Station becoming operational were used as a baseline with which these operational data were compared. For the purpose of this report, Zion Nuclear Power Station was considered operational at initial criticality. In addition, data was compared to previous years' operational data for consistency and trending. Several factors were important in the interpretation of the data:

1. Lower Limit of Detection and Minimum Detectable Concentration

The lower limit of detection (LLD) is defined as the smallest concentration of radioactive material in a sample that would yield a net count (above background) that would be detected with only a 5% probability of falsely concluding that a blank observation represents a "real" signal. The LLD is intended as a before the fact estimate of a system (including instrumentation, procedure and sample type) and not as an after the fact criteria for the presence of activity. All analyses were designed to achieve the required ZNPS detection capabilities for environmental sample analysis.

The minimum detectable concentration (MDC) is defined above with the exception that the measurement is an after the fact estimate of the presence of activity.

2. Net Activity Calculation and Reporting of Results

Net activity for a sample was calculated by subtracting background activity from the sample activity. Since the REMP measures extremely small changes in radioactivity in the environment, background variations may result in sample activity being lower than the background activity affecting a negative number. A less than MDC value was reported in all cases where positive activity was not detected at the MDC.

Gamma spectroscopy results for each type of sample were grouped as follows:

For public water, fish, vegetation, sediment and air particulates 11 nuclides, Mn-54, Co-58, Fe-59, Co-60, Zn-65, Nb-95, Zr-95, Cs-134, Cs-137, Ba-140, and La-140 were reported.

Means and standard deviations of the results were calculated. The standard deviations represent the variability of measured results for different samples rather than single analysis uncertainty.

D. Program Exceptions

For 2019 the ZNPS REMP had a sample recovery rate in excess of 99%. Sample anomalies and missed samples are listed in the tables below:

Table D-1 LISTING OF SAMPLE ANOMALIES

Sample Type	Location Code	Collection Date	Reason
AP	Z-01	01/02/19	Filter light; possibly due to pump lower flow of 55 cfh. Collector adjusted flow to 60 cfh.
AP	Z-01, Z-02, Z-03, Z-13	02/01/19	Exchange moved from 01/30/19 to 02/01/19 due to severe winter conditions.
PW	Z-14, Z-15, Z-16, Z-18	02/01/19	Sample collection moved from 01/30/19 to 02/01/19 due to sever winter conditions.
AP	Z-13	02/20/19	Low timer reading of 107.0 hrs possibly caused by switching power source to the location. Station notified. NOTE: timer reading of 168.0 hrs on 02/27/19 collection.
AP	Z-03	04/17/19	Possible power outage. Pump and timer operating correctly. Station powered by a generator. NOTE: On 04/24/19 the timer indicated 167.1 hrs; normal reading for 7-day run.
AP	Z-03	06/26/19	Low timer reading of 75.8 hrs due to the powering generator running out of fuel. NOTE: On 07/03/19 the timer indicated 167.2 hrs; normal reading for 7-day run.
AP	Z-03	07/10/19	Low timer reading of 77 hrs due to the powering generator running out of fuel. NOTE: On 07/17/19 the timer indicated 168.1 hrs; normal reading for 7-day run.
AP	Z-03	08/07/19	Low timer reading of 139.9 hrs. Pump found not working. Station informed; technician found a tripped breaker. Pump reset and working properly.

Table D-1 LISTING OF SAMPLE ANOMALIES (cont'd)

AP	Z-03	08/14/19	Low timer reading of 143.2 hrs. No apparent reason; pump running properly. NOTE: During the collection on 08/21/19, the timer indicated 168.6 rhs; normal reading for 7-day run.
AP	Z-03	08/21/19	Lower pump flow rate 45 cfh. No apparent reason. Pump adjusted to 60 cfh; filter residue appears similar to other samples.
AP	Z-03	09/05/19	Low timer reading of 151.5 hrs in 8-day collection period due to possible vandalism of the station. NOTE: On 09/11/19 the timer indicated 143.8 hrs; normal time for 6-day run.
F	Z-26	October, 2019	The collectors could not catch bottom feeding fish. During the 2-day period and multiple net settings, only 3 bottom feeders (totaling 240 g) observed. The station informed; rock bass collected as a substitute.
AP	Z-03	11/13/19	Low reading of 102.7 hours, possible caused by lack of fuel. Pump found running.
TLD	Z-211-1, Z-214-1 & 2	12/25/19	TLDs found on the ground.

Table D-2 LISTING OF MISSED SAMPLES

Sample Type	Location Code	Collection Date	Reason
TLD	101-2	03/27/19	TLD 101-2 was missing during the quarterly exchange and could not be found. Vandalism or construction work are the suspected causes of its disappearance.

Each program exception was reviewed to understand the causes of the program exception. Sampling and maintenance errors were reviewed with the personnel involved to prevent recurrence. Occasional equipment breakdowns and power outages were unavoidable. The overall sample recovery rate indicates that the appropriate procedures and equipment are in place to assure reliable program implementation.

E. Program Changes

There were no program changes for 2019.

IV. Results and Discussion

A. Aquatic Environment

1. Public Water

Samples were taken weekly and composited monthly at four locations (Z-14, Z-15, Z-16 and Z-18). The following analyses were performed.

Gross Beta

Samples from all locations were analyzed for concentrations of gross beta. Gross beta was detected in 21 of 48 samples. The values ranged from 1.9 pCi/L to 4.2 pCi/L. Concentrations detected were consistent with those detected in previous years. (Table C-I.1, Appendix C) (Figures C-1 and C-2, Appendix C)

Tritium

Quarterly composites of weekly collections were analyzed for tritium activity (Table C-I.2, Appendix C). No tritium was detected and the LLD was met (Figures C-3 and C-4, Appendix C).

Gamma Spectrometry

Samples from both locations were analyzed for gamma-emitting nuclides. No nuclides were detected and all required LLDs were met. (Table C-I.3, Appendix C)

2. Fish

Fish samples comprised of white sucker, yellow perch, brown trout, rock bass, lake trout and burbot were collected at two locations (Z-26 and Z-27) semiannually. The following analysis was performed:

Gamma Spectrometry

The edible portion of fish samples from both locations was analyzed for gamma-emitting nuclides. No nuclides were detected and all required LLDs were met. (Table C-II.1, Appendix C)

3. Sediment

Aquatic sediment samples are collected at one location (Z-25) semiannually. The following analysis was performed:

Gamma Spectrometry

Sediment samples from Z-25 were analyzed for gamma-emitting nuclides. No nuclides were detected and all required LLDs were met. (Table C-III.1, Appendix C)

B. Atmospheric Environment

1. Airborne - Air Particulates

Continuous air particulate samples were collected from four locations on a weekly basis. Three locations were within the ZNPS site boundary (Z-01, Z-02 and Z-03) and the fourth is located 10 miles north and is the control location (Z-13). The following analyses were performed:

Gross Beta

Weekly samples were analyzed for concentrations of beta emitters. Detectable gross beta activity was observed at all locations, except one control air sample (see Table C-IV.1). Comparison of results among the three groups aids in determining the effects, if any, resulting from the operation of ZNPS. The positive results from the three On-Site locations ranged from $6\text{E-}3$ pCi/m³ to $31\text{E-}3$ pCi/m³ with a mean of $14\text{E-}3$ pCi/m³ and one result <LLD.

The results from the Control location ranged from $8\text{E-}3$ pCi/m³ to $34\text{E-}3$ pCi/m³ with a mean of $15\text{E-}3$ pCi/m³. Comparison of the 2019 air particulate data with previous year's data indicates there is no offsite impact resulting from demolition activities at ZNPS. Concentrations detected were consistent with those detected in previous years. (Table C-IV.1 and C-IV.2, Appendix C)

Gamma Spectrometry

Weekly samples were composited quarterly and analyzed for gamma-emitting nuclides. No plant-related nuclides were detected and all required LLDs were met. Naturally occurring Be-7 was detected; the source of this is described later in this report. (Table C-IV.3, Appendix C)

C. Terrestrial Environment

1. Food Product

Food product samples were collected at three locations (Z-Control, Z-Quad 3 and Z-Quad 4) when available. The following analysis was performed:

Gamma Spectrometry

Samples from all locations were analyzed for gamma-emitting nuclides. No nuclides were detected and all required LLDs were met. (Table C-V.1, Appendix C)

D. Ambient Gamma Radiation

Ambient gamma radiation levels were measured utilizing Panasonic Environmental Type 814 CaSO₄ thermoluminescent dosimeters (TLD's). Sixty-four TLDs were mounted at 30 locations around the site. Results of TLD measurements are listed in Tables C-VI.1 to C-VI.3, Appendix C.

Most TLD measurements were below 25 mR/quarter, with a range of 14 mR/quarter to 33 mR/quarter. As there are duplicate TLDs posted at each location, the highest value is always reported in Appendix C for each location. The 17 mR/quarter reading was from the first quarter at location Z-102-1, but the higher value of 18 mR/quarter was reported (Z-102-2) in Appendix C.

When direct dose in 2019 is compared to direct dose the previous five years (2014-2019) at the four compass points surrounding decommissioning activities (Figure C-8) within the site boundary, there is a visible drop in direct dose. This is attributed to a steady reduction in source term over the same period, including demolition of structures inside the former protected area, and shipment by rail and truck of the debris to Energy Solutions low level waste facilities in Utah.

When looking at a more specific set of TLD's, those most likely to be impacted by direct radiation from the Independent Spent Fuel Storage Installation (ISFSI) by close proximity and line of site positioning inside the site boundary (Figure C-7), a significant increase in direct dose is evident in 2015 following completion of the transfer of spent fuel to the ISFSI. After 2015, a drop in direct dose is evident due in part to site source term reduction, and to a lesser extent, decay of the spent fuel. The drop was sharp initially with a leveling off from 2017 to 2019.

E. Land Use Survey

A Land Use Census conducted during October 2019 around the Zion Nuclear Power Station (ZNPS) was performed by Zion Station Personnel for ZS to comply with Chapter 3 of the Zion Offsite Dose Calculation Manual. The purpose of the survey was to document the nearest resident, milk producing animal and garden of greater than 500 ft² in each of the sixteen 22 ½ degree sectors around the site. The results of this survey are summarized below:

Sector	Distance in Miles from ZS		
	Residence Miles	Garden Miles	Milk Farm Miles
N	2.5	3.4	>10
NNE	-	-	-
NE	-	-	-
ENE	-	-	-
E	-	-	-
ESE	-	-	-
SE	-	-	-
SSE	-	-	-
S	-	-	-
SSW	1.9	>10	>10
SW	1.1	4.8	>10
WSW	1.0	3.0	>10
W	1.1	2.9	>10
WNW	1.0	2.7	>10
NW	1.0	3.2	>10
NNW	1.3	3.5	>10

Source: Ill. Department of Agriculture and USGS recommended using google maps to locate garden areas due to gardens and milk animals are voluntary declarations, also aerial photographs on ARCGIS layers updated by government sources are 5-10 years old.

Gardens are located using Google Maps to narrow down areas that appeared to have been ploughed by aerial photographs, then visually verified by visiting these new locations.

Milk-producing animal located by internet search for dairies advertising the sale of milk for public consumption. No milk-producing farms were found within 10 miles of the site.

F. Errata Data

There was no errata data for 2019.

G. Summary of Results – Inter-Laboratory Comparison Program

The TBE Laboratory analyzed Performance Evaluation (PE) samples of air particulate, air iodine, milk, soil, vegetation, and water matrices for various analytes. The PE samples supplied by Analytics Inc., Environmental Resource Associates (ERA) and Department of Energy (DOE) Mixed Analyte Performance Evaluation Program (MAPEP), were evaluated against the following pre-set acceptance criteria:

A. Analytics Evaluation Criteria

Analytics' evaluation report provides a ratio of TBE's result and

Analytics' known value. Since flag values are not assigned by Analytics, TBE evaluates the reported ratios based on internal QC requirements based on the DOE MAPEP criteria.

B. ERA Evaluation Criteria

ERA's evaluation report provides an acceptance range for control and warning limits with associated flag values. ERA's acceptance limits are established per the USEPA, National Environmental Laboratory Accreditation Conference (NELAC), state-specific Performance Testing (PT) program requirements or ERA's SOP for the Generation of Performance Acceptance Limits, as applicable. The acceptance limits are either determined by a regression equation specific to each analyte or a fixed percentage limit promulgated under the appropriate regulatory document.

C. DOE Evaluation Criteria

MAPEP's evaluation report provides an acceptance range with associated flag values. MAPEP defines three levels of performance:

- Acceptable (flag = "A") - result within $\pm 20\%$ of the reference value
- Acceptable with Warning (flag = "W") - result falls in the $\pm 20\%$ to $\pm 30\%$ of the reference value
- Not Acceptable (flag = "N") – bias is greater than 30% of the reference value

Note: The Department of Energy (DOE) Mixed Analyte Performance Evaluation Program (MAPEP) samples are created to mimic conditions found at DOE sites which do not resemble typical environmental samples obtained at commercial nuclear power facilities.

For the TBE laboratory, 119 out of 129 analyses performed met the specified acceptance criteria. Ten analyses did not meet the specified acceptance criteria for the following reasons and were addressed through the TBE Corrective Action Program. A summary is found below:

1. The ERA April 2019 water Cs-134 result was evaluated as *Not Acceptable*. The reported value was 15.2 pCi/L (error 2.82 pCi/L) and the known result was 12.1 pCi/L (acceptance range of 8.39 - 14.4 pCi/L). With the error, the reported result overlaps the acceptable range. This sample was run as the workgroup duplicate on a different detector with a result of 10.7 pCi/L (within acceptable range). (NCR 19-10)
2. The ERA April 2019 water Sr-89 result was evaluated as *Not Acceptable*. The reported value was 44.9 pCi/L and the known result was 33.3 pCi/L (acceptance range of 24.5 - 40.1 pCi/L). The sample was only counted for 15 minutes instead of 200 minutes. The sample

was re-prepped in duplicate and counted for 200 minutes with results of 30.7 ± 5.37 pCi/L and 33.0 ± 8.71 pCi/L. This was the 1st "high" failure for Sr-89 in 5 years. (NCR 19-11)

3. The MAPEP February 2019 soil Sr-90 result was not submitted and therefore evaluated as *Not Acceptable*. The sample was run in duplicate, with results of -1.32 ± 4.09 Bq/kg (<6.87) and -1.030 ± 3.55 Bq/kg (<5.97). The known result was a false positive test (no significant activity). TBE did not submit a result because it appeared that the results may not be accurate. TBE analyzed a substitute soil Sr-90 sample from another vendor, with a result within the acceptable range. (NCR 19-12)
4. The MAPEP February 2019 water Am-241 result was evaluated as *Not Acceptable*. The reported value was 0.764 ± 0.00725 Bq/L with a known result of 0.582 Bq/L (acceptable range 0.407 - 0.757 Bq/L). TBE's result falls within the upper acceptable range with the error. It appeared that a non-radiological interference was added and lead to an increased mass and higher result. (NCR 19-13)
5. The MAPEP February 2019 vegetation Sr-90 result was evaluated as *Not Acceptable*. The reported result was -0.1060 ± 0.0328 Bq/kg and the known result was a false positive test (no significant activity). TBE's result was correct in that there was no activity. MAPEP's evaluation was a "statistical failure" at 3 standard deviations. (NCR 19-14)
6. The ERA October 2019 water Gross Alpha result was evaluated as *Not Acceptable*. TBE's reported result was 40.5 ± 10.3 pCi/L and the known result was 27.6 pCi/L (ratio of TBE to known result at 135%). With the associated error, the result falls within the acceptable range (14.0 - 36.3 pCi/L). The sample was run as the workgroup duplicate on a different detector with a result of 30.8 ± 9.17 pCi/L (within the acceptable range). This was the first failure for drinking water Gr-A since 2012. (NCR 19-23)
7. The ERA October 2019 water Sr-90 result was evaluated as *Not Acceptable*. TBE's reported result was 32.5 ± 2.12 pCi/L and the known result was 26.5 pCi/L (ratio of TBE to known result at 123%). With the associated error, the result falls within the acceptable range (19.2 - 30.9 pCi/L). The sample was run as the workgroup duplicate on a different detector with a result of 20.0 ± 1.91 pCi/L (within the acceptable range). Both TBE results are within internal QC limits. A substitute "quick response" sample was analyzed with an acceptable result of 18.6 pCi/L (known range of 13.2 - 22.1 pCi/L). (NCR 19-24)
8. The MAPEP August 2019 soil Ni-63 result of 436 ± 22.8 Bq/kg was evaluated as *Not Acceptable*. The known result was 629 Bq/kg (acceptable range 440 - 818 Bq/sample). With the associated error, the TBE result falls within the lower acceptance range. All associated QC

was acceptable. No reason for failure could be found. This is the first failure for soil Ni-63 since 2012. (NCR 19-25).

9. The MAPEP August 2019 water Am-241 result was not reported and therefore evaluated as *Not Acceptable*. Initial review of the results showed a large peak where Am-241 should be (same as the February, 2019 sample results). It is believed that Th-228 was intentionally added as an interference. The sample was re-prepped and analyzed using a smaller sample aliquot. The unusual large peak (Th-228) was seen again and also this time a smaller peak (Am-241). The result was 436 ± 22.8 Bq/L (acceptable range 0.365 ± 0.679 Bq/L). Th-228 is not a typical nuclide requested by clients, so there is no analytical purpose to take samples through an additional separation step. TBE will pursue using another vendor for Am-241 water cross-checks that more closely reflects actual customer samples. (NCR 19-26)
10. The Analytics September 2019 soil Cr-51 sample was evaluated as *Not Acceptable*. TBE's reported result of 0.765 ± 0.135 pCi/g exceeded the upper acceptance range (140% of the known result of 0.547 pCi/g). The TBE result was within the acceptable range (0.63 - 0.90 pCi/g) with the associated error. The Cr-51 result is very close to TBE's normal detection limit. In order to get a reportable result, the sample must be counted for 15 hours (10x longer than client samples). There is no client or regulatory requirement for this nuclide and TBE will remove Cr-51 from the reported gamma nuclides going forward. (NCR 19-27)

The Inter-Laboratory Comparison Program provides evidence of "in control" counting systems and methods, and that the laboratories are producing accurate and reliable data.

APPENDIX A

**RADIOLOGICAL ENVIRONMENTAL MONITORING
REPORT SUMMARY**

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**TABLE A-1 RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM ANNUAL SUMMARY FOR
THE ZION NUCLEAR POWER STATION, 2019**

Name of Facility:		ZION NUCLEAR POWER STATION			DOCKET NUMBER:		50-295 & 50-304	
Location of Facility:		ZION, IL			REPORTING PERIOD:		2019	
MEDIUM OR PATHWAY SAMPLED (UNIT OF MEASUREMENT)	TYPES OF ANALYSIS PERFORMED	NUMBER OF ANALYSIS PERFORMED	REQUIRED LOWER LIMIT OF DETECTION (LLD)	INDICATOR LOCATIONS MEAN ^(M) (f) RANGE	CONTROL LOCATION MEAN ^(M) (f) RANGE	LOCATION WITH HIGHEST ANNUAL MEAN (M) MEAN ^(M) (f) RANGE	STATION # NAME DISTANCE AND DIRECTION	NUMBER OF NONROUTINE REPORTED MEASUREMENTS
PUBLIC WATER (PCI/LITER)	GR-B	48	4	2.8 (11/24) 1.9 - 4.2	2.8 (10/24) 1.9 - 3.4	3.2 (5/12) 2.2 - 4.2	Z-15 INDICATOR LAKE COUNTY WATER WORKS 1.4 MILES NNW OF SITE	0
	H-3	16	200	<LLD	<LLD	-		0
	GAMMA	48						
		MN-54		15	<LLD	<LLD	-	0
		CO-58		15	<LLD	<LLD	-	0
		FE-59		30	<LLD	<LLD	-	0
		CO-60		15	<LLD	<LLD	-	0
		ZN-65		30	<LLD	<LLD	-	0
		NB-95		15	<LLD	<LLD	-	0
		ZR-95		15	<LLD	<LLD	-	0
	CS-134		15	<LLD	<LLD	-	0	
	CS-137		18	<LLD	<LLD	-	0	
	BA-140		NA	<LLD	<LLD	-	0	
	LA-140		NA	<LLD	<LLD	-	0	
FISH (PCI/KG WET)	GAMMA	8						
		MN-54		130	<LLD	NA	-	0
		CO-58		130	<LLD	NA	-	0
		FE-59		260	<LLD	NA	-	0
		CO-60		130	<LLD	NA	-	0
		ZN-65		260	<LLD	NA	-	0
		NB-95		NA	<LLD	NA	-	0
		ZR-95		NA	<LLD	NA	-	0
		CS-134		100	<LLD	NA	-	0
		CS-137		100	<LLD	NA	-	0
	BA-140		NA	<LLD	NA	-	0	
	LA-140		NA	<LLD	NA	-	0	

^(M) Mean and ranged based upon detectable measurements only. Fraction of detectable measurements at specified loactions is indicated in parentheses (f)

**TABLE A-1 RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM ANNUAL SUMMARY FOR
THE ZION NUCLEAR POWER STATION, 2019**

Name of Facility:	ZION NUCLEAR POWER STATION			DOCKET NUMBER:	50-295 & 50-304			
Location of Facility:	ZION, IL			REPORTING PERIOD:	2019			
MEDIUM OR PATHWAY SAMPLED (UNIT OF MEASUREMENT)	TYPES OF ANALYSIS PERFORMED	NUMBER OF ANALYSIS PERFORMED	REQUIRED LOWER LIMIT OF DETECTION (LLD)	INDICATOR LOCATIONS MEAN ^(M) (f) RANGE	CONTROL LOCATION MEAN ^(M) (f) RANGE	LOCATION WITH HIGHEST ANNUAL MEAN (M) MEAN ^(M) (f) RANGE	STATION # NAME DISTANCE AND DIRECTION	NUMBER OF NONROUTINE REPORTED MEASUREMENTS
SEDIMENT (PCI/KG DRY)	GAMMA	2						
	MN-54		NA	<LLD	NA	-		0
	CO-58		NA	<LLD	NA	-		0
	FE-59		NA	<LLD	NA	-		0
	CO-60		NA	<LLD	NA	-		0
	ZN-65		NA	<LLD	NA	-		0
	NB-95		NA	<LLD	NA	-		0
	ZR-95		NA	<LLD	NA	-		0
	CS-134		150	<LLD	NA	-		0
	CS-137		180	<LLD	NA	-		0
	BA-140		NA	<LLD	NA	-		0
	LA-140		NA	<LLD	NA	-		0
AIR PARTICULATE (E-3 PCI/CU.METER)	GR-B	212	10	14 (158/159) 6-31	15 (53/53) 8-34	15 (53/53) 8-34	Z-13 CONTROL OFFSITE CONTROL 10.0 MILES NW OF SITE	0
	GAMMA	16						
	MN-54		NA	<LLD	<LLD	-		0
	CO-58		NA	<LLD	<LLD	-		0
	FE-59		NA	<LLD	<LLD	-		0
	CO-60		NA	<LLD	<LLD	-		0
	ZN-65		NA	<LLD	<LLD	-		0
	NB-95		NA	<LLD	<LLD	-		0
	ZR-95		NA	<LLD	<LLD	-		0
	CS-134		10	<LLD	<LLD	-		0
	CS-137		10	<LLD	<LLD	-		0
	BA-140		NA	<LLD	<LLD	-		0
	LA-140		NA	<LLD	<LLD	-		0

^(M) Mean and ranged based upon detectable measurements only. Fraction of detectable measurements at specified locations is indicated in parentheses (f)

**TABLE A-1 RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM ANNUAL SUMMARY FOR
THE ZION NUCLEAR POWER STATION, 2019**

Name of Facility:	ZION NUCLEAR POWER STATION			DOCKET NUMBER:	50-295 & 50-304			
Location of Facility:	ZION, IL			REPORTING PERIOD:	2019			
MEDIUM OR PATHWAY SAMPLED (UNIT OF MEASUREMENT)	TYPES OF ANALYSIS PERFORMED	NUMBER OF ANALYSIS PERFORMED	REQUIRED LOWER LIMIT OF DETECTION (LLD)	INDICATOR LOCATIONS MEAN ^(M) (f) RANGE	CONTROL LOCATION MEAN ^(M) (f) RANGE	LOCATION WITH HIGHEST ANNUAL MEAN (M) MEAN ^(M) (f) RANGE	STATION # NAME DISTANCE AND DIRECTION	NUMBER OF NONROUTINE REPORTED MEASUREMENTS
VEGETATION (PCI/KGWET)	GAMMA	6						
	MN-54		NA	<LLD	<LLD	-		0
	CO-58		NA	<LLD	<LLD	-		0
	FE-59		NA	<LLD	<LLD	-		0
	CO-60		NA	<LLD	<LLD	-		0
	ZN-65		NA	<LLD	<LLD	-		0
	NB-95		NA	<LLD	<LLD	-		0
	ZR-95		NA	<LLD	<LLD	-		0
	CS-134		60	<LLD	<LLD	-		0
	CS-137		80	<LLD	<LLD	-		0
	BA-140		NA	<LLD	<LLD	-		0
	LA-140		NA	<LLD	<LLD	-		0
DIRECT RADIATION (MILLI-ROENTGEN/QTR.)	TLD-QUARTERLY	765	NA	19 (231/231) 14 - 33*	19.3 (24/24) 15 - 23*	33 (4/4) 27 - 33*	Z-131 INDICATOR 0.2 MIIES WSW	0

^(M) Mean and ranged based upon detectable measurements only. Fraction of detectable measurements at specified loactions is indicated in parentheses (f)

*Two TLDs are posted at each location for redudency. The averages are based on the highest reading at each station. The ranges are based on all results.

The total number of analyses is based on all TLD results - there are 3 chips read in each TLD, so literally, there are 765 analytses performed on 255 TLD's - the 2019 TLD results reflect 1 TLD that was lost.

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APPENDIX B

LOCATION DESIGNATION, DISTANCE & DIRECTION, AND SAMPLE COLLECTION & ANALYTICAL METHODS

TABLE B-1: Radiological Environmental Monitoring Program - Sampling Locations, Distance and Direction, Zion Nuclear Power Station, 2019

Location	Location Description	Distance & Direction From Site
<u>A. Public Water</u>		
Z-14	Kenosha Water Works (control)	10.0 miles N
Z-15	Lake County Water Works (indicator)	1.4 miles NNW
Z-16	Waukegan Water Works (indicator)	6.1 miles S
Z-18	Lake Forest Water Works (control)	12.9 miles S
<u>B. Air Particulates</u>		
Z-01	Onsite 1 (indicator)	0.3 miles S
Z-02	Onsite 2 (indicator)	0.2 miles W
Z-03	Onsite 3 (indicator)	0.2 miles NNW
Z-13	Offsite Control	10 miles NW
<u>C. Fish</u>		
Z-26	Lake Michigan Nearsite (indicator)	At station
Z-27	Lake Michigan Farsite (indicator)	10.1 miles N
<u>D. Sediment</u>		
Z-25	Lake Michigan, Illinois Beach State Park (indicator)	0.2 miles S
<u>E. Vegetation</u>		
Z-Control	Control (control)	0.3 miles S
Z-Quad 3	Farm 3 (indicator)	0.2 miles W
Z-Quad 4	Farm 4 (indicator)	0.2 miles NNW
<u>F. Environmental Dosimetry - TLD</u>		
<u>Inner Ring</u>		
Z-101-1 and -2		0.2 miles N
Z-102-1 and -2		0.2 miles NNE
Z-103-1 and -2		0.2 miles NE
Z-104-1 and -2		0.1 miles ENE
Z-105-1 and -2		0.1 miles E
Z-106-1 and -2		0.1 miles ESE
Z-107-1 and -2		0.1 miles SE
Z-108-1 and -2		0.1 miles SSE
Z-109-1 and -2		0.2 miles SSE
Z-112-1 and -2		0.7 miles WSW
Z-113-1 and -2		0.6 miles W
Z-114-1 and -2		0.6 miles WNW
Z-115-1 and -2		0.4 miles NW
Z-121-1 and -2		0.2 miles NNW
Z-124-1 and -2		0.5 miles SW
Z-125-1 and -2		0.4 miles SSW
Z-129-1 and -2		0.2 miles NW
Z-130-1 and -2		0.2 miles WNW
Z-131-1 and -2		0.2 miles WSW
<u>Other</u>		
Z-01-1 and -2	Onsite 1 (indicator)	0.3 miles S
Z-02-1 and -2	Onsite 2 (indicator)	0.2 miles W
Z-03-1 and -2	Onsite 3 (indicator)	0.2 miles NNW
<u>Outer Ring</u>		
Z-209-1 and -2		5.1 miles S
Z-211-1 and -2		4.7 miles SW
Z-212-1 and -2		5.1 miles WSW
Z-213-1 and -2		5.1 miles W
Z-214-1 and -2		4.6 miles WNW
Z-215-1 and -2		4.0 miles NW
Z-216-1 and -2		3.0 miles NNW
<u>Control</u>		
Z-13-1 thru -6	Control	10 miles NW

TABLE B-2:

Radiological Environmental Monitoring Program – Summary of Sample Collection and Analytical Methods, Zion Nuclear Power Station, 2019

Sample Medium	Analysis	Sampling Method	Analytical Procedure Number
Public Water	Gamma Spectroscopy	Monthly composite from weekly grab samples.	TBE, TBE-2007 Gamma emitting radioisotope analysis
Public Water	Gross Beta	Monthly composite from weekly grab samples.	TBE, TBE-2008 Gross Alpha and/or gross beta activity in various matrices
Public Water	Tritium	Quarterly composite from weekly grab samples.	TBE, TBE-2011 Tritium analysis in drinking water by liquid scintillation
Fish	Gamma Spectroscopy	Semi-annual samples collected via electroshocking or other techniques	TBE-2007 Gamma emitting radioisotope analysis
Sediment	Gamma Spectroscopy	Semi-annual grab samples	TBE, TBE-2007 Gamma emitting radioisotope analysis
Vegetation	Gamma Spectroscopy	Annual collection at harvest	TBE, TBE-2007 Gamma emitting radioisotope analysis
Air Particulates	Gross Beta	One-week composite of continuous air sampling through glass fiber filter paper	TBE, TBE-2008 Gross Alpha and/or gross beta activity in various matrices
Air Particulates	Gamma Spectroscopy	Quarterly composite of each station	TBE, TBE-2007 Gamma emitting radioisotope analysis
TLD	Thermo-luminescent Dosimetry	Quarterly TLDs comprised of two Panasonic Environmental TLD type 814 with 3 CaSO ₄ elements at each location.	Mirion Technologies

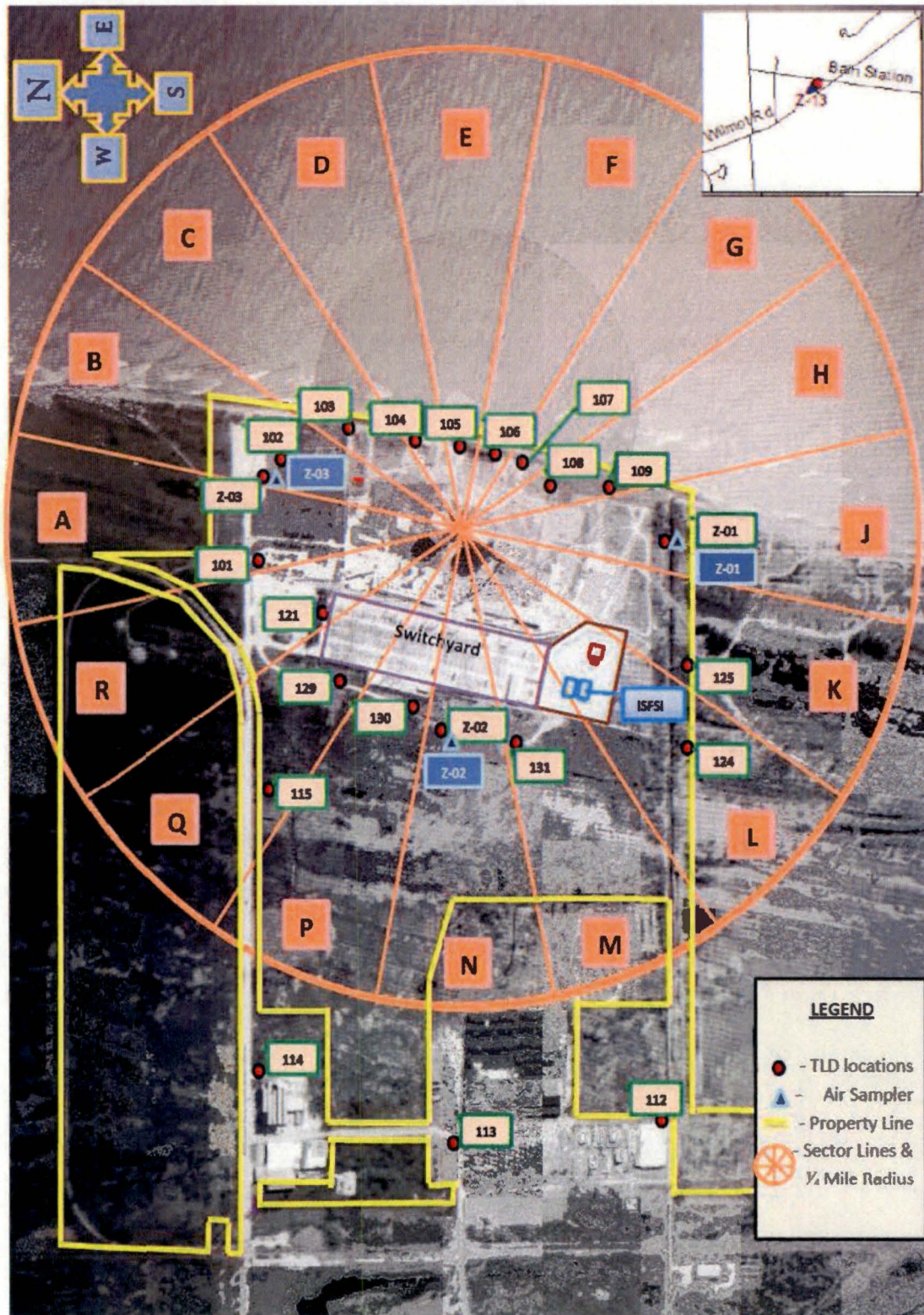


Figure B-1
 Inner Ring TLD and Fixed Air Sampler Locations of the Zion Nuclear Power Station, 2019

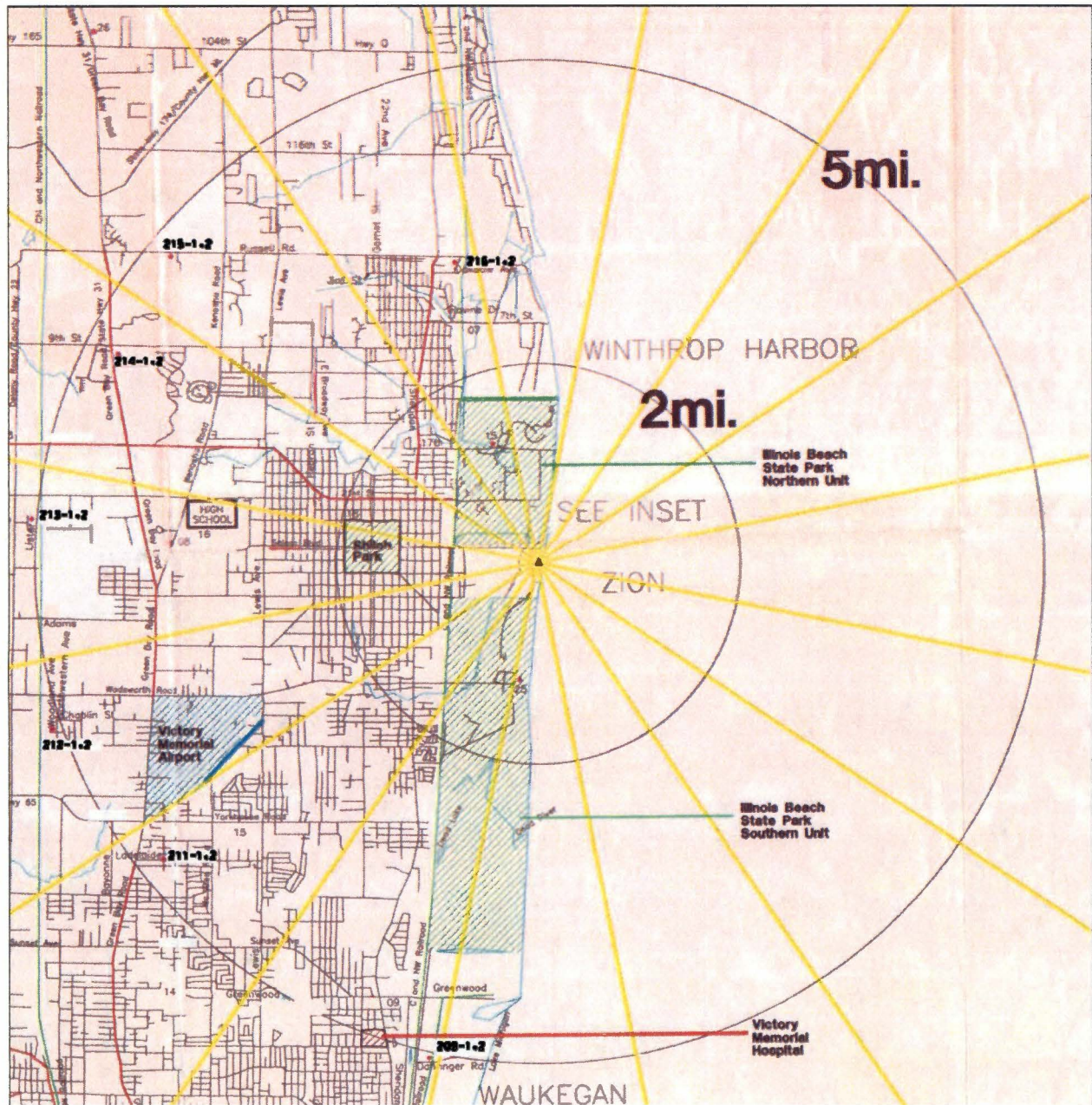


Figure B-2
Outer Ring TLD and Fixed Air Sampler Locations of the Zion Nuclear Power Station, 2019

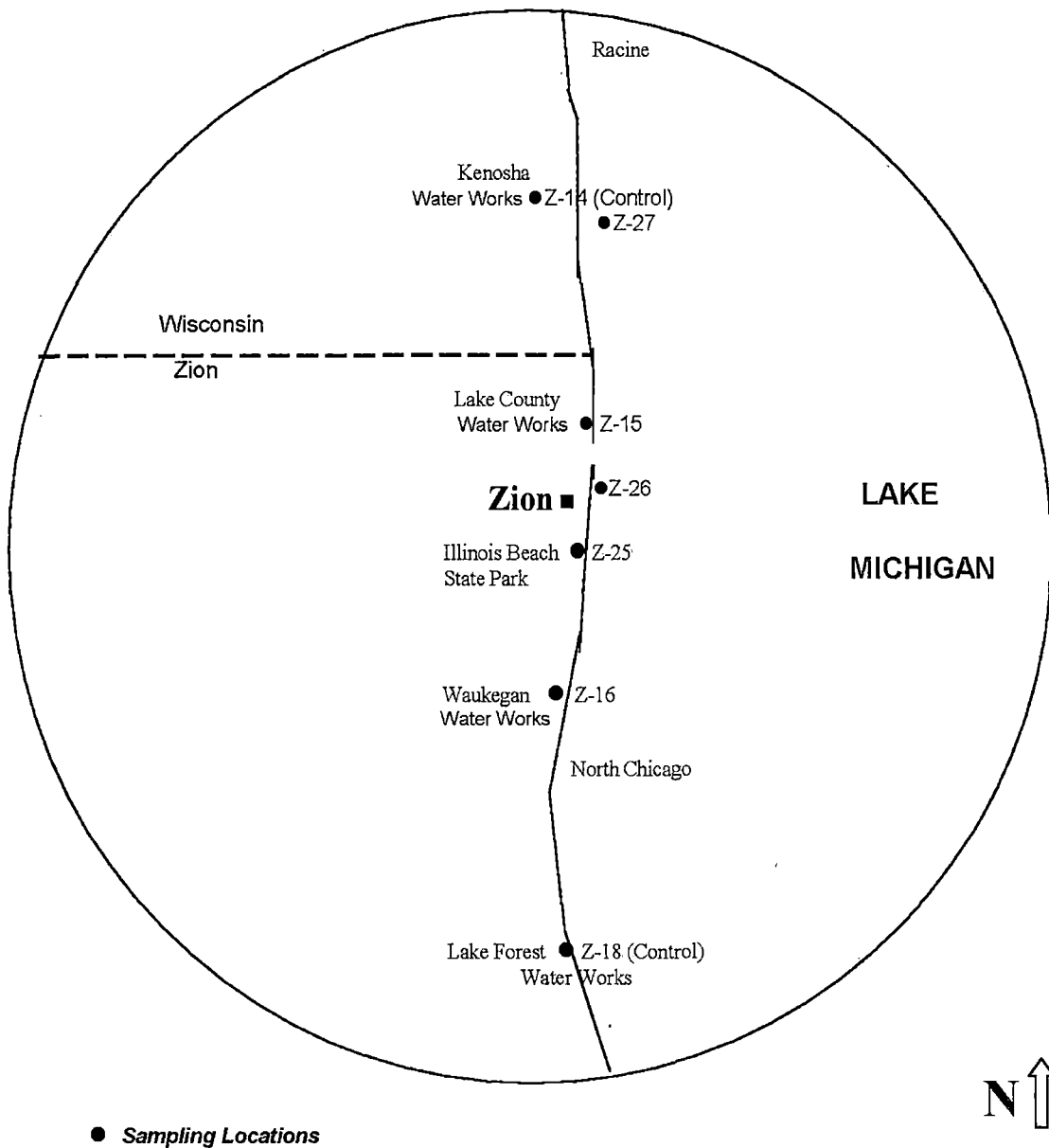


Figure B-3
 Fish, Water and Sediment Sampling Locations of the Zion Nuclear Power Station, 2019

APPENDIX C

DATA TABLES AND FIGURES

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Table C-I.1 Concentrations of Gross Beta in Public Water Samples Collected in the Vicinity of Zion Nuclear Power Station, 2019
Results in Units of pCi/liter \pm 2 Sigma

COLLECTION PERIOD	Z-14	Z-15	Z-16	Z-18
01/02/19 - 01/23/19	2.9 \pm 1.6	< 2.3	< 2.2	< 2.3
02/01/19 - 02/27/19	3.4 \pm 1.5	4.2 \pm 1.6	2.2 \pm 1.4	2.7 \pm 1.5
03/06/19 - 03/27/19	2.8 \pm 1.5	< 2.0	3.2 \pm 1.6	< 2.0
04/03/19 - 04/24/19	< 2.3	2.2 \pm 1.5	3.0 \pm 1.6	< 2.2
05/01/19 - 05/29/19	< 2.3	< 2.3	< 2.3	< 2.3
06/05/19 - 06/26/19	< 2.5	< 2.5	< 2.4	< 2.4
07/03/19 - 07/31/19	2.8 \pm 1.4	3.0 \pm 1.5	2.8 \pm 1.5	3.1 \pm 1.5
08/07/19 - 08/28/19	< 2.1	< 2.1	< 2.2	< 2.1
09/05/19 - 09/25/19	< 2.3	4.1 \pm 1.8	< 2.2	< 2.3
10/03/19 - 10/30/19	< 1.9	2.3 \pm 1.4	2.2 \pm 1.4	3.0 \pm 1.5
11/06/19 - 11/27/19	2.7 \pm 1.6	< 2.3	< 2.2	< 2.2
12/04/19 - 12/26/19	1.9 \pm 1.3	< 1.8	1.9 \pm 1.3	2.4 \pm 1.3
<i>MEAN \pm 2 STD DEV</i>	2.7 \pm 0.9	3.2 \pm 1.9	2.5 \pm 1.1	2.8 \pm 0.6

Table C-I.2 Concentrations of Tritium in Public Water Samples Collected in the Vicinity of Zion Nuclear Power Station, 2019
Results in Units of pCi/liter \pm 2 Sigma

COLLECTION PERIOD	Z-14	Z-15	Z-16	Z-18
01/02/19 - 03/27/19	< 191	< 193	< 192	< 192
04/03/19 - 06/26/19	< 190	< 189	< 190	< 187
07/03/19 - 09/25/19	< 192	< 196	< 194	< 195
10/03/19 - 12/26/19	< 194	< 192	< 193	< 198
<i>MEAN</i>	-	-	-	-

THE MEAN AND TWO STANDARD DEVIATION ARE CALCULATED USING THE POSITIVE VALUES

Table C-I.3

**Concentrations of Gamma Emitters in Public Water Samples Collected in the
Vicinity of Zion Nuclear Power Station, 2019**

Results in Units of pCi/liter \pm 2 Sigma

SITE	COLLECTION PERIOD	Mn-54	Co-58	Fe-59	Co-60	Zn-65	Nb-95	Zr-95	Cs-134	Cs-137	Ba-140	La-140
Z-14	01/02/19 - 01/23/19	< 6	< 7	< 13	< 7	< 15	< 8	< 9	< 7	< 6	< 47	< 18
	02/01/19 - 02/27/19	< 6	< 5	< 11	< 6	< 9	< 6	< 8	< 5	< 6	< 27	< 14
	03/06/19 - 03/27/19	< 6	< 6	< 16	< 6	< 12	< 6	< 11	< 8	< 7	< 33	< 11
	04/03/19 - 04/24/19	< 6	< 7	< 12	< 5	< 13	< 6	< 13	< 6	< 7	< 49	< 12
	05/01/19 - 05/29/19	< 3	< 5	< 9	< 6	< 13	< 6	< 8	< 5	< 5	< 25	< 5
	06/05/19 - 06/26/19	< 5	< 5	< 11	< 6	< 11	< 5	< 10	< 6	< 6	< 25	< 10
	07/03/19 - 07/31/19	< 8	< 7	< 20	< 8	< 15	< 6	< 12	< 6	< 7	< 45	< 15
	08/07/19 - 08/28/19	< 7	< 5	< 12	< 5	< 12	< 6	< 9	< 6	< 6	< 25	< 5
	09/05/19 - 09/25/19	< 7	< 6	< 15	< 7	< 12	< 7	< 9	< 6	< 6	< 38	< 13
	10/03/19 - 10/30/19	< 4	< 6	< 11	< 4	< 8	< 4	< 11	< 5	< 5	< 35	< 14
	11/06/19 - 11/27/19	< 8	< 7	< 17	< 9	< 17	< 11	< 13	< 8	< 6	< 62	< 25
	12/04/19 - 12/26/19	< 6	< 6	< 16	< 6	< 9	< 7	< 12	< 6	< 7	< 44	< 15
		MEAN	-	-	-	-	-	-	-	-	-	-
Z-15	01/02/19 - 01/23/19	< 6	< 6	< 19	< 7	< 15	< 9	< 12	< 6	< 5	< 43	< 12
	02/01/19 - 02/27/19	< 6	< 6	< 12	< 6	< 15	< 7	< 11	< 5	< 6	< 38	< 12
	03/06/19 - 03/27/19	< 5	< 6	< 12	< 8	< 17	< 7	< 10	< 7	< 5	< 29	< 8
	04/03/19 - 04/24/19	< 4	< 7	< 14	< 4	< 13	< 8	< 13	< 7	< 6	< 45	< 11
	05/01/19 - 05/29/19	< 5	< 6	< 10	< 6	< 9	< 5	< 8	< 6	< 4	< 21	< 11
	06/05/19 - 06/26/19	< 6	< 6	< 12	< 6	< 12	< 5	< 9	< 6	< 5	< 22	< 7
	07/03/19 - 07/31/19	< 6	< 7	< 15	< 8	< 16	< 8	< 12	< 6	< 8	< 46	< 16
	08/07/19 - 08/28/19	< 7	< 6	< 14	< 7	< 15	< 6	< 10	< 6	< 7	< 38	< 8
	09/05/19 - 09/25/19	< 4	< 7	< 16	< 6	< 10	< 4	< 13	< 7	< 6	< 41	< 13
	10/03/19 - 10/30/19	< 5	< 6	< 11	< 5	< 11	< 6	< 11	< 6	< 5	< 37	< 9
	11/06/19 - 11/27/19	< 7	< 8	< 17	< 8	< 14	< 7	< 12	< 8	< 7	< 46	< 18
	12/04/19 - 12/26/19	< 5	< 5	< 10	< 6	< 8	< 6	< 9	< 4	< 4	< 40	< 16
		MEAN	-	-	-	-	-	-	-	-	-	-

Table C-I.3

**Concentrations of Gamma Emitters in Public Water Samples Collected in the
Vicinity of Zion Nuclear Power Station, 2019**

Results in Units of pCi/liter \pm 2 Sigma

SITE	COLLECTION		Mn-54	Co-58	Fe-59	Co-60	Zn-65	Nb-95	Zr-95	Cs-134	Cs-137	Ba-140	La-140
	PERIOD												
Z-16	1/2/2019 - 01/23/19		< 7	< 8	< 17	< 8	< 17	< 9	< 12	< 8	< 7	< 38	< 18
	2/1/2019 - 02/27/19		< 7	< 7	< 19	< 8	< 10	< 8	< 11	< 7	< 8	< 43	< 12
	3/6/2019 - 03/27/19		< 6	< 8	< 11	< 5	< 10	< 7	< 14	< 8	< 8	< 25	< 10
	4/3/2019 - 04/24/19		< 6	< 8	< 13	< 8	< 15	< 7	< 11	< 7	< 6	< 40	< 11
	5/1/2019 - 05/29/19		< 5	< 4	< 10	< 5	< 11	< 6	< 9	< 6	< 5	< 21	< 8
	06/05/19 - 06/26/19		< 5	< 6	< 8	< 6	< 9	< 5	< 9	< 5	< 6	< 25	< 6
	07/03/19 - 07/31/19		< 6	< 6	< 12	< 7	< 12	< 7	< 11	< 6	< 8	< 33	< 15
	08/07/19 - 08/28/19		< 6	< 7	< 13	< 7	< 15	< 8	< 12	< 7	< 7	< 29	< 10
	09/05/19 - 09/25/19		< 7	< 6	< 11	< 8	< 14	< 6	< 10	< 5	< 7	< 35	< 15
	10/03/19 - 10/30/19		< 5	< 4	< 11	< 6	< 9	< 5	< 8	< 5	< 5	< 35	< 12
	11/06/19 - 11/27/19		< 7	< 2	< 15	< 6	< 12	< 7	< 13	< 7	< 7	< 48	< 17
	12/04/19 - 12/26/19		< 6	< 6	< 12	< 6	< 9	< 7	< 10	< 5	< 6	< 33	< 12
		MEAN		-	-	-	-	-	-	-	-	-	-
Z-18	01/02/19 - 01/23/19		< 7	< 7	< 16	< 7	< 10	< 8	< 12	< 8	< 4	< 46	< 7
	02/01/19 - 02/27/19		< 5	< 8	< 16	< 11	< 11	< 8	< 12	< 7	< 9	< 44	< 6
	03/06/19 - 03/27/19		< 5	< 6	< 10	< 5	< 12	< 6	< 9	< 6	< 6	< 30	< 7
	04/03/19 - 04/24/19		< 5	< 5	< 13	< 5	< 9	< 6	< 11	< 6	< 6	< 37	< 11
	05/01/19 - 05/29/19		< 5	< 6	< 14	< 6	< 10	< 6	< 11	< 5	< 6	< 28	< 8
	06/05/19 - 06/26/19		< 4	< 5	< 9	< 5	< 9	< 5	< 9	< 5	< 5	< 23	< 5
	07/03/19 - 07/31/19		< 7	< 8	< 15	< 7	< 14	< 8	< 13	< 8	< 8	< 42	< 12
	08/07/19 - 08/28/19		< 7	< 7	< 14	< 8	< 12	< 9	< 13	< 7	< 7	< 36	< 10
	09/05/19 - 09/25/19		< 7	< 7	< 14	< 8	< 12	< 8	< 12	< 7	< 7	< 46	< 15
	10/03/19 - 10/30/19		< 4	< 5	< 9	< 5	< 9	< 5	< 8	< 5	< 4	< 25	< 10
	11/06/19 - 11/27/19		< 5	< 5	< 11	< 7	< 10	< 7	< 13	< 6	< 6	< 44	< 11
	12/04/19 - 12/26/19		< 6	< 6	< 15	< 6	< 11	< 7	< 11	< 6	< 5	< 41	< 13
		MEAN		-	-	-	-	-	-	-	-	-	-

Table C-II.1

**Concentrations of Gamma Emitters in Fish Samples Collected in the
Vicinity of Zion Nuclear Power Station, 2019**

Results in Units of pCi/kilograms wet \pm 2 Sigma

SITE	COLLECTION		Mn-54	Co-58	Fe-59	Co-60	Zn-65	Nb-95	Zr-95	Cs-134	Cs-137	Ba-140	La-140
	PERIOD												
Z-26	(Predator)												
<i>White Sucker</i>	05/10/19		< 77	< 55	< 153	< 85	< 152	< 64	< 115	< 65	< 81	< 291	< 100
<i>Yellow Perch</i>	05/10/19		< 54	< 70	< 112	< 65	< 115	< 55	< 105	< 64	< 72	< 298	< 88
<i>Brown Trout</i>	10/25/19		< 58	< 45	< 139	< 62	< 103	< 57	< 86	< 61	< 60	< 268	< 76
<i>Rock Bass</i>	10/25/19		< 59	< 58	< 133	< 72	< 122	< 76	< 121	< 63	< 70	< 313	< 78
	MEAN		-	-	-	-	-	-	-	-	-	-	-
Z-27	(Predator)												
<i>Lake Trout</i>	05/10/19		< 52	< 56	< 114	< 64	< 129	< 59	< 103	< 54	< 62	< 270	< 77
<i>Burbot</i>	05/10/19		< 62	< 67	< 115	< 66	< 110	< 58	< 120	< 65	< 69	< 212	< 91
<i>Lake Trout</i>	10/24/19		< 56	< 37	< 84	< 54	< 122	< 40	< 70	< 52	< 48	< 195	< 58
<i>Burbot</i>	10/24/19		< 38	< 44	< 81	< 42	< 113	< 44	< 88	< 50	< 52	< 207	< 43
	MEAN		-	-	-	-	-	-	-	-	-	-	-

Table C-III.1

**Concentrations of Gamma Emitters in Sediment Samples Collected in the
Vicinity of Zion Nuclear Power Station, 2019**
Results in Units of pCi/kilograms Dry + 2 Sigma

SITE	COLLECTION	Mn-54	Co-58	Fe-59	Co-60	Zn-65	Nb-95	Zr-95	Cs-134	Cs-137	Ba-140	La-140
	PERIOD											
Z-25	05/15/19	< 41	< 37	< 76	< 43	< 86	< 38	< 78	< 49	< 31	< 157	< 53
	10/09/19	< 33	< 30	< 63	< 31	< 70	< 39	< 56	< 43	< 30	< 112	< 38
	<i>MEAN</i>	-	-	-	-	-	-	-	-	-	-	-

Table C-IV.1 Concentrations of Gross Beta in Air Particulate Samples Collected in the Vicinity of Zion Nuclear Power Station, 2019
Results in Units of E-3 pCi/cubic meter \pm 2 Sigma

COLLECTION PERIOD	GROUP I			GROUP II
	Z-01	Z-02	Z-03	Z-13
12/26/18 - 01/02/19	13 \pm 4	12 \pm 3	16 \pm 4	16 \pm 4
01/02/19 - 01/09/19	22 \pm 4	16 \pm 4	21 \pm 4	19 \pm 4
01/09/19 - 01/16/19	12 \pm 4	9 \pm 3	13 \pm 4	12 \pm 4
01/16/19 - 01/23/19	12 \pm 4	10 \pm 4	11 \pm 4	11 \pm 4
01/23/19 - 02/01/19	20 \pm 4	15 \pm 3	22 \pm 4	17 \pm 4
02/01/19 - 02/06/19	15 \pm 5	12 \pm 5	19 \pm 6	15 \pm 5
02/06/19 - 02/13/19	14 \pm 4	15 \pm 4	18 \pm 4	10 \pm 4
02/13/19 - 02/20/19	19 \pm 4	14 \pm 4	20 \pm 6	21 \pm 4
02/20/19 - 02/27/19	23 \pm 4	22 \pm 4	25 \pm 5	21 \pm 4
02/27/19 - 03/06/19	19 \pm 4	21 \pm 4	19 \pm 4	22 \pm 4
03/06/19 - 03/13/19	23 \pm 5	24 \pm 5	22 \pm 5	21 \pm 4
03/13/19 - 03/20/19	16 \pm 4	16 \pm 4	17 \pm 4	17 \pm 4
03/20/19 - 03/27/19	7 \pm 4	10 \pm 4	7 \pm 4	8 \pm 4
03/27/19 - 04/03/19	12 \pm 4	10 \pm 4	9 \pm 4	11 \pm 4
04/03/19 - 04/10/19	12 \pm 4	11 \pm 4	11 \pm 4	12 \pm 4
04/10/19 - 04/17/19	8 \pm 4	9 \pm 4	9 \pm 4	8 \pm 4
04/17/19 - 04/24/19	10 \pm 3	12 \pm 4	9 \pm 4	11 \pm 4
04/24/19 - 05/01/19	10 \pm 4	11 \pm 4	11 \pm 4	11 \pm 4
05/01/19 - 05/08/19	12 \pm 4	10 \pm 4	8 \pm 3	10 \pm 4
05/08/19 - 05/15/19	8 \pm 4	8 \pm 4	12 \pm 4	13 \pm 4
05/15/19 - 05/22/19	7 \pm 3	10 \pm 4	9 \pm 4	14 \pm 4
05/22/19 - 05/29/19	8 \pm 3	9 \pm 3	9 \pm 3	9 \pm 3
05/29/19 - 06/05/19	13 \pm 4	9 \pm 4	8 \pm 4	9 \pm 4
06/05/19 - 06/12/19	12 \pm 4	12 \pm 4	12 \pm 4	14 \pm 4
06/12/19 - 06/19/19	14 \pm 4	13 \pm 4	12 \pm 4	14 \pm 4
06/19/19 - 06/26/19	8 \pm 4	9 \pm 4	12 \pm 5	9 \pm 4
06/26/19 - 07/03/19	14 \pm 4	12 \pm 4	15 \pm 4	12 \pm 4
07/03/19 - 07/10/19	9 \pm 3	9 \pm 3	< 9	9 \pm 3
07/10/19 - 07/17/19	12 \pm 4	12 \pm 4	10 \pm 4	17 \pm 4
07/17/19 - 07/24/19	12 \pm 4	10 \pm 4	8 \pm 4	10 \pm 4
07/24/19 - 07/31/19	15 \pm 4	14 \pm 4	17 \pm 4	15 \pm 4
07/31/19 - 08/07/19	13 \pm 4	11 \pm 4	13 \pm 5	15 \pm 4
08/07/19 - 08/14/19	20 \pm 4	16 \pm 4	17 \pm 5	22 \pm 4
08/14/19 - 08/21/19	14 \pm 4	9 \pm 4	13 \pm 4	13 \pm 4
08/21/19 - 08/28/19	7 \pm 4	14 \pm 4	7 \pm 4	8 \pm 4
08/28/19 - 09/05/19	13 \pm 3	11 \pm 3	10 \pm 4	16 \pm 4
09/05/19 - 09/11/19	14 \pm 5	15 \pm 5	12 \pm 5	14 \pm 5
09/11/19 - 09/18/19	13 \pm 4	17 \pm 4	16 \pm 4	16 \pm 4
09/18/19 - 09/25/19	21 \pm 5	18 \pm 4	22 \pm 5	16 \pm 4
09/25/19 - 10/03/19	12 \pm 4	12 \pm 4	12 \pm 4	11 \pm 4
10/03/19 - 10/09/19	9 \pm 4	11 \pm 4	17 \pm 5	10 \pm 4
10/09/19 - 10/16/19	17 \pm 4	15 \pm 4	20 \pm 4	18 \pm 4
10/16/19 - 10/23/19	15 \pm 4	12 \pm 3	13 \pm 4	11 \pm 3
10/23/19 - 10/30/19	11 \pm 4	11 \pm 4	14 \pm 4	11 \pm 4
10/30/19 - 11/06/19	10 \pm 4	8 \pm 4	10 \pm 4	8 \pm 4
11/06/19 - 11/13/19	15 \pm 4	9 \pm 4	19 \pm 6	11 \pm 4
11/13/19 - 11/20/19	29 \pm 5	27 \pm 5	27 \pm 5	34 \pm 5
11/20/19 - 11/27/19	15 \pm 4	15 \pm 4	14 \pm 4	20 \pm 4
11/27/19 - 12/04/19	8 \pm 3	8 \pm 3	6 \pm 3	9 \pm 3
12/04/19 - 12/11/19	18 \pm 4	16 \pm 4	14 \pm 4	15 \pm 4
12/11/19 - 12/18/19	23 \pm 4	25 \pm 5	19 \pm 4	24 \pm 5
12/18/19 - 12/26/19	31 \pm 5	26 \pm 4	29 \pm 5	30 \pm 5
12/26/19 - 01/02/20	22 \pm 4	19 \pm 4	22 \pm 5	22 \pm 5
MEAN \pm 2 STD DEV	14 \pm 11	13 \pm 10	14 \pm 11	15 \pm 11

THE MEAN AND TWO STANDARD DEVIATION ARE CALCULATED USING THE POSITIVE VALUES

Table C-IV.2 Monthly and Yearly Mean Values of Gross Beta Concentrations in Air Particulate Samples Collected in the Vicinity of Zion Nuclear Power Station, 2019

Results in Units of E-3 pCi/cubic meter \pm 2 Sigma

GROUP I - ONSITE LOCATIONS				GROUP II - OFFSITE CONTROL LOCATION			
COLLECTION PERIOD	MIN	MAX	MEAN \pm 2SD	COLLECTION PERIOD	MIN	MAX	MEAN \pm 2SD
01/02/19 - 02/01/19	9	22	15 \pm 9	01/02/19 - 02/01/19	11	19	15 \pm 8
02/01/19 - 02/27/19	12	25	18 \pm 8	02/01/19 - 02/27/19	10	21	17 \pm 11
02/27/19 - 04/03/19	7	24	15 \pm 12	02/27/19 - 04/03/19	8	22	16 \pm 13
04/03/19 - 05/01/19	8	12	10 \pm 3	04/03/19 - 05/01/19	8	12	11 \pm 3
05/01/19 - 05/29/19	7	12	9 \pm 3	05/01/19 - 05/29/19	9	14	12 \pm 5
05/29/19 - 07/03/19	8	15	12 \pm 4	05/29/19 - 07/03/19	9	14	12 \pm 5
07/03/19 - 07/31/19	8	17	12 \pm 6	07/03/19 - 07/31/19	9	17	13 \pm 7
07/31/19 - 08/28/19	7	20	13 \pm 8	07/31/19 - 08/28/19	8	22	14 \pm 12
08/28/19 - 10/03/19	10	22	15 \pm 7	08/28/19 - 10/03/19	11	16	14 \pm 4
10/03/19 - 10/30/19	9	20	14 \pm 6	10/03/19 - 10/30/19	10	18	13 \pm 7
10/30/19 - 12/04/19	6	29	15 \pm 15	10/30/19 - 12/04/19	8	34	16 \pm 22
12/26/18 - 01/02/20	12	31	20 \pm 11	12/26/18 - 01/02/20	15	30	22 \pm 12
12/26/18 - 01/02/20	6	31	14 \pm 10	12/26/18 - 01/02/20	8	34	15 \pm 11

Table C-IV.3

**Concentrations of Gamma Emitters in Air Particulate Samples Collected
in the Vicinity of Zion Nuclear Power Station, 2019**

Results in Units of E-3 pCi/cubic meter + 2 Sigma

SITE	COLLECTION PERIOD	Mn-54	Co-58	Fe-59	Co-60	Zn-65	Nb-95	Zr-95	Cs-134	Cs-137	Ba-140	La-140
Z-01	12/26/18 - 03/27/19	< 3	< 3	< 7	< 2	< 7	< 3	< 6	< 2	< 2	< 35	< 10
	03/27/19 - 06/26/19	< 2	< 3	< 6	< 3	< 6	< 3	< 4	< 2	< 2	< 21	< 7
	06/26/19 - 10/03/19	< 2	< 1	< 4	< 2	< 5	< 1	< 3	< 2	< 2	< 10	< 3
	10/03/19 - 01/02/20	< 2	< 2	< 5	< 2	< 6	< 3	< 4	< 2	< 2	< 13	< 4
	MEAN	-	-	-	-	-	-	-	-	-	-	-
Z-02	12/26/18 - 03/27/19	< 2	< 3	< 4	< 3	< 7	< 2	< 5	< 3	< 2	< 34	< 16
	03/27/19 - 06/26/19	< 2	< 2	< 6	< 2	< 3	< 2	< 4	< 2	< 2	< 16	< 7
	06/26/19 - 10/03/19	< 2	< 2	< 4	< 2	< 6	< 2	< 3	< 2	< 1	< 12	< 5
	10/03/19 - 01/02/20	< 2	< 1	< 5	< 2	< 5	< 2	< 3	< 2	< 2	< 8	< 4
	MEAN	-	-	-	-	-	-	-	-	-	-	-
Z-03	12/26/18 - 03/27/19	< 3	< 3	< 7	< 2	< 7	< 3	< 5	< 2	< 2	< 34	< 11
	03/27/19 - 06/26/19	< 2	< 2	< 3	< 1	< 5	< 3	< 4	< 2	< 2	< 21	< 4
	06/26/19 - 10/03/19	< 2	< 2	< 5	< 2	< 5	< 2	< 3	< 1	< 2	< 9	< 6
	10/03/19 - 01/02/20	< 3	< 3	< 9	< 4	< 9	< 4	< 7	< 3	< 3	< 20	< 9
	MEAN	-	-	-	-	-	-	-	-	-	-	-
Z-13	12/26/18 - 03/27/19	< 2	< 2	< 5	< 3	< 5	< 3	< 4	< 2	< 2	< 21	< 14
	03/27/19 - 06/26/19	< 2	< 3	< 7	< 3	< 6	< 3	< 5	< 3	< 2	< 21	< 7
	06/26/19 - 10/03/19	< 2	< 2	< 3	< 2	< 5	< 2	< 4	< 2	< 2	< 10	< 5
	10/03/19 - 01/02/20	< 2	< 2	< 5	< 2	< 5	< 2	< 3	< 2	< 1	< 12	< 2
	MEAN	-	-	-	-	-	-	-	-	-	-	-

Table C-V.1

**Concentrations of Gamma Emitters in Vegetation Samples
Collected in the Vicinity of Zion Nuclear Power Station, 2019**

Results in Units of pCi/kilograms wet \pm 2 Sigma

SITE	COLLECTION	Mn-54	Co-58	Fe-59	Co-60	Zn-65	Nb-95	Zr-95	Cs-134	Cs-137	Ba-140	La-140
	PERIOD											
Z-CONTROL												
<i>Onions</i>	09/18/19	< 22	< 22	< 36	< 20	< 48	< 20	< 36	< 23	< 24	< 73	< 20
<i>Cabbage</i>	09/18/19	< 20	< 24	< 43	< 24	< 48	< 24	< 34	< 26	< 25	< 88	< 25
	<i>MEAN</i>	-	-	-	-	-	-	-	-	-	-	-
Z-QUAD 3												
<i>Cabbage</i>	09/18/19	< 24	< 15	< 47	< 24	< 51	< 20	< 42	< 24	< 21	< 72	< 16
<i>Sweet Potatoes</i>	09/18/19	< 25	< 23	< 54	< 32	< 57	< 24	< 44	< 30	< 32	< 103	< 25
	<i>MEAN</i>	-	-	-	-	-	-	-	-	-	-	-
Z-QUAD 4												
<i>Cabbage</i>	09/18/19	< 25	< 24	< 37	< 23	< 34	< 23	< 41	< 25	< 22	< 91	< 25
<i>Sweet Potatoes</i>	09/18/19	< 20	< 21	< 42	< 26	< 49	< 22	< 43	< 24	< 23	< 87	< 27
	<i>MEAN</i>	-	-	-	-	-	-	-	-	-	-	-

Table C-VI.1

Quarterly TLD Results for Zion Nuclear Power Station, 2019⁽¹⁾
 Results in Units of Milli-Roentgen/Quarter \pm 2 Standard Deviations

STATION CODE	MEAN \pm 2 S.D.	JAN - MAR	APR - JUN	JUL - SEP	OCT - DEC
Z-01	17 \pm 3	18	20	17	16
Z-02	17 \pm 3	17	19	17	15
Z-03	18 \pm 3	17	20	18	16
Z-13	19 \pm 4	21	21	18	17
Z-101	17 \pm 4	17	20	17	15
Z-102	19 \pm 4	18	22	19	17
Z-103	19 \pm 3	17	21	18	18
Z-104	18 \pm 3	17	20	18	16
Z-105	18 \pm 4	17	21	18	16
Z-106	19 \pm 4	17	21	19	17
Z-107	18 \pm 4	17	20	19	16
Z-108	20 \pm 5	18	22	21	17
Z-109	19 \pm 4	18	21	20	17
Z-112	19 \pm 3	18	21	19	17
Z-113	18 \pm 3	17	20	17	16
Z-114	18 \pm 4	17	21	18	16
Z-115	18 \pm 3	18	20	19	16
Z-121	17 \pm 5	16	21	17	15
Z-124	18 \pm 5	18	21	18	16
Z-125	18 \pm 5	19	20	17	14
Z-129	18 \pm 5	19	21	18	15
Z-130	19 \pm 5	21	22	18	16
Z-131	31 \pm 5	33	32	29	28
Z-209	19 \pm 7	19	23	18	15
Z-211	22 \pm 5	22	25	21	19
Z-212	22 \pm 4	22	25	22	20
Z-213	23 \pm 4	24	25	23	20
Z-214	22 \pm 3	22	24	22	21
Z-215	22 \pm 5	22	25	21	19
Z-216	19 \pm 6	20	22	18	15

⁽¹⁾ NOTE: There are 2 TLDs posted at each indicator station for redundancy and data recovery. In reporting results, the higher of the two readings are reported, except when reporting minimums, which are based on all results. There are six (6) TLDs posted at the control location, and that value is based on an average of all six results each quarter.

Table C-VI.2 MEAN QUARTERLY TLD RESULTS FOR INNER RING, OUTER RING, SPECIAL INTEREST AND CONTROL STATIONS FOR ZION NUCLEAR POWER STATION, 2019⁽¹⁾

Results in Units of Milli-Roentgen/Quarter \pm 2 Standard Deviations of the Station Data

COLLECTION PERIOD	INNER RING \pm 2 S.D.	OUTER RING \pm 2 S.D.	SPECIAL INTEREST \pm 2 S.D.	CONTROL \pm 2 S.D.
JAN-MAR	19 \pm 8	22 \pm 3	18 \pm 1	21 \pm 2
APR-JUN	21 \pm 6	24 \pm 2	21 \pm 1	21 \pm 3
JUL-SEP	19 \pm 6	21 \pm 4	18 \pm 2	18 \pm 2
OCT-DEC	17 \pm 6	18 \pm 5	16 \pm 1	17 \pm 2

Table C-VI.3

**SUMMARY OF THE AMBIENT DOSIMETRY PROGRAM
FOR ZION NUCLEAR POWER STATION, 2019
RESULTS IN UNITS OF MILLI-ROENTGEN/QUARTER**

LOCATION	SAMPLES ANALYZED	PERIOD MINIMUM	PERIOD MAXIMUM	PERIOD MEAN \pm 2 S.D.
INNER RING	429	14	33	19 \pm 7
OUTER RING	168	15	25	21 \pm 5
SPECIAL INTEREST	96	16	21	18 \pm 3
CONTROL	72	18	23	19 \pm 4

INNER RING STATIONS - Z-01, Z-02, Z-03, Z-101, Z-102, Z-103, Z-104, Z-105, Z-106, Z-107, Z-108, Z-109, Z-121, Z-124, Z-125, Z-129, Z130, Z-131

SPECIAL INTEREST STATIONS - Z-112, Z-113, Z-114, Z-115

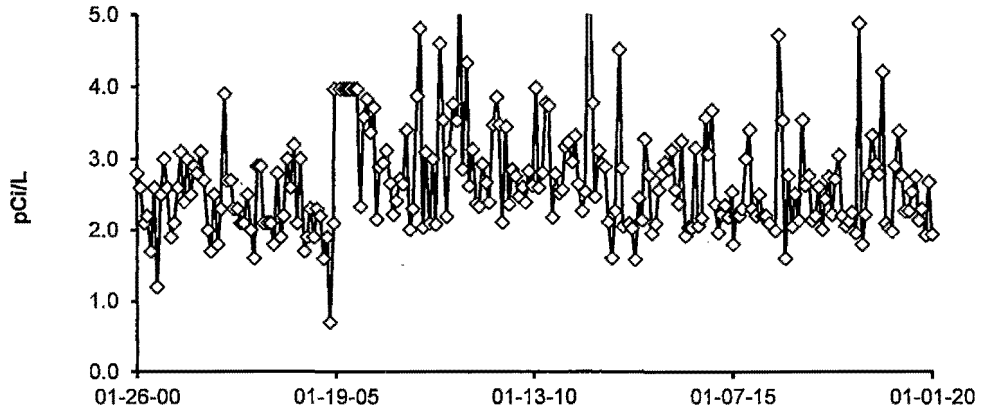
OUTER RING STATIONS - Z-209, Z-211, Z-212, Z-213, Z-214, Z-215, Z-216

CONTROL STATION - Z-13

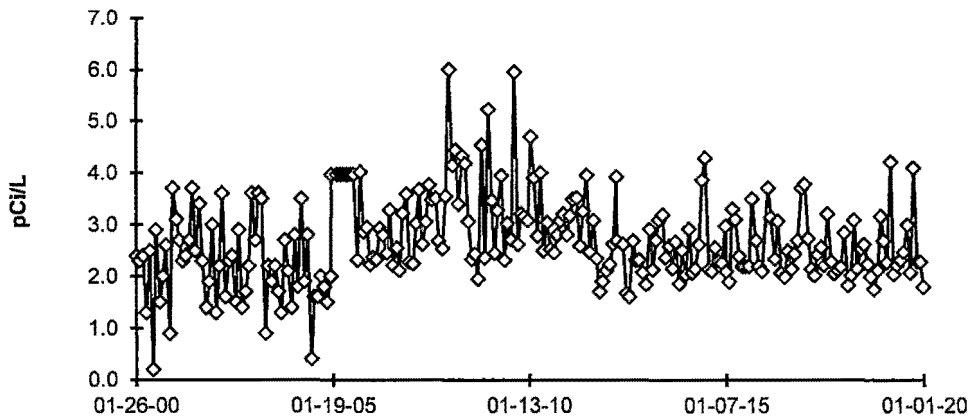
⁽¹⁾ NOTE: There are 2 TLDs posted at each indicator station for redundancy and data recovery. In reporting results, the higher of the two readings are reported, except when reporting minimums, which are based on all results. There are six (6) TLDs posted at the control location, and that value is based on an average of all six results each quarter.

**FIGURE C-1
PUBLIC WATER - GROSS BETA - STATIONS Z-14 AND
Z-15 COLLECTED IN THE VICINITY OF ZNPS, 2000 - 2019**

Z-14 (C) Kenosha Water Works



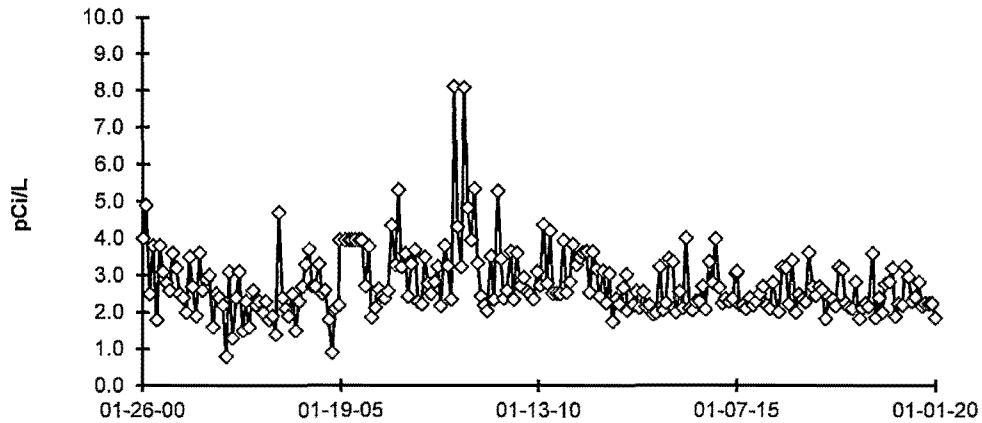
Z-15 Lake County Water Works



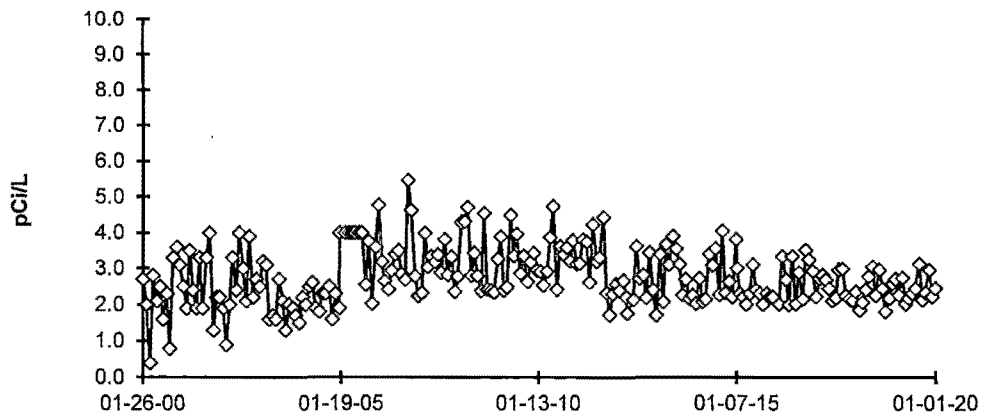
DUE TO VENDOR CHANGE IN 2005, < VALUES ARE LLD VALUES JANUARY THROUGH JUNE 2005 AND MDC VALUES AFTER JUNE 2005

**FIGURE C-2
PUBLIC WATER - GROSS BETA - STATIONS Z-16 AND
Z-18 COLLECTED IN THE VICINITY OF ZNPS, 2000 - 2019**

Z-16 Waukegan Water Works



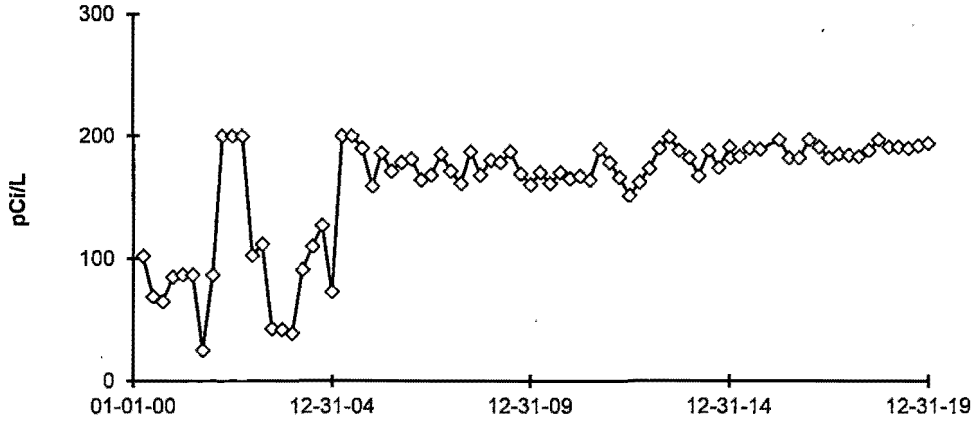
Z-18 (C) Lake Forest Water Works



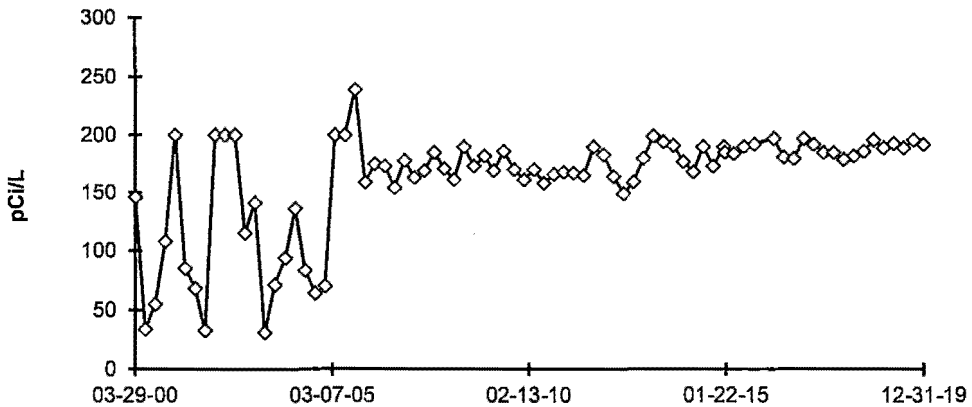
DUE TO VENDOR CHANGE IN 2005, < VALUES ARE LLD VALUES JANUARY THROUGH JUNE 2005 AND MDC VALUES AFTER JUNE 2005

**FIGURE C-3
PUBLIC WATER - TRITIUM - STATION Z-14 AND Z-15
COLLECTED IN THE VICINITY OF ZNPS, 2000 - 2019**

Z-14 (C) Kenosha Water Works



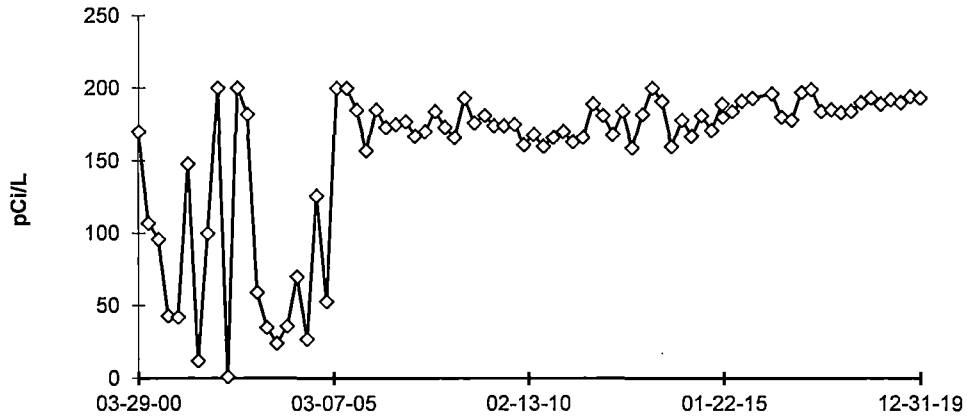
Z-15 Lake County Water Works



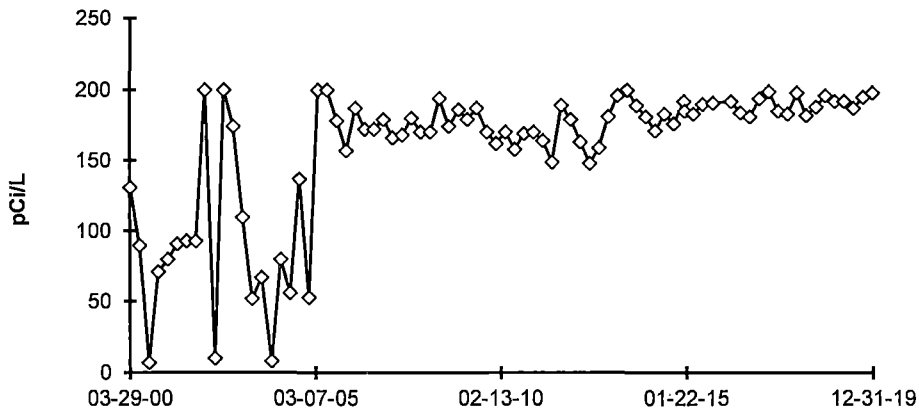
DUE TO VENDOR CHANGE IN 2005, < VALUES ARE LLD VALUES JANUARY THROUGH JUNE 2005 AND MDC VALUES AFTER JUNE 2005

**FIGURE C-4
PUBLIC WATER - TRITIUM - STATION Z-16 AND Z-18
COLLECTED IN THE VICINITY OF ZNPS, 2000 - 2019**

Z-16 Waukegan Water Works



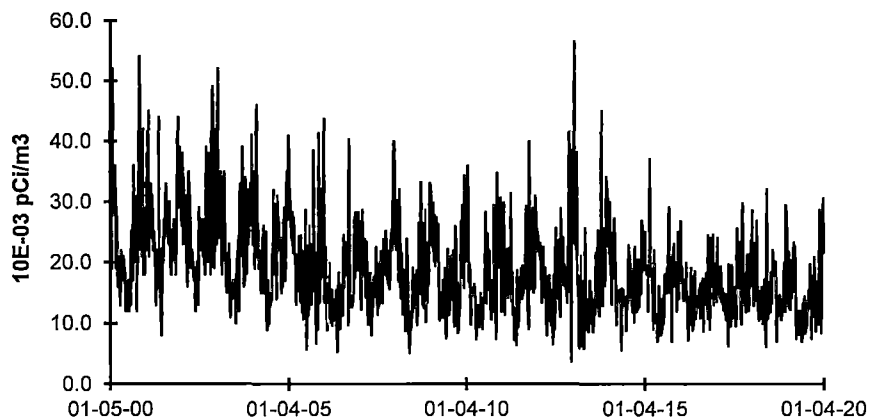
Z-18 (C) Lake Forest Water Works



DUE TO VENDOR CHANGE IN 2005, < VALUES ARE LLD VALUES JANUARY THROUGH JUNE 2005 AND MDC VALUES AFTER JUNE 2005

FIGURE C-5
AIR PARTICULATES - GROSS BETA - STATIONS Z-01 AND
Z-02 COLLECTED IN THE VICINITY OF ZNPS, 2000 - 2019

Z-01 Onsite No. 1, Southside



Z-02 Onsite No. 2, Westside

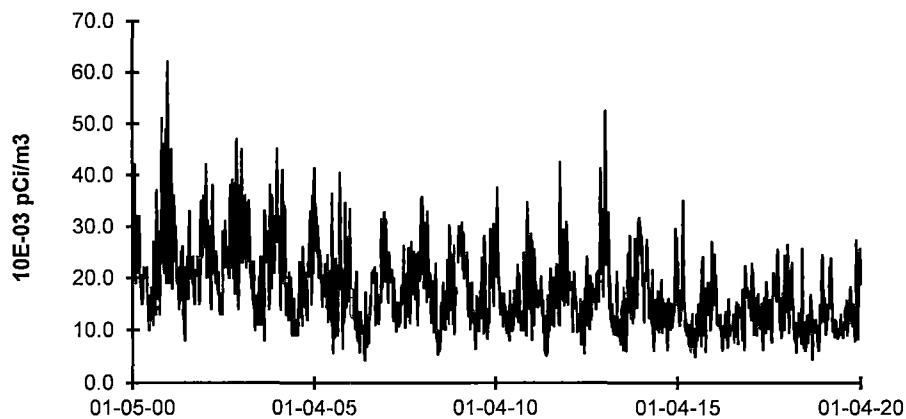
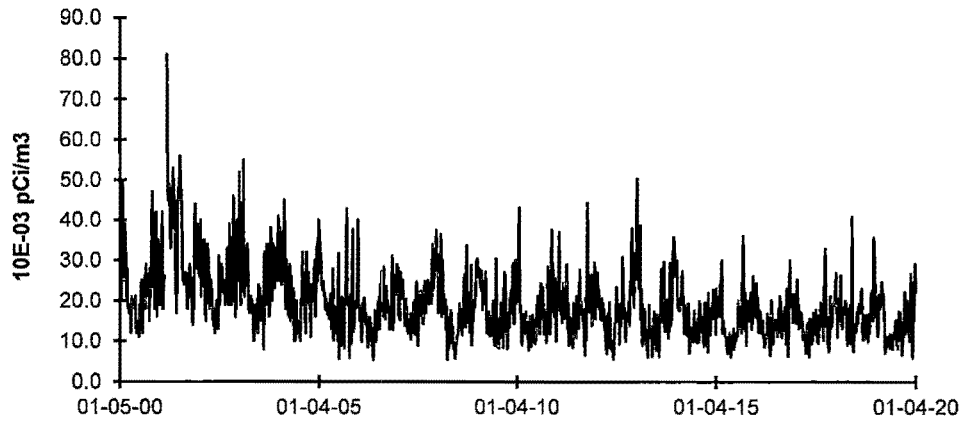


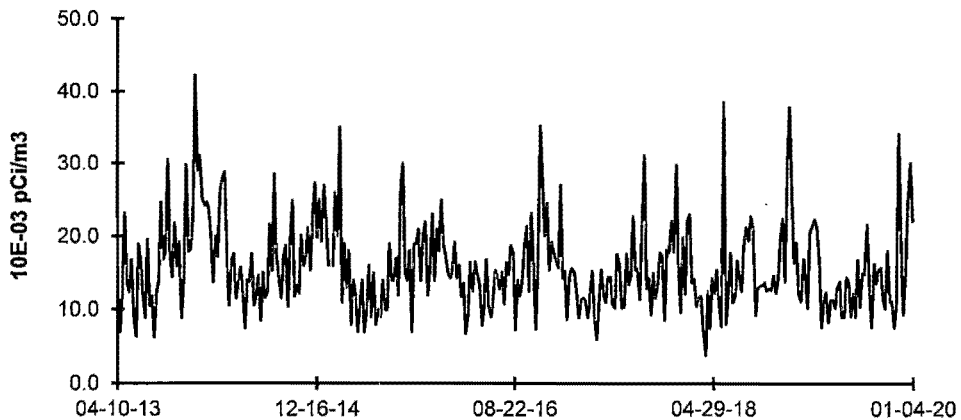
FIGURE C-6
AIR PARTICULATES - GROSS BETA - STATIONS Z-03
COLLECTED IN THE VICINITY OF ZNPS, 2000 - 2019

Z-03 Onsite No. 3, Northside

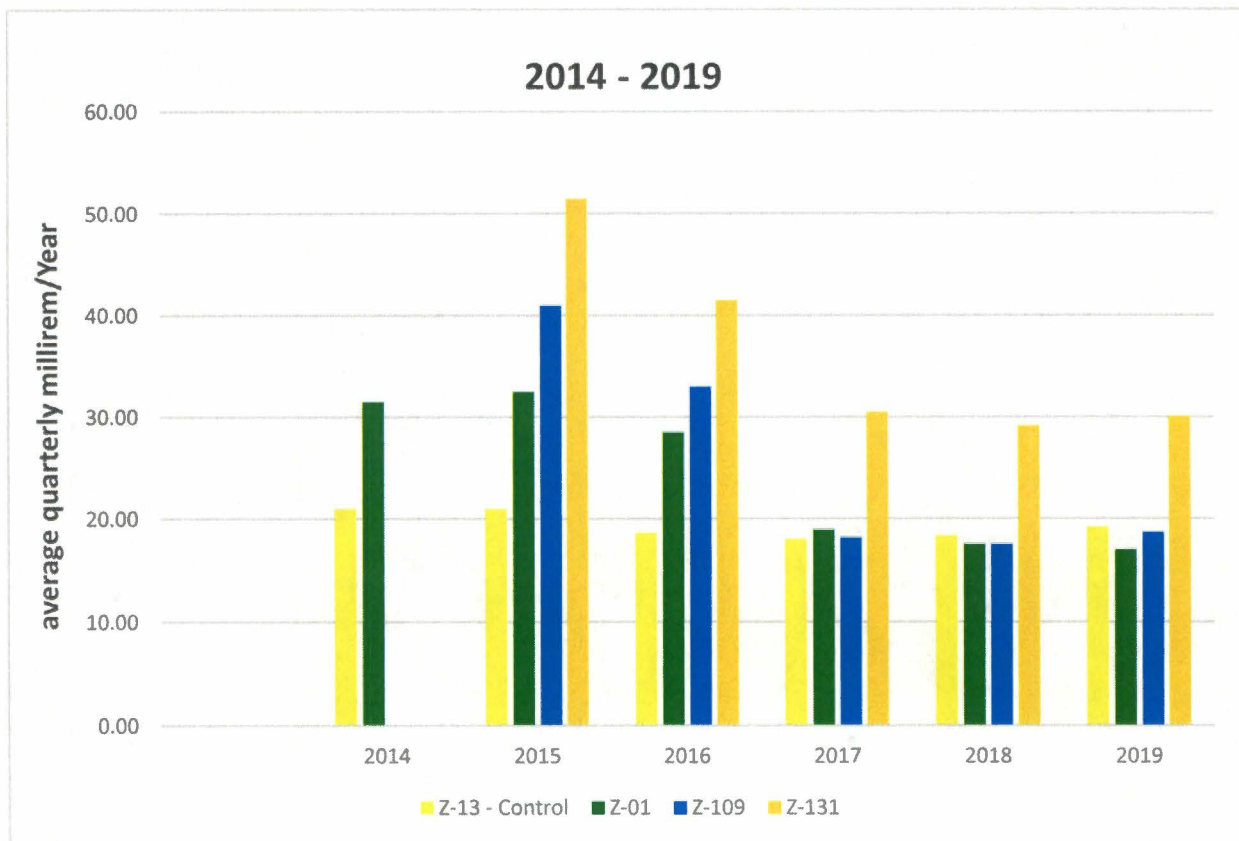
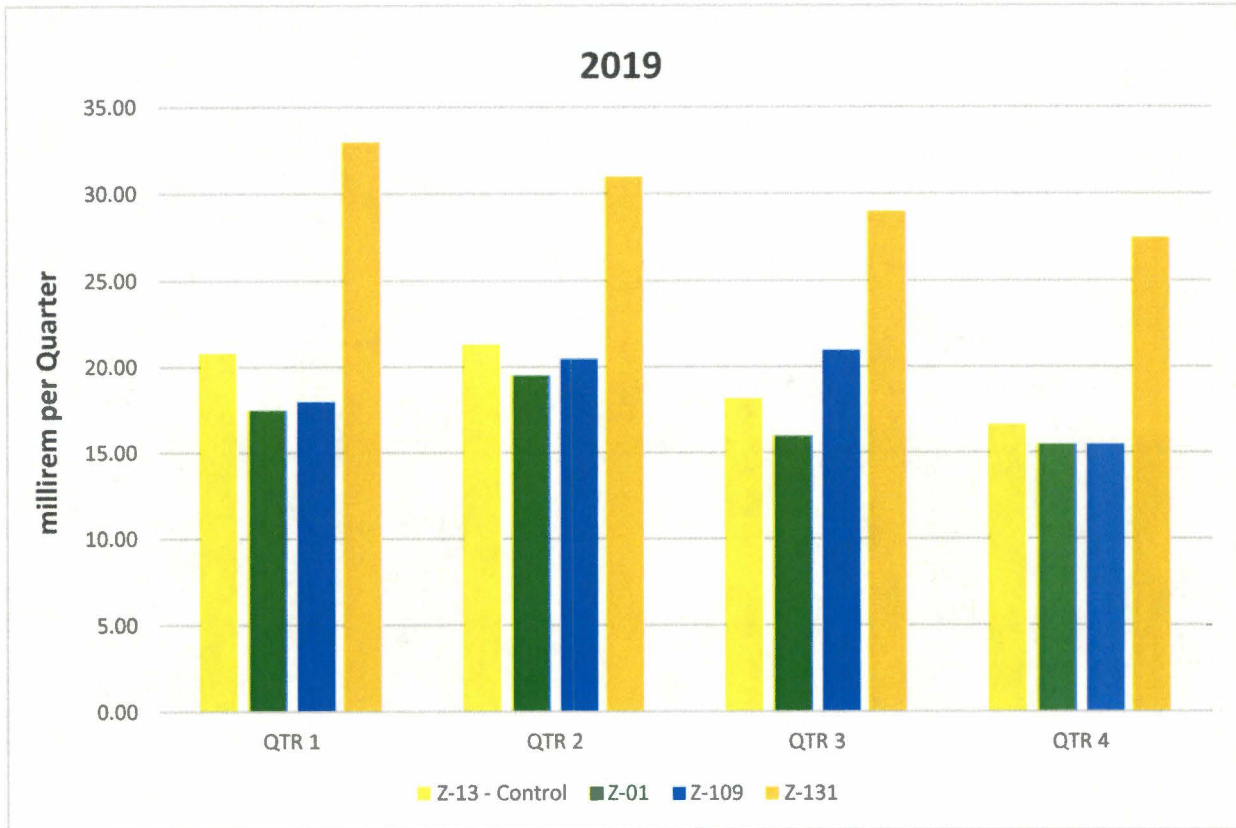


AIR PARTICULATES - GROSS BETA - STATION Z-13
COLLECTED IN THE VICINITY OF ZNPS, 2013 - 2019

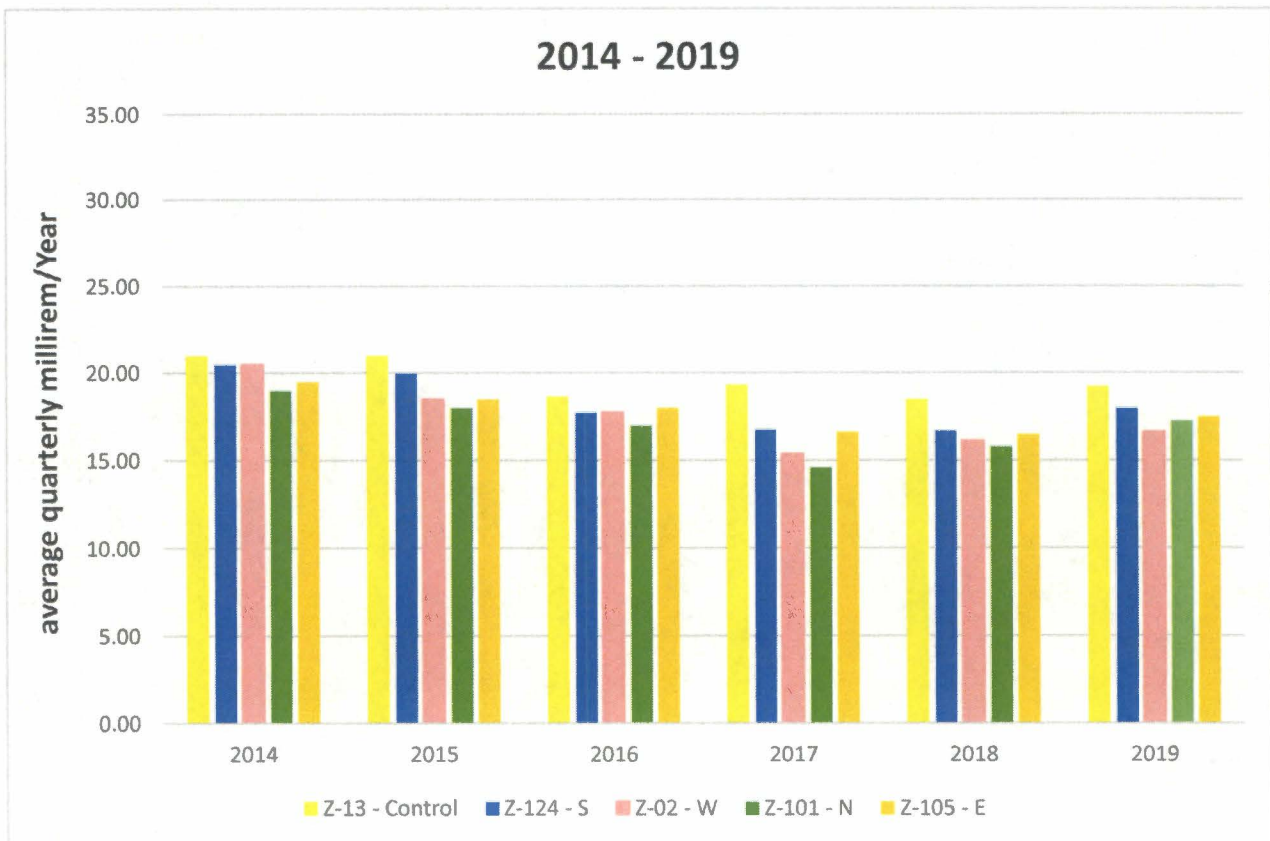
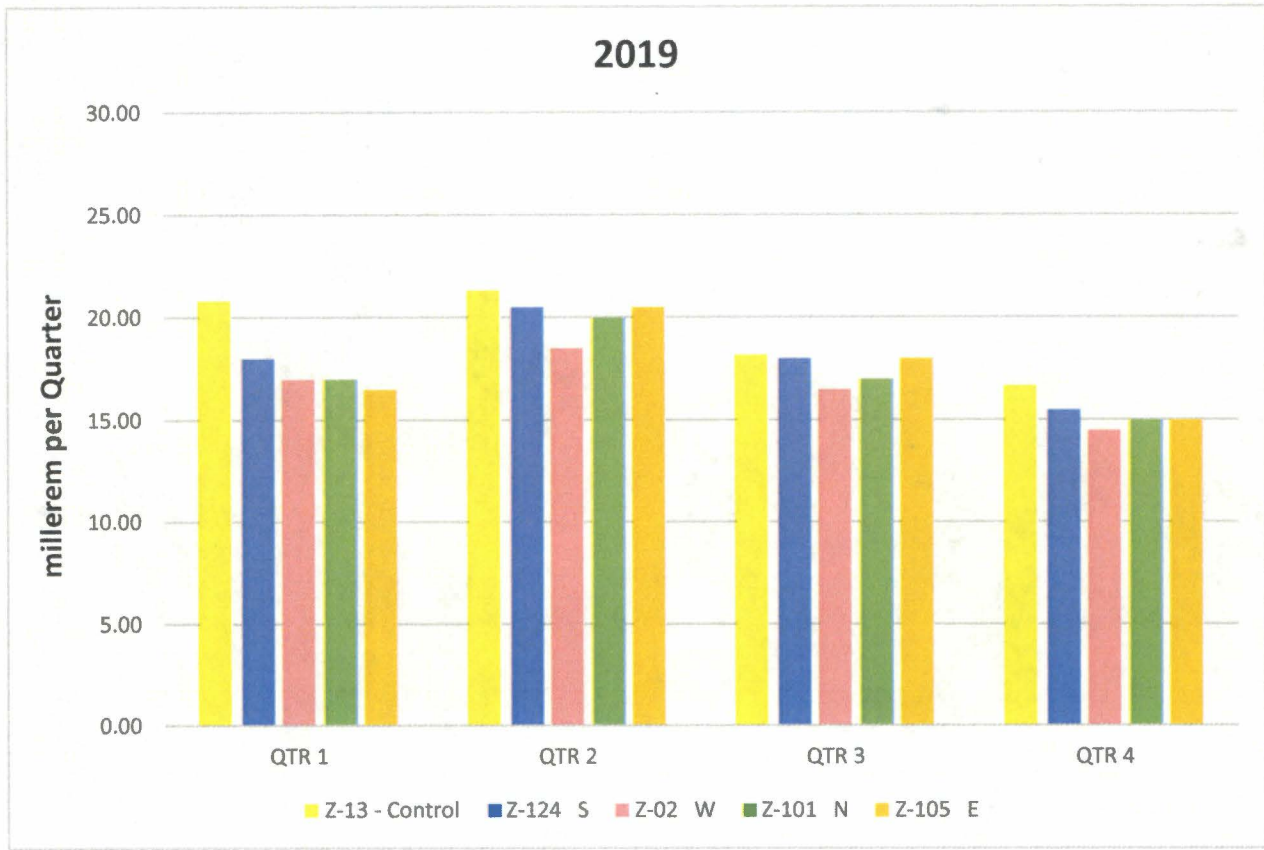
Z-13 Offsite Control



**FIGURE C-7
ZNPS INNER RING TLD'S POTENTIALLY IMPACTED BY ISFSI**



**FIGURE C-8
ZNPS AREA BOUNDARY TLD'S AT 4 COMPASS POINTS**



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APPENDIX D

**INTER-LABORATORY COMPARISON
PROGRAM**

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**Analytcs Environmental Radioactivity Cross Check Program
Teledyne Brown Engineering Environmental Services**

Table D.1

Month/Year	Identification Number	Matrix	Nuclide	Units	TBE Reported Value	Known Value ^(a)	Ratio of TBE to Analytics Result	Evaluation ^(b)		
March 2019	E12468A	Milk	Sr-89	pCi/L	87.1	96	0.91	A		
			Sr-90	pCi/L	12.6	12.6	1.00	A		
	E12469A	Milk	Ce-141	pCi/L	113	117	0.97	A		
			Co-58	pCi/L	153	143	1.07	A		
			Co-60	pCi/L	289	299	0.97	A		
			Cr-51	pCi/L	233	293	0.80	A		
			Cs-134	pCi/L	147	160	0.92	A		
			Cs-137	pCi/L	193	196	0.98	A		
			Fe-59	pCi/L	153	159	0.96	A		
			I-131	pCi/L	91.5	89.5	1.02	A		
			Mn-54	pCi/L	149	143	1.04	A		
			Zn-65	pCi/L	209	220	0.95	A		
			E12470	Charcoal	I-131	pCi	77.5	75.2	1.03	A
			E12471	AP	Ce-141	pCi	60.7	70.2	0.87	A
Co-58	pCi	87.9			85.8	1.02	A			
Co-60	pCi	175			179	0.98	A			
Cr-51	pCi	165			176	0.94	A			
Cs-134	pCi	91.2			95.9	0.95	A			
Cs-137	pCi	120			118	1.02	A			
Fe-59	pCi	108			95.3	1.13	A			
Mn-54	pCi	94.2			85.7	1.10	A			
Zn-65	pCi	102	132	0.77	W					
E12472	Water	Fe-55	pCi/L	2230	1920	1.16	A			
E12473	Soil	Ce-141	pCi/g	0.189	0.183	1.03	A			
		Co-58	pCi/g	0.209	0.224	0.93	A			
		Co-60	pCi/g	0.481	0.466	1.03	A			
		Cr-51	pCi/g	0.522	0.457	1.14	A			
		Cs-134	pCi/g	0.218	0.250	0.87	A			
		Cs-137	pCi/g	0.370	0.381	0.97	A			
		Fe-59	pCi/g	0.263	0.248	1.06	A			
		Mn-54	pCi/g	0.248	0.223	1.11	A			
Zn-65	pCi/g	0.371	0.344	1.08	A					
E12474	AP	Sr-89	pCi	88.3	95.2	0.93	A			
		Sr-90	pCi	11.7	12.5	0.94	A			
August 2019	E12562	Soil	Sr-90	pCi/g	4.710	6.710	0.70	W		

(a) The Analytics known value is equal to 100% of the parameter present in the standard as determined by gravimetric and/or volumetric measurements made during standard preparation

(b) Analytics evaluation based on TBE internal QC limits:

A = Acceptable - reported result falls within ratio limits of 0.80-1.20

W = Acceptable with warning - reported result falls within 0.70-0.80 or 1.20-1.30

N = Not Acceptable - reported result falls outside the ratio limits of < 0.70 and > 1.30

**Analytics Environmental Radioactivity Cross Check Program
Teledyne Brown Engineering Environmental Services, 2019**

Table D.1

Month/Year	Identification Number	Matrix	Nuclide	Units	TBE Reported Value	Known Value ^(a)	Ratio of TBE to Analytics Result	Evaluation ^(b)			
September 2019	E12475	Milk	Sr-89	pCi/L	70.0	93.9	0.75	W			
			Sr-90	pCi/L	12.0	12.9	0.93	A			
September 2019	E12476	Milk	Ce-141	pCi/L	150	167	0.90	A			
			Co-58	pCi/L	170	175	0.97	A			
			Co-60	pCi/L	211	211	1.00	A			
			Cr-51	pCi/L	323	331	0.98	A			
			Cs-134	pCi/L	180	207	0.87	A			
			Cs-137	pCi/L	147	151	0.97	A			
			Fe-59	pCi/L	156	148	1.05	A			
			I-131	pCi/L	81.1	92.1	0.88	A			
			Mn-54	pCi/L	160	154	1.04	A			
			Zn-65	pCi/L	303	293	1.03	A			
			E12477	Charcoal	I-131	pCi	95.9	95.1	1.01	A	
			September 2019	E12478	AP	Ce-141	pCi	129	138	0.93	A
						Co-58	pCi	128	145	0.88	A
Co-60	pCi	181				174	1.04	A			
Cr-51	pCi	292				274	1.07	A			
Cs-134	pCi	166				171	0.97	A			
Cs-137	pCi	115				125	0.92	A			
Fe-59	pCi	119				123	0.97	A			
Mn-54	pCi	129				128	1.01	A			
Zn-65	pCi	230				242	0.95	A			
September 2019	E12479	Water	Fe-55	pCi/L	1810	1850	0.98	A			
September 2019	E12480	Soil	Ce-141	pCi/g	0.305	0.276	1.10	A			
			Co-58	pCi/g	0.270	0.289	0.93	A			
			Co-60	pCi/g	0.358	0.348	1.03	A			
			Cr-51	pCi/g	0.765	0.547	1.40	N ⁽¹⁾			
			Cs-134	pCi/g	0.327	0.343	0.95	A			
			Cs-137	pCi/g	0.308	0.321	0.96	A			
			Fe-59	pCi/g	0.257	0.245	1.05	A			
			Mn-54	pCi/g	0.274	0.255	1.07	A			
			Zn-65	pCi/g	0.536	0.485	1.11	A			
September 2019	E12481	AP	Sr-89	pCi	95.9	91.9	1.04	A			
			Sr-90	pCi	12.3	12.6	0.97	A			
September 2019	E12563	Soil	Sr-90	pCi/g	0.392	0.360	1.09	A			

(a) The Analytics known value is equal to 100% of the parameter present in the standard as determined by gravimetric and/or volumetric measurements made during standard preparation

(b) Analytics evaluation based on TBE internal QC limits:

A = Acceptable - reported result falls within ratio limits of 0.80-1.20

W = Acceptable with warning - reported result falls within 0.70-0.80 or 1.20-1.30

N = Not Acceptable - reported result falls outside the ratio limits of < 0.70 and > 1.30

(1) See NCR 19-27

DOE's Mixed Analyte Performance Evaluation Program (MAPEP)

Table D.2

Teledyne Brown Engineering, Environmental Services, 2019

Month/Year	Identification Number	Matrix	Nuclide	Units	TBE Reported Value	Known Value ^(a)	Acceptance Range	Evaluation ^(b)
February 2019	19-GrF40	AP	Gross Alpha	Bq/sample	0.184	0.528	0.158 - 0.898	A
			Gross Beta	Bq/sample	0.785	0.948	0.474 - 1.422	A
	19-MaS40	Soil	Ni-63	Bq/kg	420	519.0	363 - 675	A
			Sr-90	Bq/kg			(1)	NR ⁽³⁾
19-MaW40	Water		Am-241	Bq/L	0.764	0.582	0.407 - 0.757	N ⁽⁴⁾
			Ni-63	Bq/L	4.72	5.8	4.1 - 7.5	A
			Pu-238	Bq/L	0.443	0.451	0.316 - 0.586	A
			Pu-239/240	Bq/L	-0.00161	0.0045	(2)	A
19-RdF40	AP		U-234/233	Bq/sample	0.1138	0.106	0.074 - 0.138	A
			U-238	Bq/sample	0.107	0.110	0.077 - 0.143	A
19-RdV40	Vegetation		Cs-134	Bq/sample	2.14	2.44	1.71 - 3.17	A
			Cs-137	Bq/sample	2.22	2.30	1.61 - 2.99	A
			Co-57	Bq/sample	2.16	2.07	1.45 - 2.69	A
			Co-60	Bq/sample	0.02382		(1)	A
			Mn-54	Bq/sample	-0.03607		(1)	A
			Sr-90	Bq/sample	-0.1060		(1)	N ⁽⁵⁾
			Zn-65	Bq/sample	1.35	1.71	1.20 - 2.22	W
August 2019	19-GrF41	AP	Gross Alpha	Bq/sample	0.192	0.528	0.158 - 0.898	W
			Gross Beta	Bq/sample	0.722	0.937	0.469 - 1.406	A
	19-MaS41	Soil	Ni-63	Bq/kg	436	629	440 - 818	N ⁽⁶⁾
			Sr-90	Bq/kg	444	572	400 - 744	W
19-MaW41	Water		Am-241	Bq/L				NR ⁽⁷⁾
			Ni-63	Bq/L	7.28	9.7	6.8 - 12.6	W
			Pu-238	Bq/L	0.0207	0.0063	(2)	A
			Pu-239/240	Bq/L	0.741	0.727	0.509 - 0.945	A
19-RdF41	AP		U-234/233	Bq/sample	0.0966	0.093	0.065 - 0.121	A
			U-238	Bq/sample	0.0852	0.096	0.067-0.125	A
19-RdV41	Vegetation		Cs-134	Bq/sample	0.0197		(1)	A
			Cs-137	Bq/sample	3.21	3.28	2.30 - 4.26	A
			Co-57	Bq/sample	4.62	4.57	3.20 - 5.94	A
			Co-60	Bq/sample	4.88	5.30	3.71 - 6.89	A
			Mn-54	Bq/sample	4.54	4.49	3.14 - 5.84	A
			Sr-90	Bq/sample	0.889	1.00	0.70 - 1.30	A
			Zn-65	Bq/sample	2.78	2.85	2.00 - 3.71	A

(a) The MAPEP known value is equal to 100% of the parameter present in the standard as determined by gravimetric and/or volumetric measurements made during standard preparation

(b) DOE/MAPEP evaluation:

A = Acceptable - reported result falls within ratio limits of 0.80-1.20

W = Acceptable with warning - reported result falls within 0.70-0.80 or 1.20-1.30

N = Not Acceptable - reported result falls outside the ratio limits of < 0.70 and > 1.30

(1) False positive test

(2) Sensitivity evaluation

(3) See NCR 19-12

(4) See NCR 19-13

(5) See NCR 19-14

(6) See NCR 19-25

(7) See NCR 19-26

**ERA Environmental Radioactivity Cross Check Program
Teledyne Brown, Engineering Environmental Services, 2019**

Table D.3

Month/Year	Identification Number	Matrix	Nuclide	Units	TBE Reported Value	Known Value ^(a)	Acceptance Limits	Evaluation ^(b)
April 2019	Rad-117	Water	Ba-133	pCi/L	26.3	24.1	18.6 - 27.8	A
			Cs-134	pCi/L	15.2	12.1	8.39 - 14.4	N ⁽¹⁾
			Cs-137	pCi/L	33.6	33.1	28.8 - 39.4	A
			Co-60	pCi/L	11.9	11.5	8.67 - 15.5	A
			Zn-65	pCi/L	87.1	89.2	80.3 - 107	A
			GR-A	pCi/L	19	19.3	9.56 - 26.5	A
			GR-B	pCi/L	20.2	29.9	19.1 - 37.7	A
			U-Nat	pCi/L	55.5	55.9	45.6 - 61.5	A
			H-3	pCi/L	21500	21400	18700 - 23500	A
			Sr-89	pCi/L	44.9	33.3	24.5 - 40.1	N ⁽²⁾
			Sr-90	pCi/L	24.5	26.3	19.0 - 30.7	A
			I-131	pCi/L	28.9	28.4	23.6 - 33.3	A
October 2019	Rad-119	Water	Ba-133	pCi/L	42.7	43.8	35.7 - 48.8	A
			Cs-134	pCi/L	53.5	55.9	45.2 - 61.5	A
			Cs-137	pCi/L	77.7	78.7	70.8 - 89.2	A
			Co-60	pCi/L	51.5	53.4	48.1 - 61.3	A
			Zn-65	pCi/L	36.6	34.0	28.5 - 43.1	A
			GR-A	pCi/L	40.5	27.6	14.0 - 36.3	N ⁽³⁾
			GR-B	pCi/L	36.3	39.8	26.4 - 47.3	A
			U-Nat	pCi/L	27.66	28.0	22.6 - 31.1	A
			H-3	pCi/L	22800	23400	20500 - 25700	A
			Sr-89	pCi/L	47.1	45.5	35.4 - 52.7	A
			Sr-90	pCi/L	32.5	26.5	19.2 - 30.9	N ⁽⁴⁾
			I-131	pCi/L	26.0	23.9	19.8 - 28.4	A
December 2019	QR 120419D	Water	Sr-90	pCi/L	20.1	18.6	13.2 - 22.1	A

(a) The ERA known value is equal to 100% of the parameter present in the standard as determined by gravimetric and/or volumetric measurements made during standard preparation.

(b) ERA evaluation:

A = Acceptable - Reported value falls within the Acceptance Limits

N = Not Acceptable - Reported value falls outside of the Acceptance Limits

(1) See NCR 19-10

(2) See NCR 19-11

(3) See NCR 19-23

(4) See NCR 19-24

APPENDIX E

**ANNUAL RADIOLOGICAL GROUNDWATER
PROTECTION PROGRAM REPORT (ARGPPR)**

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