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ZION NUCLEAR POWER STATION
UNITS 1 and 2

Annual Radiological Environmental Operating Report

1 January through 31 December 2016

Prepared By
Teledyne Brown Engineering
Environmental Services

ZIONSOLUTIONS LLC
An EnergySolutions Company

Zion Nuclear Power Station
Zion, IL 60099

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I. Summary and Conclusions

This report on the Radiological Environmental Monitoring Program conducted for the Zion Nuclear Power Station (ZNPS) by Zion*Solutions* (ZS) covers the period 1 January 2016 through 31 December 2016. During that time period, 609 analyses were performed on 529 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.

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.

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II. Introduction

The Zion Nuclear Power Station (ZNPS), consisted of two 1,100 MWt pressurized water reactors was owned and operated by Exelon Corporation, 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. The plant is in an advanced state of decommissioning. 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), Mirion Technologies and Environmental Inc. (Midwest Labs) on samples collected during the period 1 January 2016 through 31 December 2016.

A. Objectives of the REMP

The objectives of the REMP are to:

1. Provide data on measurable levels of radiation and radioactive materials in the site environs

2. Evaluate the relationship between quantities of radioactive material released from the plant and resultant radiation doses to individuals from principal pathways of exposure

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 effects (if any) on man and the environment

III. Program Description

A. Sample Collection

Samples for the ZNPS REMP were collected for 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 2016. Sample locations

and descriptions can be found in Table B–1 and Figures B–1 and B–2, 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 comprising the flesh of white sucker, northern pike, 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 locations (Z-01, Z-02, Z-03, and Z-13). The control location was Z-13. 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 September 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 using 2 CaF 200 and 2 LiF 100 LiF 4-chip Harshaw thermoluminescent dosimeters (TLD) until the 3rd Quarter of 2016. Starting the 4th Quarter of 2016, all TLD's were replaced with Panasonic Environmental TLD type 814 with 3 $CaSO_4$ elements that do not give an over-response to neutrons. Each location consisted of 2 TLD sets. The TLD locations were placed on and around 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-112, Z-113, Z-114, Z-115, Z-121, Z-124, Z-125, Z-129, Z-130, Z-131

Special Interest: Z-113, Z-114, Z-115, Z-116

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 sight of the vents (where practical);

4. And near the closest dwelling to the vents in the prevailing downwind direction.

(Two TLDs – each comprised of two CaF_2 200 and 2 LiF 100 LiF 4-chip thermoluminescent phosphors 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 and Environmental Inc. (Midwest Labs) to analyze the environmental samples for radioactivity for the ZNPS REMP in 2016. 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

2. Concentrations of gamma emitters in public water, air particulates, fish, and sediment

3. Concentrations of tritium in public water

4. Ambient gamma radiation levels at various site environs

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. An MDC was reported in all cases where positive activity was not detected.

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

For public water, 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 2016 the ZNPS REMP had a sample recovery rate in excess of 98%. 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-02	01/20/16	No apparent reason for low reading of 121.6 hours
AP	Z-02	11/16/16	Timer malfunction; collector replaced timer. Timer reading of 1638.4 hours based on previous weeks' time.

Table D-2 LISTING OF MISSED SAMPLES

Sample Type	Location Code	Collection Date	Reason
TLD	Z-02-2	12/20/16	TLD missing during weekly check; collector placed spare.

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

Harshaw TLD100 chip was removed as environmental TLD because it contains natural Lithium which has a percentage of Li-6. When Li-6 is in a neutron field, the Li-6 responds to the neutrons and gives a gamma over-response. Neutron dose is already handled in a different manner using TLD's that are calibrated correctly to respond to neutrons. Thus the Environmental TLD type was changed to Panasonic 814's that do not contain the natural Li in the TLD chips, but are suitable to measure the same dose range as proven by a study conducted and over 1 year of data was obtained to compare responses.

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 (Table C–I.1, Appendix C). Gross beta was detected in 30 of 48 samples. The values ranged from 2.1 pCi/l to 4.7 pCi/l. Concentrations detected were consistent with those detected in previous years (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 (Table C–I.3, Appendix C). No nuclides were detected and all required LLDs were met.

2. Fish

Fish samples comprised of white sucker, northern pike, common carp, brown trout, 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 (Table C–II.1, Appendix C). No nuclides were detected and all required LLDs were met.

3. Sediment

Aquatic sediment samples were 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 (Table C–III.1, Appendix C). No nuclides were detected and all required LLDs were met.

B. Atmospheric Environment

1. Airborne

a. Air Particulates

Continuous air particulate samples were collected from three locations on a weekly basis. The three locations were within the ZNPS site boundary (Z-01, Z-02 and Z-03). The following analyses were performed:

Gross Beta

Weekly samples were analyzed for concentrations of beta emitters (Table C–IV.1 and C–IV.2, Appendix C). Detectable gross beta activity was observed at all locations. Comparison of results among the three groups aid in determining the effects, if any, resulting from the operation of ZNPS. The results from the On-Site locations ranged from 6E-3 pCi/m^3 to 30E–3 pCi/m^3 with a mean of 14E–3 pCi/m^3. The results from the Control location ranged from 7E-3 pCi/m^3 to 30E–3 pCi/m^3 with a mean of 16E–3 pCi/m^3. Comparison of the 2016 air particulate data with previous year's data indicate no effects from the operation of ZNPS. Concentrations detected were consistent with those detected in previous years.

Gamma Spectrometry

Weekly samples were composited quarterly and analyzed for gamma-emitting nuclides (Table C–IV.3, Appendix C). 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.

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 (Table C–V.1, Appendix C). No nuclides were detected and all required LLDs were met.

D. Ambient Gamma Radiation

Ambient gamma radiation levels were measured utilizing Harshaw (CaF and LiF) thermoluminescent dosimeters. Sixty-four TLD locations were hanging 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 13 mR/quarter to 50 mR/quarter.

E. Land Use Survey

A Land Use Census conducted during August 2016 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 ft_2 in each of the sixteen 22 ½ degree sectors around the site. The results of this survey are summarized below:

	Distance in Miles from ZS		
Sector	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 located using Google Maps to narrow down areas that appeared to have been ploughed by aerial photographs, then visually verified by visiting locations.

Milk-producing animal located by internet search for dairies advertising selling milk for public consumption.

F. Errata Data

There is no errata data for 2016.

G. Summary of Results – Inter-Laboratory Comparison Program

The primary and secondary laboratories analyzed Performance Evaluation (PE) samples of air particulate, air iodine, milk, soil, vegetation and water matrices for (Appendix D). The PE samples, supplied by Analytics Inc., Environmental Resource Associates (ERA) and DOE's Mixed Analyte Performance Evaluation Program (MAPEP), were evaluated against the following pre-set acceptance criteria:

1. Analytics Evaluation Criteria

   Analytics' evaluation report provides a ratio of laboratory results and Analytics' known value. Since flag values are not assigned by Analytics, TBE-ES evaluates the reported ratios based on internal QC requirements, which are based on the DOE MAPEP criteria.

2. 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.

3. DOE Evaluation Criteria

   MAPEP's evaluation report provides an acceptance range with associated flag values.

The MAPEP defines three levels of performance: Acceptable (flag = "A"), Acceptable with Warning (flag = "W"), and Not Acceptable (flag = "N"). Performance is considered acceptable when a mean result for the specified analyte is ± 20% of the reference value. Performance is acceptable with warning when a mean result falls in the range from ±20% to ±30% of the reference value (i.e., 20% < bias < 30%). If the bias is greater than 30%, the results are deemed not acceptable.

For the TBE laboratory, 156 out of 160 analyses performed met the specified acceptance criteria. Four analyses (Milk - Sr-90, Vegetation - Sr-90, and Water - H-3 samples) did not meet the specified acceptance criteria for the following reasons and were addressed through the TBE Corrective Action Program.

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.

1. Teledyne Brown Engineering's MAPEP March 2016 air particulate cross check sample is now being provided to TBE by Analytics. MAPEP's policy is to evaluate as failed non reported nuclides that were reported in the previous study. Since the Sr-90 was reported in the previous MAPEP study but not in this study MAPEP evaluated the Sr-90 for Soil as failed. NCR 16-14

   The MAPEP March 2016 Sr-90 in vegetation was evaluated as failing a false positive test. In reviewing the data that was reported vs the data in LIMS, it was found that the error was incorrectly reported as 0.023 rather than the correct value of 0.230. If the value had been reported with the activity and correct uncertainty of 0.301 ± 0.230, MAPEP would have evaluated the result as acceptable. NCR 16-14

2. Teledyne Brown Engineering's Analytics' March 2016 milk Sr-90 result of 15 ± .125 pCi/L was higher than the known value of 11.4 pCi/L with a ratio of 1.32. The upper ratio of 1.30 (acceptable with warning) was exceeded. After an extensive review of the data it is believed the technician did not rinse the filtering apparatus properly and some cross contamination from one of the internal laboratory spike samples may have been transferred to the analytics sample. We feel the issue is specific to the March 2016 Analytics sample. NCR 16-26

3. Teledyne Brown Engineering's ERA November 2016 sample for H-3 in water was evaluated as failing. A result of 918 pCi/L was reported incorrectly due to a data entry issue. If the correct value

of 9180 had been reported, ERA would have evaluated the result as acceptable. NCR 16-34

4. Teledyne Brown Engineering's Analytics' December 2016 milk Sr-90 sample result of 14.7 ± .26 pCi/L was higher than the known value of 10 pCi/L with a ratio of 1.47. The upper ratio of 1.30 (acceptable with warning) was exceeded. The technician entered the wrong aliquot into the LIMS system. To achieve a lower error term TBE uses a larger aliquot of 1.2L (Normally we use .6L for client samples). If the technician had entered an aliquot of 1.2L into the LIMS system, the result would have been 12.2 pCi/L, which would have been considered acceptable. NCR 16-35

For the EIML laboratory, 198 of 203 analyses met the specified acceptance criteria. Five analyses (Water – Ba-133, Co-57; Soil – Ni-63, U-233/234, U-238) did not meet the specified acceptance criteria for the following reasons:

1. The Environmental Inc., Midwest Laboratory's ERA April 2016 water Ba-133 result of 65.2 pCI/L was higher than the known value of 58.8 pCi/L, exceeding the upper control limit of 64.9 pCi/L. The reanalysis result of 57.8 pCI/L fell within acceptance criteria.

2. The Environmental Inc., Midwest Laboratory's MAPEP February 2016 water Co-57 result of 1.38 Bq/L sample was higher than the known value of 0.00 Bq/L sample. This sample is considered a false positive.

3. The Environmental Inc., Midwest Laboratory's MAPEP August 2016 soil Ni-60 result of 648 Bq/kg was lower than the known value of 990 Bq/kg, exceeding the lower control limit of 693 Bq/kg. Reanalysis with a smaller aliquot resulted in acceptable results. An investigation is in process to identify better techniques for analyzing samples with complex matrices.

4. The Environmental Inc., Midwest Laboratory's MAPEP August 2016 soil U-233/234 result of 46.8 Bq/kg was lower than the known value of 122 Bq/kg, exceeding the lower control limit of 85 Bq/kg. MAPEP states that samples contain two fractions of Uranium; one that is soluble in concentrated HNO3 and HCL acid and one that is "fundamentally insoluble in these acids". They also state that HF treatment cannot assure complete dissolution. Results are consistent with measuring the soluble form.

5. The Environmental Inc., Midwest Laboratory's MAPEP August 2016 soil U-238 result of 46.6 Bq/kg was lower than the known value of 121 Bq/kg, exceeding the lower control limit of 85 Bq/kg.

MAPEP states that samples contain two fractions of Uranium; one that is soluble in concentrated HNO3 and HCL acid and one that is "fundamentally insoluble in these acids". They also state that HF treatment cannot assure complete dissolution. Results are consistent with measuring the soluble form.

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

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APPENDIX A

RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT SUMMARY

TABLE A-1 RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM ANNUAL SUMMARY FOR THE ZION NUCLEAR POWER STATION, 2016

Name of Facility:	**ZION NUCLEAR POWER STATION**				**DOCKET NUMBER:**		**50-295 & 50-304**	
Location of Facility:	**ZION, IL**				**REPORTING PERIOD:**		**2016**	
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	**GR-B**	48	**4**	3	3	3.1	Z-15 INDICATOR	0
(PCI/LITER)				(25/36)	(8/12)	(8/12)	LAKE COUNTY WATER WORKS	
				2.1 - 4.7	*2.2 - 3.5*	*2.3 - 3.8*	1.4 MILES NNW OF SITE	
	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	**GAMMA**	2						
(PCI/KG WET)	*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) The Mean Values are calculated using the positive values. (F) Fraction of detectable measurement are indicated in parentheses.

TABLE A-1 RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM ANNUAL SUMMARY FOR THE ZION NUCLEAR POWER STATION, 2016

Name of Facility:	**ZION NUCLEAR POWER STATION**				**DOCKET NUMBER:**		**50-295 & 50-304**	
Location of Facility:	**ZION, IL**				**REPORTING PERIOD:**		**2016**	
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	**GAMMA**	2						
(PCI/KG DRY)	*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	**GR-B**	208	**10**	14	16	16	Z-13 CONTROL	0
(E-3 PCI/CU.METER)				(154/156)	(52/52)	(52/52)	OFFSITE CONTROL	
				6 - 30	*7 - 35*	*7 - 35*	10.0 MILES NW OF SITE	
	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) The Mean Values are calculated using the positive values. (F) Fraction of detectable measurement are indicated in parentheses.

TABLE A-1 RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM ANNUAL SUMMARY FOR THE ZION NUCLEAR POWER STATION, 2016

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Location of Facility:	**ZION, IL**	**REPORTING PERIOD:**	**2016**

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	**GAMMA**	7						
(PCI/KGWET)	*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	**TLD-QUARTERLY**	256	*NA*	19.8	18.1	41.5	Z-131-1 INDICATOR	0
(MILLI-ROENTGEN/QTR.)				(232/232)	(24/24)	(4/4)		
				13 - 50	*15 - 21*	*28 - 50*	0.2 MIIES WSW	

(M) The Mean Values are calculated using the positive values. (F) Fraction of detectable measurement are indicated in parentheses.

APPENDIX B

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

TABLE B-1: Radiological Environmental Monitoring Program - Sampling Locations, Distance and Direction, Zion Nuclear Power Station, 2016

Location	Location Description	Distance & Direction From Site
A. Public Water		
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
B. Air Particulates		
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
C. Fish		
Z-26	Lake Michigan Nearsite (indicator)	At station
Z-27	Lake Michigan Farsite (indicator)	10.1 miles N
D. Sediment		
Z-25	Lake Michigan, Illinois Beach State Park (indicator)	0.2 miles S
E. Environmental Dosimetry - TLD		
Inner Ring		
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-110-1 and -2		0.2 miles SSW
Z-111-1 and -2		0.3 miles SW
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
Other		
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
Outer Ring		
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		
Control		
Z-13-1 thru -6		10 miles NW

TABLE B-2: Radiological Environmental Monitoring Program – Summary of Sample Collection and Analytical Methods, Zion Nuclear Power Station, 2016

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 Env. Inc., GS-01 Determination of gamma emitters by gamma spectroscopy
Public Water	Gross Beta	Monthly composite from weekly grab samples.	TBE, TBE-2008 Gross Alpha and/or gross beta activity in various matrices Env. Inc., W(DS)-01 Determination of gross alpha and/or gross beta in water (dissolved solids or total residue)
Public Water	Tritium	Quarterly composite from weekly grab samples.	TBE, TBE-2011 Tritium analysis in drinking water by liquid scintillation Env. Inc., T-02 Determination of tritium in water (direct method)
Fish	Gamma Spectroscopy	Semi-annual samples collected via electroshocking or other techniques	TBE-2007 Gamma emitting radioisotope analysis Env. Inc., GS-01 Determination of gamma emitters by gamma spectroscopy
Sediment	Gamma Spectroscopy	Semi-annual grab samples	TBE, TBE-2007 Gamma emitting radioisotope analysis Env. Inc., GS-01 Determination of gamma emitters by gamma spectroscopy
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 Env. Inc., AP-02 Determination of gross alpha and/or gross beta in air particulate filters
Air Particulates	Gamma Spectroscopy	Quarterly composite of each station	TBE, TBE-2007 Gamma emitting radioisotope analysis Env. Inc., GS-01 Determination of gamma emitters by gamma spectroscopy
TLD	Thermoluminescence Dosimetry	Quarterly TLDs comprised of two CaF 200 and two LiF 100 LiF 4-chip Harshaw elements.	Mirion Technologies

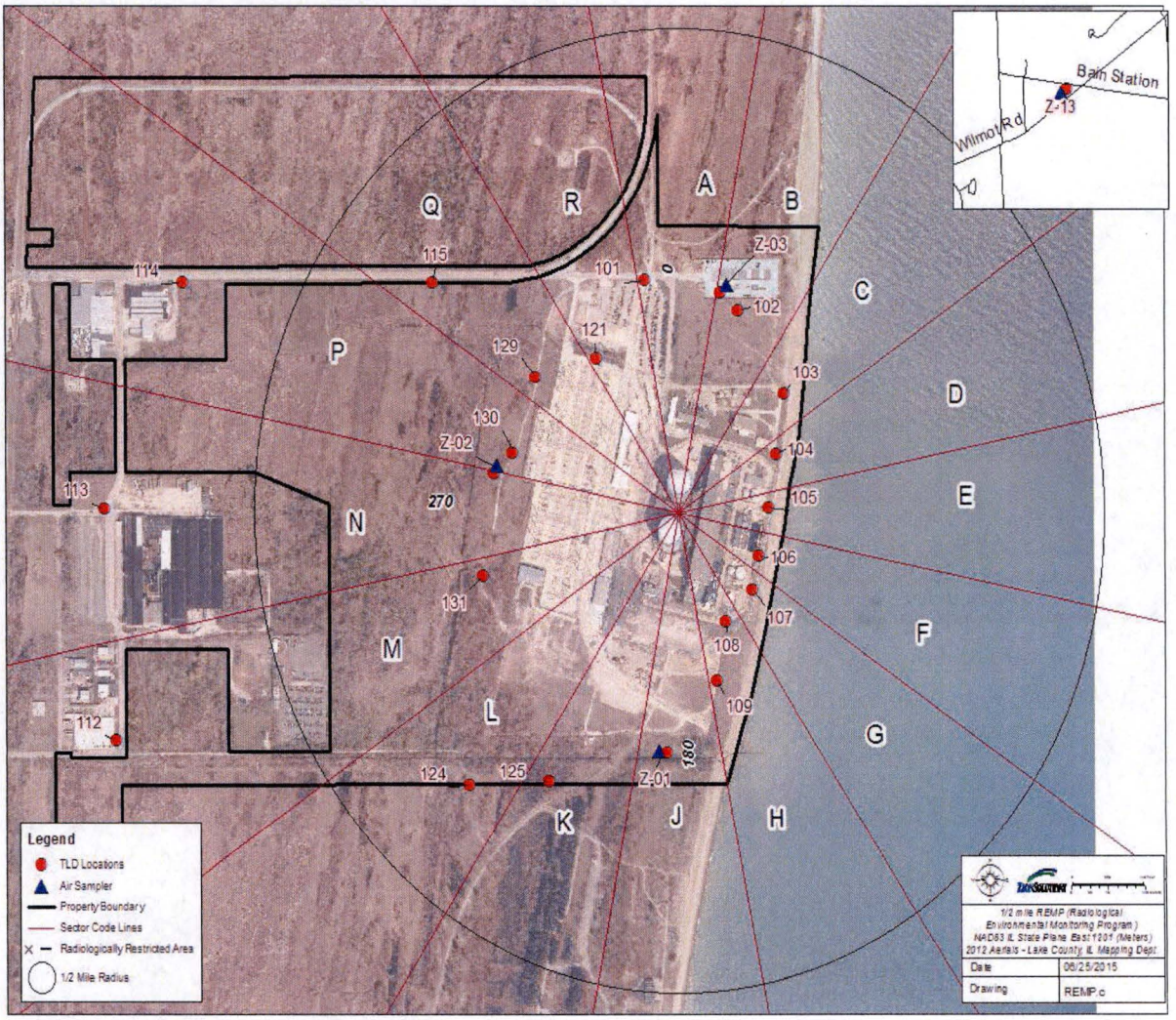


Figure B-1
Inner Ring TLD and Fixed Air Sampler Locations of the Zion Nuclear Power Station, 2016

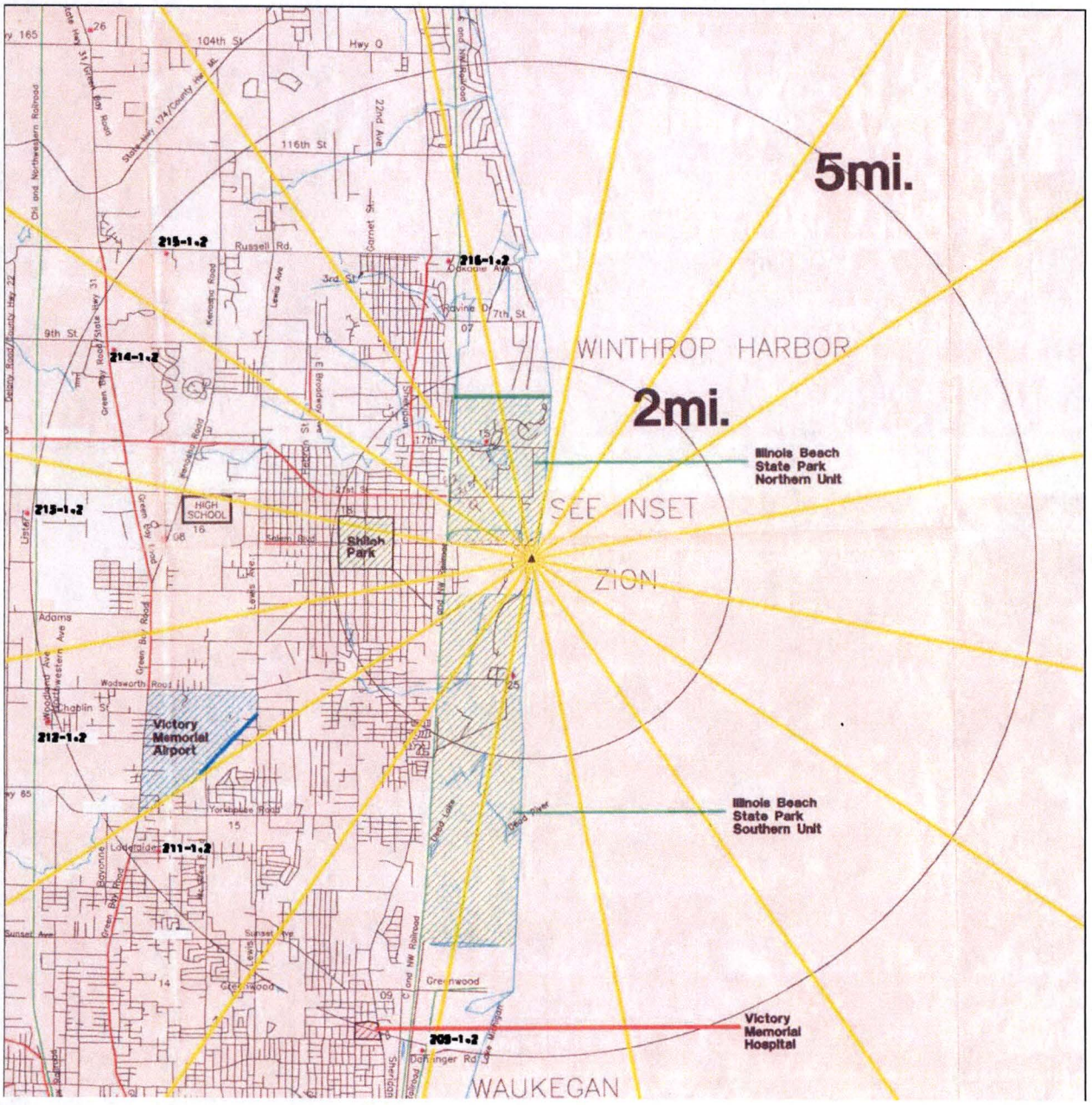


Figure B-2
Outer Ring TLD and Fixed Air Sampler Locations of the Zion Nuclear Power Station, 2016

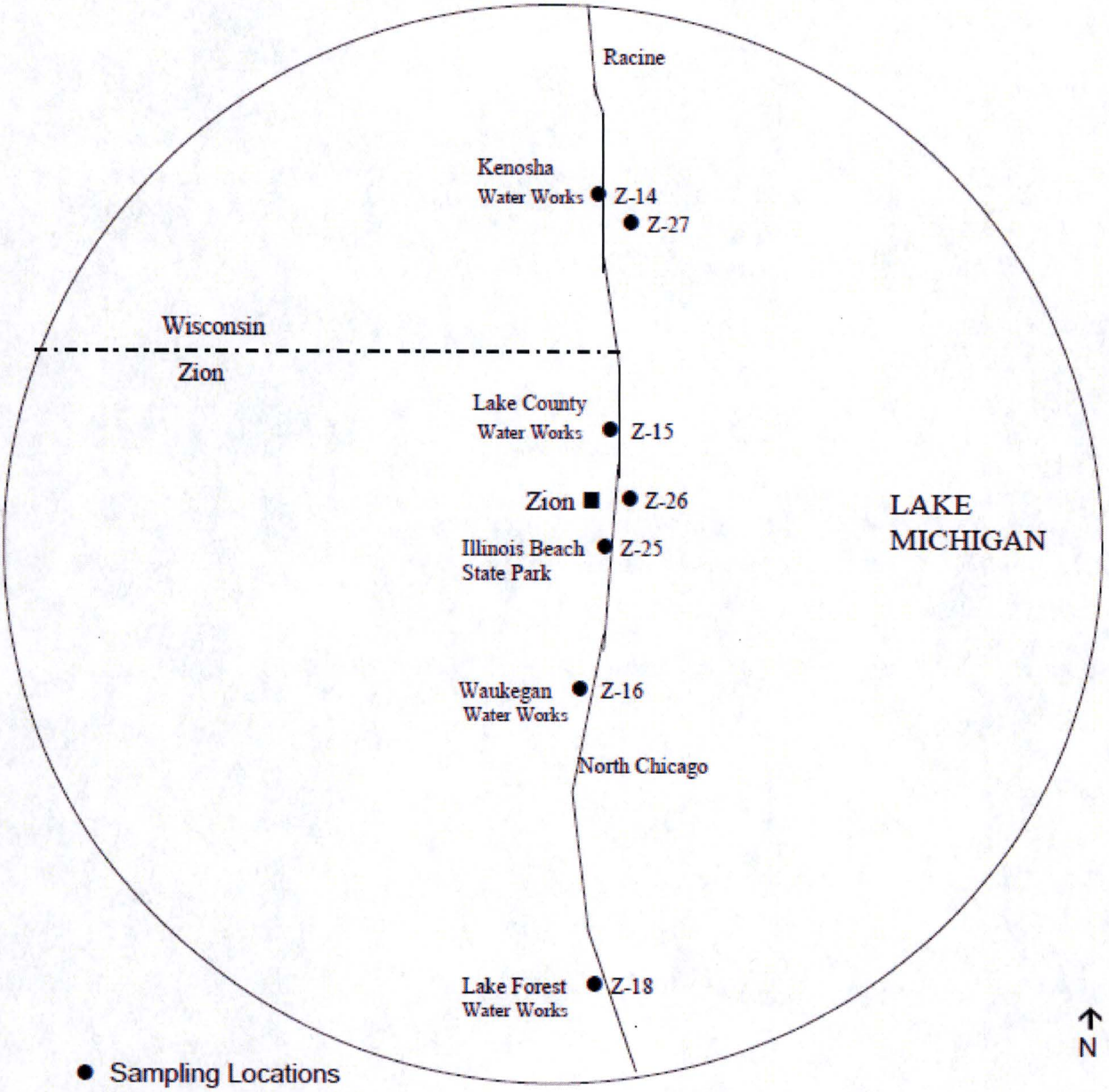


Figure B-3
Fish, Water and Sediment Sampling Locations of the Zion Nuclear Power Station, 2016

APPENDIX C

DATA TABLES AND FIGURES
PRIMARY LABORATORY

Table C-I.1 **Concentrations of Gross Beta in Public Water Samples Collected in the Vicinity of Zion Nuclear Power Station, 2016**

Results in Units of pCi/liter ± 2 Sigma

COLLECTION PERIOD	Z-14	Z-15	Z-16	Z-18
01/06/16 - 01/27/16	< 2.0	3.7 ± 1.8	< 2.0	< 2.0
02/03/16 - 02/24/16	4.7 ± 1.7	3.1 ± 1.5	3.2 ± 1.5	3.3 ± 1.5
03/02/16 - 03/30/16	3.5 ± 1.6	2.3 ± 1.4	3.2 ± 1.5	2.7 ± 1.5
04/06/16 - 04/27/16	< 1.6	3.1 ± 1.5	2.2 ± 1.4	< 2.0
05/04/16 - 05/25/16	2.8 ± 1.5	< 2.1	3.4 ± 1.6	3.3 ± 1.6
06/01/16 - 06/29/16	2.1 ± 1.4	< 2.0	< 2.0	< 2.0
07/06/16 - 07/27/16	< 2.5	< 2.5	< 2.5	2.9 ± 1.9
08/03/16 - 08/31/16	< 2.1	< 2.2	2.4 ± 1.5	< 2.2
09/07/16 - 09/28/16	3.5 ± 1.4	2.4 ± 1.3	2.3 ± 1.3	3.5 ± 1.4
10/05/16 - 10/27/16	2.6 ± 1.5	2.7 ± 1.5	3.6 ± 1.8	3.2 ± 1.6
11/03/16 - 11/30/16	2.8 ± 1.3	3.7 ± 1.4	2.7 ± 1.3	2.9 ± 1.3
12/07/16 - 12/29/16	2.1 ± 1.3	3.8 ± 1.5	2.5 ± 1.3	2.2 ± 1.3
MEAN ± 2 STD DEV	3.0 ± 1.8	3.1 ± 1.2	2.8 ± 1.1	3.0 ± 0.9

Table C-I.2 **Concentrations of Tritium in Public Water Samples Collected in the Vicinity of Zion Nuclear Power Station, 2016**

Results in Units of pCi/liter ± 2 Sigma

COLLECTION PERIOD	Z-14	Z-15	Z-16	Z-18
01/06/16 - 03/30/16	< 197	< 197	< 196	< 192
04/06/16 - 06/29/16	< 182	< 181	< 180	< 184
07/06/16 - 09/28/16	< 182	< 180	< 178	< 181
10/05/16 - 12/29/16	< 197	< 197	< 197	< 194
MEAN	-	-	-	-

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, 2016**

Results in Units of pCi/liter ± 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	01/06/16 - 01/27/16	< 6	< 6	< 11	< 6	< 12	< 5	< 10	< 6	< 4	< 35	< 10
	02/03/16 - 02/24/16	< 7	< 6	< 13	< 7	< 13	< 8	< 15	< 6	< 7	< 38	< 16
	03/02/16 - 03/30/16	< 6	< 5	< 13	< 9	< 11	< 5	< 11	< 6	< 6	< 53	< 15
	04/06/16 - 04/27/16	< 8	< 8	< 17	< 7	< 14	< 8	< 14	< 7	< 9	< 59	< 17
	05/04/16 - 05/25/16	< 4	< 5	< 11	< 5	< 9	< 6	< 10	< 4	< 5	< 59	< 20
	06/01/16 - 06/29/16	< 8	< 7	< 24	< 11	< 15	< 8	< 14	< 7	< 8	< 66	< 15
	07/06/16 - 07/27/16	< 2	< 2	< 5	< 2	< 3	< 2	< 4	< 2	< 2	< 25	< 9
	08/03/16 - 08/31/16	< 6	< 8	< 14	< 5	< 14	< 9	< 14	< 6	< 7	< 55	< 15
	09/07/16 - 09/28/16	< 6	< 8	< 7	< 8	< 12	< 9	< 15	< 6	< 5	< 46	< 14
	10/05/16 - 10/27/16	< 8	< 7	< 16	< 6	< 13	< 8	< 15	< 6	< 7	< 63	< 20
	11/03/16 - 11/30/16	< 8	< 9	< 14	< 6	< 17	< 9	< 12	< 5	< 8	< 48	< 16
	12/07/16 - 12/29/16	< 6	< 6	< 12	< 6	< 13	< 7	< 11	< 5	< 6	< 48	< 16
	MEAN	-	-	-	-	-	-	-	-	-	-	-
Z-15	01/06/16 - 01/27/16	< 6	< 7	< 13	< 7	< 12	< 8	< 12	< 6	< 6	< 45	< 13
	02/03/16 - 02/24/16	< 6	< 7	< 14	< 7	< 17	< 7	< 10	< 6	< 7	< 40	< 15
	03/02/16 - 03/30/16	< 7	< 7	< 16	< 7	< 14	< 7	< 14	< 7	< 7	< 46	< 13
	04/06/16 - 04/27/16	< 5	< 6	< 10	< 5	< 11	< 5	< 10	< 4	< 6	< 38	< 12
	05/04/16 - 05/25/16	< 5	< 5	< 11	< 5	< 11	< 6	< 10	< 5	< 5	< 58	< 16
	06/01/16 - 06/29/16	< 5	< 7	< 16	< 7	< 11	< 8	< 13	< 7	< 7	< 46	< 14
	07/06/16 - 07/27/16	< 2	< 2	< 5	< 2	< 4	< 2	< 4	< 2	< 2	< 25	< 7
	08/03/16 - 08/31/16	< 6	< 5	< 16	< 5	< 14	< 8	< 14	< 5	< 6	< 44	< 17
	09/07/16 - 09/28/16	< 7	< 6	< 14	< 6	< 14	< 9	< 11	< 7	< 6	< 52	< 16
	10/05/16 - 10/27/16	< 5	< 8	< 17	< 7	< 15	< 8	< 15	< 9	< 7	< 77	< 22
	11/03/16 - 11/30/16	< 7	< 7	< 17	< 6	< 13	< 6	< 14	< 7	< 7	< 45	< 17
	12/07/16 - 12/29/16	< 6	< 6	< 13	< 6	< 12	< 7	< 13	< 5	< 5	< 55	< 10
	MEAN	-	-	-	-	-	-	-	-	-	-	-

Table C-I.3 **Concentrations of Gamma Emitters in Public Water Samples Collected in the Vicinity of Zion Nuclear Power Station, 2016**

Results in Units of pCi/liter ± 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-16	1/6/2016 - 01/27/16	< 7	< 7	< 13	< 8	< 13	< 7	< 12	< 6	< 7	< 44	< 14
	2/3/2016 - 02/24/16	< 6	< 6	< 11	< 5	< 11	< 6	< 12	< 6	< 6	< 34	< 9
	3/2/2016 - 03/30/16	< 8	< 7	< 16	< 8	< 15	< 8	< 15	< 7	< 7	< 49	< 15
	4/6/2016 - 04/27/16	< 6	< 6	< 11	< 5	< 10	< 7	< 12	< 6	< 6	< 47	< 15
	5/4/2016 - 05/25/16	< 4	< 6	< 10	< 3	< 8	< 5	< 10	< 4	< 5	< 54	< 18
	06/01/16 - 06/29/16	< 4	< 7	< 14	< 5	< 11	< 6	< 10	< 5	< 6	< 35	< 10
	07/06/16 - 07/27/16	< 2	< 2	< 6	< 2	< 4	< 3	< 5	< 2	< 2	< 31	< 9
	08/03/16 - 08/31/16	< 6	< 6	< 14	< 7	< 10	< 9	< 14	< 6	< 7	< 49	< 15
	09/07/16 - 09/28/16	< 6	< 8	< 19	< 6	< 15	< 8	< 15	< 7	< 7	< 45	< 14
	10/05/16 - 10/27/16	< 7	< 6	< 14	< 7	< 13	< 8	< 14	< 8	< 7	< 53	< 30
	11/03/16 - 11/30/16	< 7	< 7	< 20	< 8	< 20	< 9	< 14	< 9	< 9	< 41	< 15
	12/07/16 - 12/29/16	< 8	< 7	< 16	< 7	< 14	< 9	< 14	< 8	< 8	< 72	< 19
	MEAN	-	-	-	-	-	-	-	-	-	-	-
Z-18	01/06/16 - 01/27/16	< 6	< 3	< 20	< 6	< 15	< 10	< 14	< 6	< 7	< 55	< 17
	02/03/16 - 02/24/16	< 8	< 7	< 16	< 7	< 15	< 10	< 11	< 7	< 9	< 40	< 12
	03/02/16 - 03/30/16	< 2	< 2	< 5	< 2	< 4	< 3	< 4	< 2	< 2	< 16	< 5
	04/06/16 - 04/27/16	< 5	< 7	< 14	< 8	< 15	< 6	< 14	< 6	< 6	< 42	< 11
	05/04/16 - 05/25/16	< 2	< 3	< 6	< 2	< 5	< 3	< 5	< 2	< 2	< 27	< 9
	06/01/16 - 06/29/16	< 6	< 6	< 13	< 8	< 12	< 7	< 12	< 6	< 7	< 42	< 15
	07/06/16 - 07/27/16	< 2	< 2	< 5	< 2	< 4	< 2	< 4	< 2	< 2	< 25	< 8
	08/03/16 - 08/31/16	< 6	< 7	< 14	< 6	< 11	< 6	< 12	< 5	< 7	< 37	< 13
	09/07/16 - 09/28/16	< 7	< 9	< 16	< 7	< 11	< 8	< 13	< 7	< 8	< 49	< 12
	10/05/16 - 10/27/16	< 6	< 6	< 14	< 7	< 13	< 8	< 15	< 6	< 7	< 60	< 20
	11/03/16 - 11/30/16	< 7	< 7	< 16	< 7	< 16	< 8	< 14	< 8	< 8	< 50	< 17
	12/07/16 - 12/29/16	< 4	< 6	< 13	< 6	< 10	< 7	< 11	< 6	< 6	< 53	< 18
	MEAN	-	-	-	-	-	-	-	-	-	-	-

Table C-II.1

Concentrations of Gamma Emitters in Fish Samples Collected in the Vicinity of Zion Nuclear Power Station, 2016

Results in Units of pCi/kg Wet ± 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-26	(Predator)											
Northern Pike	05/24/16	< 43	< 37	< 101	< 36	< 101	< 34	< 68	< 45	< 50	< 236	< 65
White Sucker	05/24/16	< 53	< 45	< 125	< 47	< 111	< 55	< 85	< 52	< 50	< 229	< 51
Brown Trout	10/27/16	< 81	< 73	< 161	< 72	< 119	< 75	< 143	< 71	< 83	< 467	< 114
Common Carp	10/27/16	< 42	< 41	< 80	< 44	< 85	< 47	< 61	< 32	< 36	< 293	< 96
	MEAN	-	-	-	-	-	-	-	-	-	-	-
Z-27	(Predator)											
Burbot	05/13/16	< 39	< 41	< 108	< 34	< 82	< 44	< 61	< 35	< 46	< 347	< 103
Lake Trout	05/13/16	< 39	< 44	< 103	< 36	< 90	< 48	< 87	< 38	< 48	< 395	< 72
Burbot	10/26/16	< 72	< 76	< 174	< 68	< 153	< 78	< 139	< 67	< 69	< 510	< 173
Lake Trout	10/26/16	< 59	< 59	< 119	< 54	< 151	< 61	< 103	< 83	< 63	< 375	< 117
	MEAN	-	-	-	-	-	-	-	-	-	-	-

Table C-III.1 **Concentrations of Gamma Emitters in Sediment Samples Collected in the Vicinity of Zion Nuclear Power Station, 2016**

Results in Units of pCi/kg Dry + 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-25	05/12/16	< 37	< 30	< 85	< 29	< 83	< 40	< 65	< 32	< 31	< 211	< 46
	10/19/16	< 45	< 46	< 104	< 44	< 101	< 64	< 92	< 40	< 46	< 267	< 83
	MEAN	-	-	-	-	-	-	-	-	-	-	-

Table C-IV.1 **Concentrations of Gross Beta in Air Particulate Samples Collected in the Vicinity of Zion Nuclear Power Station, 2016**

Results in Units of E-3 pCi/cu meter ± 2 Sigma

COLLECTION PERIOD	GROUP I			GROUP II
	Z-01	Z-02	Z-03	Z-13
12/30/15 - 01/06/16	27 ± 5	25 ± 5	24 ± 5	25 ± 5
01/06/16 - 01/13/16	17 ± 4	15 ± 4	16 ± 4	19 ± 4
01/13/16 - 01/20/16	19 ± 4	20 ± 6	21 ± 4	17 ± 4
01/20/16 - 01/27/16	15 ± 4	11 ± 4	12 ± 4	15 ± 4
01/27/16 - 02/03/16	14 ± 4	13 ± 3	18 ± 4	14 ± 4
02/03/16 - 02/10/16	14 ± 4	11 ± 4	17 ± 4	15 ± 4
02/10/16 - 02/17/16	15 ± 4	12 ± 4	15 ± 4	19 ± 4
02/17/16 - 02/24/16	15 ± 4	11 ± 4	12 ± 4	14 ± 4
02/24/16 - 03/02/16	20 ± 4	13 ± 4	15 ± 4	16 ± 4
03/02/16 - 03/09/16	14 ± 4	10 ± 4	11 ± 4	12 ± 4
03/09/16 - 03/16/16	14 ± 4	9 ± 3	11 ± 3	14 ± 4
03/16/16 - 03/22/16	7 ± 4	6 ± 4	9 ± 4	7 ± 4
03/22/16 - 03/30/16	10 ± 3	8 ± 3	12 ± 3	9 ± 3
03/30/16 - 04/06/16	13 ± 4	11 ± 4	12 ± 4	16 ± 4
04/06/16 - 04/13/16	14 ± 4	10 ± 3	11 ± 4	13 ± 4
04/13/16 - 04/20/16	19 ± 4	12 ± 4	17 ± 4	17 ± 4
04/20/16 - 04/27/16	14 ± 4	14 ± 4	15 ± 4	15 ± 4
04/27/16 - 05/04/16	9 ± 3	9 ± 3	12 ± 4	14 ± 4
05/04/16 - 05/12/16	10 ± 3	7 ± 3	6 ± 3	8 ± 3
05/12/16 - 05/18/16	11 ± 4	7 ± 3	9 ± 4	11 ± 4
05/18/16 - 05/25/16	19 ± 4	16 ± 4	20 ± 5	17 ± 4
05/25/16 - 06/01/16	13 ± 4	10 ± 4	14 ± 4	11 ± 4
06/01/16 - 06/09/16	11 ± 3	9 ± 3	9 ± 3	9 ± 3
06/09/16 - 06/15/16	15 ± 4	10 ± 4	12 ± 4	11 ± 4
06/15/16 - 06/22/16	13 ± 4	10 ± 4	13 ± 4	15 ± 4
06/22/16 - 06/29/16	13 ± 4	11 ± 3	15 ± 4	15 ± 4
06/29/16 - 07/06/16	14 ± 4	12 ± 4	13 ± 4	13 ± 4
07/06/16 - 07/14/16	16 ± 3	13 ± 3	14 ± 3	15 ± 3
07/14/16 - 07/20/16	11 ± 4	8 ± 4	11 ± 4	11 ± 4
07/20/16 - 07/27/16	17 ± 4	12 ± 4	18 ± 4	16 ± 4
07/27/16 - 08/03/16	14 ± 4	11 ± 4	12 ± 4	15 ± 4
08/03/16 - 08/10/16	16 ± 4	15 ± 3	21 ± 4	19 ± 4
08/10/16 - 08/18/16	17 ± 4	14 ± 4	19 ± 4	18 ± 4
08/18/16 - 08/24/16	9 ± 4	7 ± 4	11 ± 5	7 ± 4
08/24/16 - 08/31/16	17 ± 4	15 ± 4	11 ± 4	14 ± 4
08/31/16 - 09/07/16	13 ± 4	13 ± 4	17 ± 4	12 ± 4
09/07/16 - 09/14/16	14 ± 4	13 ± 4	13 ± 4	14 ± 4
09/14/16 - 09/21/16	18 ± 4	14 ± 4	18 ± 4	19 ± 4
09/21/16 - 09/28/16	16 ± 4	14 ± 4	18 ± 4	21 ± 4
09/28/16 - 10/05/16	11 ± 4	8 ± 3	9 ± 3	13 ± 4
10/05/16 - 10/12/16	24 ± 5	18 ± 4	23 ± 5	23 ± 5
10/12/16 - 10/19/16	16 ± 4	10 ± 3	12 ± 4	16 ± 4
10/19/16 - 10/26/16	9 ± 3	< 6	< 6	7 ± 5
10/27/16 - 11/03/16	18 ± 4	17 ± 4	17 ± 4	19 ± 4
11/03/16 - 11/09/16	24 ± 5	22 ± 5	30 ± 6	35 ± 6
11/09/16 - 11/16/16	17 ± 4	19 ± 4	20 ± 4	27 ± 5
11/16/16 - 11/23/16	18 ± 4	18 ± 5	19 ± 4	20 ± 5
11/23/16 - 11/30/16	25 ± 5	18 ± 4	22 ± 4	25 ± 5
11/30/16 - 12/07/16	13 ± 4	16 ± 4	15 ± 4	15 ± 4
12/07/16 - 12/14/16	18 ± 4	14 ± 4	22 ± 4	19 ± 4
12/14/16 - 12/20/16	20 ± 5	18 ± 4	17 ± 5	18 ± 5
12/20/16 - 12/29/16	20 ± 4	16 ± 3	18 ± 4	17 ± 3
MEAN ± 2 STD DEV	15 ± 8	13 ± 8	15 ± 9	16 ± 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, 2016

Results in Units of E-3 pCi/cu meter ± 2 Sigma

GROUP I - ONSITE LOCATIONS				GROUP II - OFFSITE CONTROL LOCATION			
COLLECTION PERIOD	MIN	MAX	MEAN ± 2SD	COLLECTION PERIOD	MIN	MAX	MEAN ± 2SD
12/30/15 - 02/03/16	11	27	18 ± 10	12/30/15 - 02/03/16	14	25	18 ± 8
02/03/16 - 03/02/16	11	20	14 ± 5	02/03/16 - 03/02/16	14	19	16 ± 4
03/02/16 - 03/30/16	6	14	10 ± 5	03/02/16 - 03/30/16	7	14	10 ± 6
03/30/16 - 05/04/16	9	19	13 ± 6	03/30/16 - 05/04/16	13	17	15 ± 4
05/04/16 - 06/01/16	6	20	12 ± 9	05/04/16 - 06/01/16	8	17	12 ± 8
06/01/16 - 06/29/16	9	15	12 ± 4	06/01/16 - 06/29/16	9	15	13 ± 6
06/29/16 - 08/03/16	8	18	13 ± 5	06/29/16 - 08/03/16	11	16	14 ± 4
08/03/16 - 08/31/16	7	21	14 ± 8	08/03/16 - 08/31/16	7	19	14 ± 10
08/31/16 - 09/28/16	13	18	15 ± 5	08/31/16 - 09/28/16	12	21	16 ± 9
09/28/16 - 11/03/16	8	24	15 ± 11	09/28/16 - 11/03/16	7	23	16 ± 12
11/03/16 - 11/30/16	17	30	21 ± 7	11/03/16 - 11/30/16	20	35	27 ± 13
11/30/16 - 12/29/16	13	22	17 ± 5	11/30/16 - 12/29/16	15	19	17 ± 3
12/30/15 - 12/29/16	6	30	14 ± 9	12/30/15 - 12/29/16	7	35	16 ± 11

Table C-IV.3

Concentrations of Gamma Emitters in Air Particulate Samples Collected in the Vicinity of Zion Nuclear Power Station, 2016

Results in Units of E-3 pCi/cu 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	12/30/15 - 03/30/16	< 3	< 4	< 10	< 3	< 6	< 3	< 5	< 3	< 3	< 70	< 16
	03/30/16 - 06/29/16	< 2	< 2	< 6	< 2	< 4	< 3	< 4	< 2	< 2	< 35	< 16
	06/29/16 - 09/28/16	< 2	< 2	< 7	< 3	< 7	< 3	< 3	< 2	< 2	< 49	< 15
	09/28/16 - 12/29/16	< 2	< 1	< 4	< 2	< 4	< 2	< 3	< 2	< 2	< 8	< 3
	MEAN	-	-	-	-	-	-	-	-	-	-	-
Z-02	12/30/15 - 03/30/16	< 3	< 3	< 8	< 2	< 7	< 3	< 6	< 3	< 2	< 59	< 18
	03/30/16 - 06/29/16	< 2	< 2	< 7	< 2	< 5	< 2	< 3	< 2	< 2	< 49	< 22
	06/29/16 - 09/28/16	< 2	< 3	< 7	< 3	< 4	< 3	< 5	< 3	< 2	< 50	< 27
	09/28/16 - 12/29/16	< 3	< 4	< 11	< 4	< 7	< 4	< 7	< 3	< 3	< 14	< 6
	MEAN	-	-	-	-	-	-	-	-	-	-	-
Z-03	12/30/15 - 03/30/16	< 4	< 5	< 10	< 3	< 10	< 5	< 8	< 5	< 3	< 86	< 32
	03/30/16 - 06/29/16	< 3	< 4	< 9	< 3	< 7	< 3	< 7	< 3	< 3	< 47	< 26
	06/29/16 - 09/28/16	< 3	< 4	< 9	< 3	< 8	< 4	< 7	< 4	< 3	< 72	< 17
	09/28/16 - 12/29/16	< 2	< 2	< 4	< 3	< 5	< 2	< 4	< 2	< 2	< 9	< 4
	MEAN	-	-	-	-	-	-	-	-	-	-	-
Z-13	12/30/15 - 03/30/16	< 2	< 3	< 9	< 2	< 6	< 3	< 5	< 2	< 2	< 58	< 20
	03/30/16 - 06/29/16	< 5	< 5	< 12	< 4	< 8	< 6	< 7	< 3	< 3	< 83	< 37
	06/29/16 - 09/28/16	< 2	< 3	< 9	< 3	< 8	< 3	< 5	< 3	< 3	< 63	< 25
	09/28/16 - 12/29/16	< 2	< 2	< 5	< 3	< 5	< 2	< 5	< 3	< 2	< 12	< 4
	MEAN	-	-	-	-	-	-	-	-	-	-	-

Table C-V.1

CONCENTRATIONS OF GAMMA EMITTERS IN VEGETATION SAMPLES COLLECTED IN THE VICINITY OF ZION NUCLEAR POWER STATION, 2016

RESULTS IN UNITS OF PC/KG WET + 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-CONTROL												
Carrots	09/01/16	< 15	< 17	< 37	< 19	< 39	< 19	< 29	< 14	< 15	< 112	< 38
Potatoes	09/01/16	< 18	< 14	< 35	< 18	< 41	< 16	< 33	< 15	< 16	< 107	< 25
Cabbage	09/08/16	< 16	< 16	< 41	< 15	< 41	< 17	< 36	< 16	< 19	< 102	< 19
	MEAN	-	-	-	-	-	-	-	-	-	-	-
Z-QUAD 3												
Cabbage	09/01/16	< 14	< 14	< 33	< 13	< 32	< 16	< 25	< 13	< 12	< 92	< 24
Potatoes	09/01/16	< 10	< 11	< 25	< 8	< 26	< 14	< 22	< 10	< 10	< 77	< 19
	MEAN	-	-	-	-	-	-	-	-	-	-	-
Z-QUAD 4												
Cabbage	09/01/16	< 20	< 21	< 40	< 25	< 36	< 25	< 35	< 15	< 17	< 137	< 45
Potatoes	09/01/16	< 18	< 18	< 40	< 15	< 46	< 21	< 30	< 24	< 17	< 108	< 32
	MEAN	-	-	-	-	-	-	-	-	-	-	-

Table C-VI.1 **Quarterly TLD Results for Zion Nuclear Power Station, 2016**

Results in Units of Milli-Roentgen/Quarter ± 2 Standard Deviations

STATION CODE	MEAN ± 2 S.D.	JAN - MAR	APR - JUN	JUL - SEP	OCT - DEC
Z-01	29 ± 12	36	30	25	23
Z-02	18 ± 7	22	18	17	14
Z-03	18 ± 4	18	20	17	15
Z-13	19 ± 3	19	19	20	17
Z-101	17 ± 5	18	20	16	14
Z-102	19 ± 5	21	19	19	15
Z-103	16 ± 4	18	18	15	14
Z-104	16 ± 2	17	17	16	15
Z-105	18 ± 4	20	19	18	15
Z-106	18 ± 5	20	20	17	15
Z-107	18 ± 6	22	19	16	15
Z-108	21 ± 3	22	21	20	19
Z-109	33 ± 23	48	35	29	20
Z-112	18 ± 3	19	19	18	16
Z-113	17 ± 4	17	18	18	14
Z-114	17 ± 3	17	19	17	15
Z-115	18 ± 3	17	19	19	16
Z-121	16 ± 5	17	19	15	13
Z-124	18 ± 4	18	19	19	15
Z-125	19 ± 3	20	19	19	17
Z-129	16 ± 5	17	19	14	14
Z-130	20 ± 5	22	22	19	17
Z-131	42 ± 20	48	50	40	28
Z-209	18 ± 5	18	17	21	15
Z-211	21 ± 4	24	20	21	19
Z-212	22 ± 5	23	25	21	19
Z-213	23 ± 6	25	23	24	18
Z-214	19 ± 3	19	19	21	17
Z-215	22 ± 4	23	23	23	19
Z-216	18 ± 3	18	20	19	16

Table C-VI.2 MEAN QUARTERLY TLD RESULTS FOR INNER RING, OUTER RING, SPECIAL INTEREST, AND CONTROL STATIONS FOR ZION NUCLEAR POWER STATION, 2016

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

COLLECTION PERIOD	INNER RING ± 2 S.D.	OUTER RING	OTHER	CONTROL
JAN-MAR	23 ± 19	20 ± 5	17 ± 2	18 ± 2
APR-JUN	22 ± 14	21 ± 5	19 ± 2	19 ± 2
JUL-SEP	20 ± 12	22 ± 5	18 ± 3	20 ± 2
OCT-DEC	17 ± 8	18 ± 3	15 ± 2	16 ± 2

Table C-VI.3 SUMMARY OF THE AMBIENT DOSIMETRY PROGRAM FOR ZION NUCLEAR POWER STATION, 2016

RESULTS IN UNITS OF MILLI-ROENTGEN/QUARTER

LOCATION	SAMPLES ANALYZED	PERIOD MINIMUM	PERIOD MAXIMUM	PERIOD MEAN ± 2 S.D.
INNER RING	144	13	50	20 ± 15
OUTER RING	56	15	25	20 ± 5
SPECIAL INTEREST	32	14	21	17 ± 4
CONTROL	24	15	21	18 ± 4

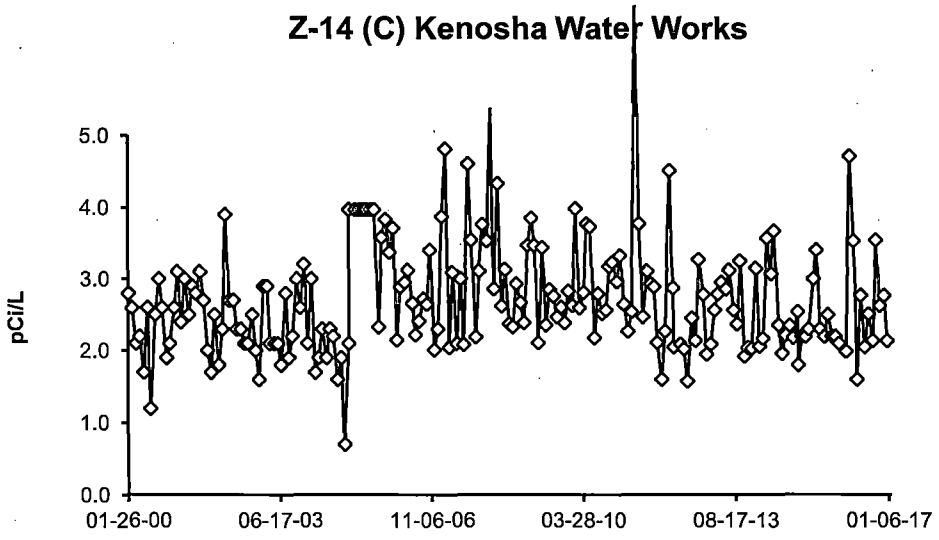
INNER RING STATIONS - Z-01, Z-02, Z-03, Z-101, Z-102-1, Z-103-1, Z-104, Z-105, Z-106, Z-107, Z-108, Z-109, Z-121, Z-124, Z-125, Z-129, Z130, Z-131

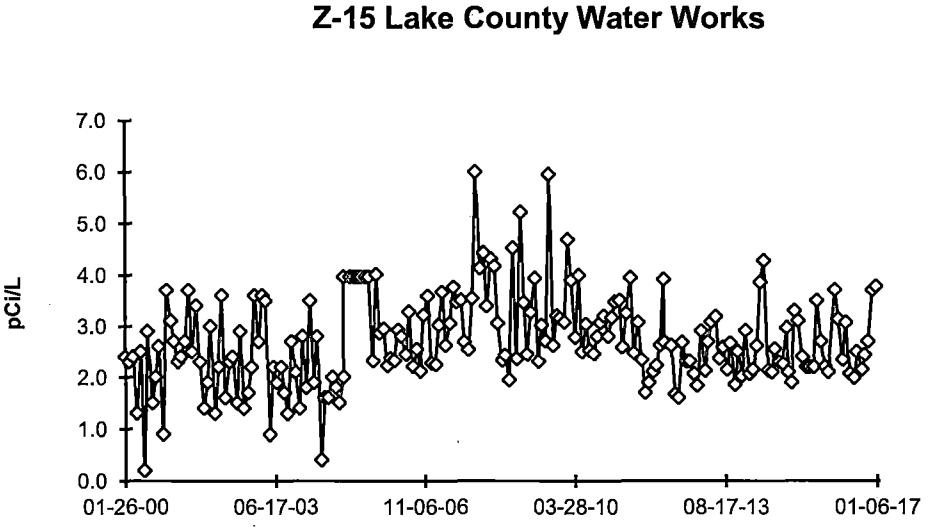
SPECIAL INTEREST STATIONS - Z-112, Z-113, Z-114, Z-115

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

CONTROL STATION - Z-13

FIGURE C-1
PUBLIC WATER - GROSS BETA - STATIONS Z-14 AND Z-15 COLLECTED IN THE VICINITY OF ZNPS, 2000 - 2016

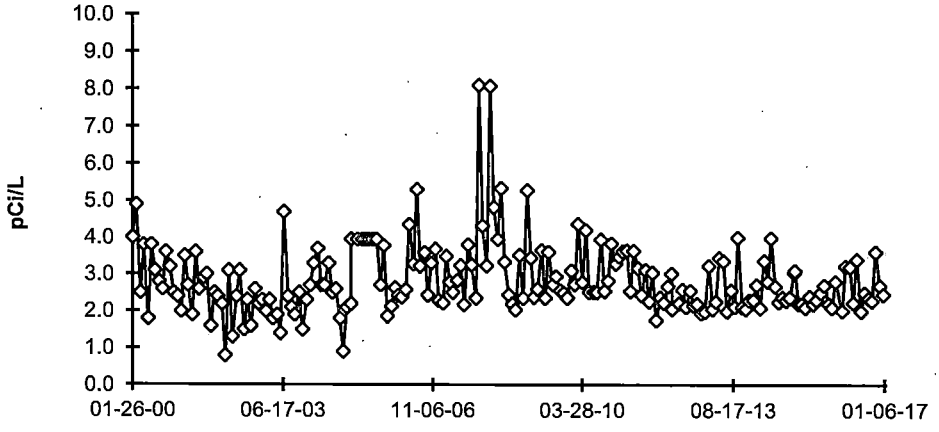




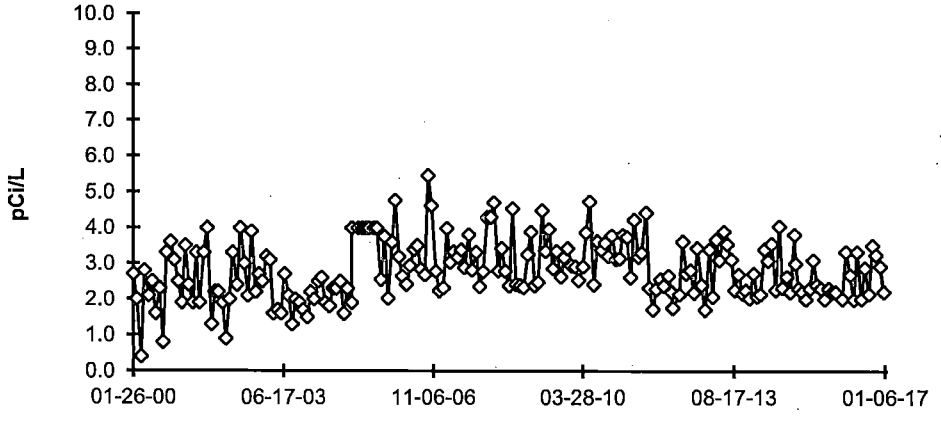
DUE TO VENDOR CHANGE IN 2005, < VALUES ARE LLD VALUES JANUARY THROUGH JUNE 2005 AND MDC VALUES AFTER JUNE 2005

FIGURE C-2
PUBLIC WATER - GROSS BETA - STATIONS Z-16 AND Z-18 COLLECTED IN THE VICINITY OF ZNPS, 2000 - 2016

Z-16 Waukegan Water Works



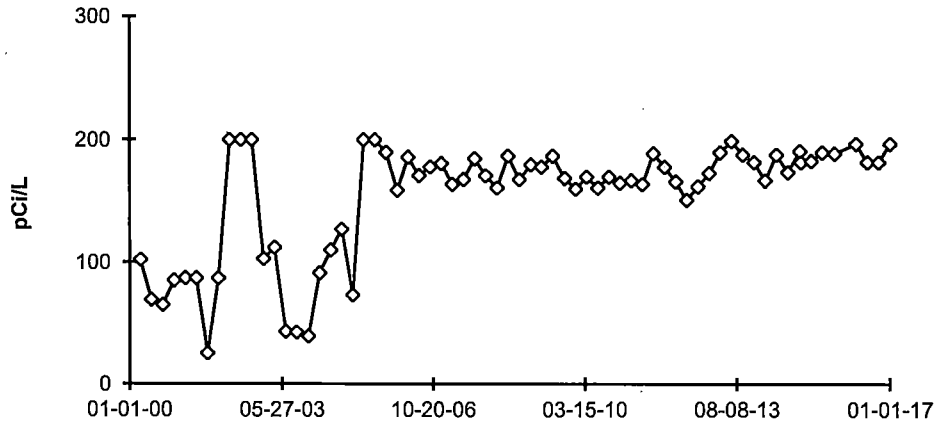
Z-18 (C) Lake Forest Water Works



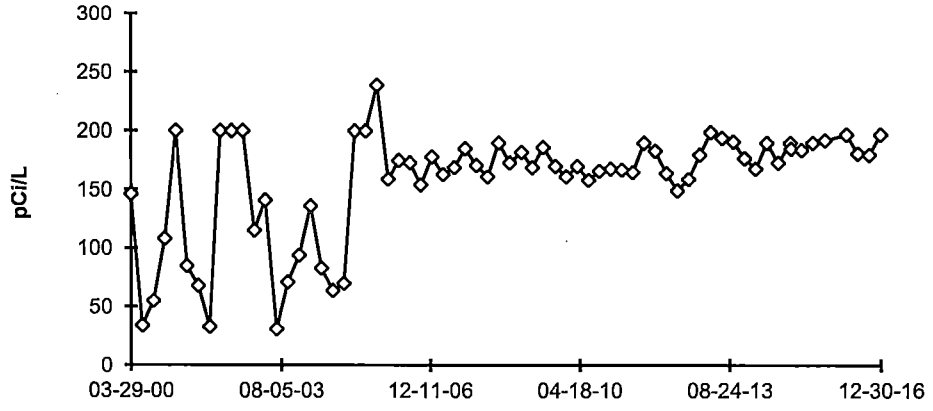
DUE TO VENDOR CHANGE IN 2005, < VALUES ARE LLD VALUES JANUARY THROUGH JUNE 2005 AND MDC VALUES AFTER JUNE 2005

FIGURE C-3
PUBLIC WATER - TRITIUM - STATION Z-14 AND Z-15 COLLECTED IN THE VICINITY OF ZNPS, 2000 - 2016

Z-14 (C) Kenosha Water Works



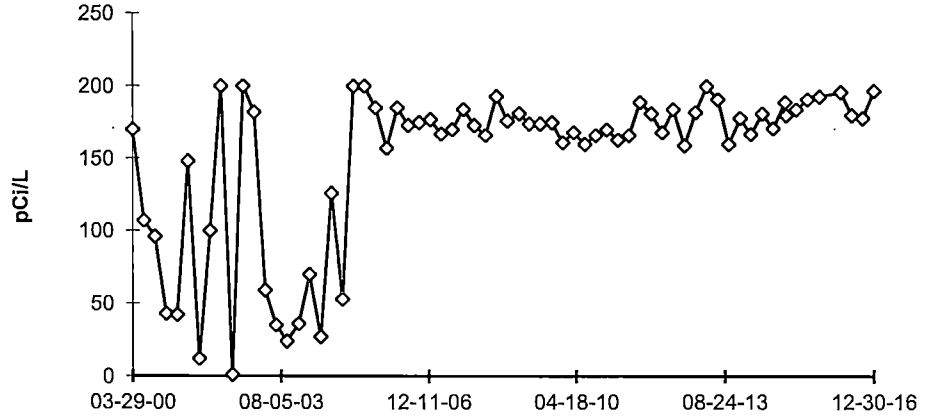
Z-15 Lake County Water Works



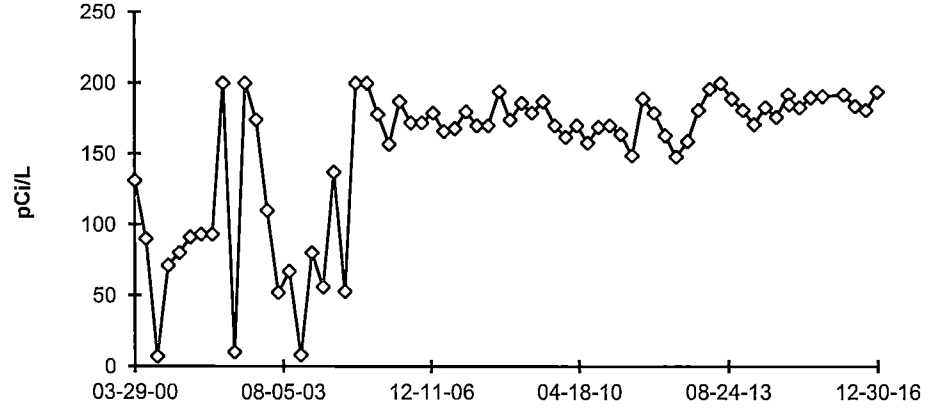
DUE TO VENDOR CHANGE IN 2005, < VALUES ARE LLD VALUES JANUARY THROUGH JUNE 2005 AND MDC VALUES AFTER JUNE 2005

FIGURE C-4
PUBLIC WATER - TRITIUM - STATION Z-16 AND Z-18 COLLECTED IN THE VICINITY OF ZNPS, 2000 - 2016

Z-16 Waukegan Water Works



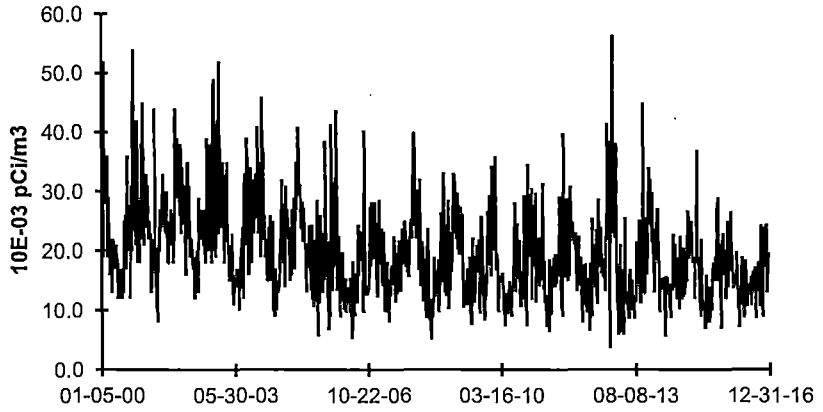
Z-18 (C) Lake Forest Water Works



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 - 2016

Z-01 Onsite No. 1, Southside



Z-02 Onsite No. 2, Westside

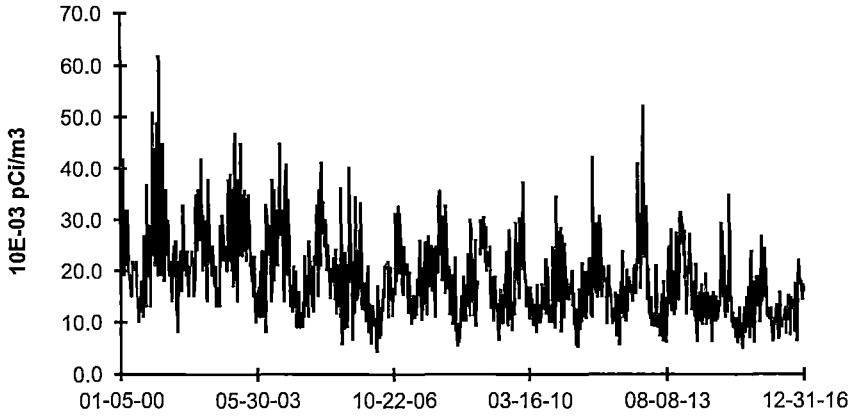
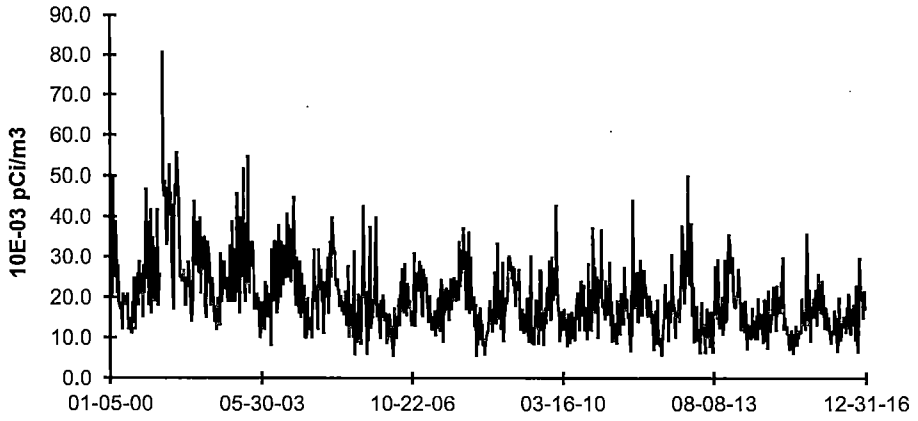


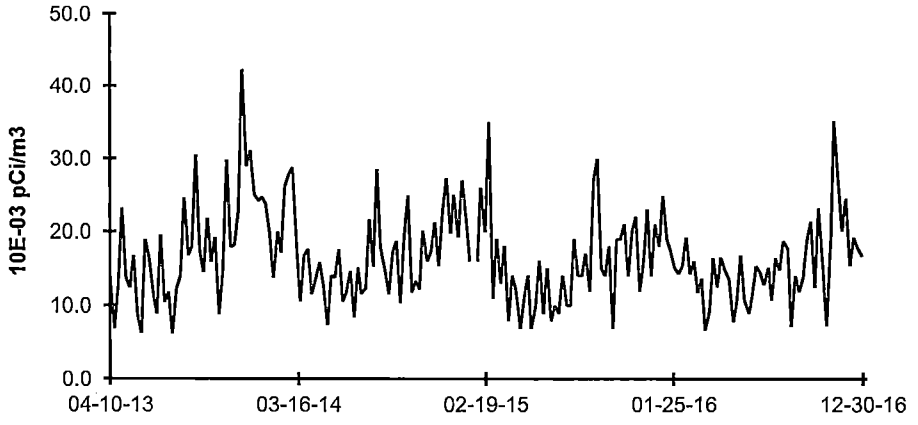
FIGURE C-6
AIR PARTICULATES - GROSS BETA - STATIONS Z-03 COLLECTED IN THE VICINITY OF ZNPS, 2000 - 2016

Z-03 Onsite No. 3, Northside



AIR PARTICULATES - GROSS BETA - STATION Z-13 COLLECTED IN THE VICINITY OF ZNPS, 2013 - 2016

Z-13 Offsite Control



APPENDIX D

INTER-LABORATORY COMPARISON PROGRAM

TABLE D-1

ANALYTICS ENVIRONMENTAL RADIOACTIVITY CROSS CHECK PROGRAM
TELEDYNE BROWN ENGINEERING ENVIRONMENTAL SERVICES

Month/Year	Identification Number	Matrix	Nuclide	Units	Reported Value (a)	Known Value (b)	Ratio (c) TBE/Analytics	Evaluation (d)
March 2016	E11476	Milk	Sr-89	pCi/L	97	86.7	1.12	A
			Sr-90	pCi/L	15	11.4	1.32	N(2)
	E11477	Milk	I-131	pCi/L	85.9	82.2	1.05	A
			Ce-141	pCi/L	106	98.4	1.08	A
			Cr-51	pCi/L	255	243	1.05	A
			Cs-134	pCi/L	134	130	1.03	A
			Cs-137	pCi/L	174	161	1.08	A
			Co-58	pCi/L	123	117	1.05	A
			Mn-54	pCi/L	141	117	1.21	W
			Fe-59	pCi/L	152	131	1.16	A
			Zn-65	pCi/L	193	179	1.08	A
			Co-60	pCi/L	259	244	1.06	A
	E11479	AP	Ce-141	pCi	69	81.1	0.85	A
			Cr-51	pCi	242	201	1.20	W
			Cs-134	pCi	98.1	107.0	0.92	A
			Cs-137	pCi	136	133	1.02	A
			Co-58	pCi	91.9	97	0.95	A
			Mn-54	pCi	98.6	96.2	1.02	A
			Fe-59	pCi	98.8	108	0.91	A
			Zn-65	pCi	131	147	0.89	A
			Co-60	pCi	209	201	1.04	A
	E11478	Charcoal	I-131	pCi	85.3	88.3	0.97	A
	E11480	Water	Fe-55	pCi/L	1800	1666	1.08	A
June 2016	E11537	Milk	Sr-89	pCi/L	94.4	94.4	1.00	A
			Sr-90	pCi/L	13.4	15.4	0.87	A
	E11538	Milk	I-131	pCi/L	96.8	94.5	1.02	A
			Ce-141	pCi/L	129	139	0.93	A
			Cr-51	pCi/L	240	276	0.87	A
			Cs-134	pCi/L	157	174	0.90	A
			Cs-137	pCi/L	117	120	0.98	A
			Co-58	pCi/L	131	142	0.92	A
			Mn-54	pCi/L	128	125	1.02	A
			Fe-59	pCi/L	132	122	1.08	A
			Zn-65	pCi/L	235	235	1.00	A
			Co-60	pCi/L	169	173	0.98	A
June 2016	E11539	Charcoal	I-131	pCi	86.1	89.4	0.96	A
	E11540	AP	Ce-141	pCi	105	99.8	1.05	A
			Cr-51	pCi	216	198.0	1.09	A
			Cs-134	pCi	113	125	0.90	A
			Cs-137	pCi	94.5	86.6	1.09	A
			Co-58	pCi	101	102	0.99	A
			Mn-54	pCi	88.8	90.2	0.98	A
			Fe-59	pCi	82	87.5	0.94	A
			Zn-65	pCi	174	169	1.03	A
			Co-60	pCi	143	124	1.15	A
	E11541	Water	Fe-55	pCi/L	164	186	0.88	A

TABLE D-1 **ANALYTICS ENVIRONMENTAL RADIOACTIVITY CROSS CHECK PROGRAM**
TELEDYNE BROWN ENGINEERING ENVIRONMENTAL SERVICES
(PAGE 2 OF 3)

Month/Year	Identification Number	Matrix	Nuclide	Units	Reported Value (a)	Known Value (b)	Ratio (c) TBE/Analytics	Evaluation (d)
September 2016	E11609	Milk	Sr-89	pCi/L	90	90.9	0.99	A
			Sr-90	pCi/L	13.3	13.7	0.97	A
	E11610	Milk	I-131	pCi/L	80.4	71.9	1.12	A
			Ce-141	pCi/L	81.3	93	0.87	A
			Cr-51	pCi/L	198	236	0.84	A
			Cs-134	pCi/L	122	136	0.90	A
			Cs-137	pCi/L	119	119	1.00	A
			Co-58	pCi/L	92.2	97.4	0.95	A
			Mn-54	pCi/L	156	152	1.03	A
			Fe-59	pCi/L	97.5	90.6	1.08	A
			Zn-65	pCi/L	189	179	1.06	A
			Co-60	pCi/L	131	135	0.97	A
	E11611	Charcoal	I-131	pCi	52.4	59.9	0.87	A
	E11612	AP	Ce-141	pCi	67.5	63.6	1.06	A
			Cr-51	pCi	192	161.0	1.19	A
			Cs-134	pCi	91.4	92.6	0.99	A
			Cs-137	pCi	93.9	80.8	1.16	A
			Co-58	pCi	66	66.4	0.99	A
			Mn-54	pCi	104	104	1.00	A
			Fe-59	pCi	60.5	61.8	0.98	A
			Zn-65	pCi	140	122	1.15	A
			Co-60	pCi	119	91.9	1.29	W
	E11613	Water	Fe-55	pCi/L	1990	1670	1.19	A
	E11614	Soil	Ce-141	pCi/g	0.153	0.175	0.87	A
			Cr-51	pCi/g	0.482	0.441	1.09	A
			Cs-134	pCi/g	0.270	0.254	1.06	A
			Cs-137	pCi/g	0.313	0.299	1.05	A
			Co-58	pCi/g	0.177	0.182	0.97	A
			Mn-54	pCi/g	0.340	0.285	1.19	A
			Fe-59	pCi/g	0.206	0.17	1.21	W
			Zn-65	pCi/g	0.388	0.335	1.16	A
			Co-60	pCi/g	0.284	0.252	1.13	A
December 2016	E11699	Milk	Sr-89	pCi/L	95	74.2	1.28	W
			Sr-90	pCi/L	14.7	10	1.47	N(3)
	E11700	Milk	I-131	pCi/L	97.5	97.4	1.00	A
			Ce-141	pCi/L	136	143	0.95	A
			Cr-51	pCi/L	247	280	0.88	A
			Cs-134	pCi/L	164	178	0.92	A
			Cs-137	pCi/L	120	126	0.95	A
			Co-58	pCi/L	139	146	0.95	A
			Mn-54	pCi/L	126	129	0.98	A
			Fe-59	pCi/L	114	125	0.91	A
			Zn-65	pCi/L	237	244	0.97	A
			Co-60	pCi/L	168	178	0.94	A
	E11701	Charcoal	I-131	pCi	95.6	98	0.98	A

TABLE D-1 **ANALYTICS ENVIRONMENTAL RADIOACTIVITY CROSS CHECK PROGRAM**
TELEDYNE BROWN ENGINEERING ENVIRONMENTAL SERVICES
(PAGE 3 OF 3)

Month/Year	Identification Number	Matrix	Nuclide	Units	Reported Value (a)	Known Value (b)	Ratio (c) TBE/Analytics	Evaluation (d)
December 2016	E11702	AP	Ce-141	pCi	91.7	97.7	0.94	A
			Cr-51	pCi	210	192.0	1.09	A
			Cs-134	pCi	122	122	1.00	A
			Cs-137	pCi	93.9	86.4	1.09	A
			Co-58	pCi	92	100	0.92	A
			Mn-54	pCi	93.7	88.5	1.06	A
			Fe-59	pCi	84.9	84.5	1.00	A
			Zn-65	pCi	176	167	1.05	A
			Co-60	pCi	151	122	1.24	W
	E11702	AP	Sr-89	pCi	79.1	92	0.86	A
			Sr-90	pCi	10	12.5	0.80	A
	E11703	Water	Fe-55	pCi/L	2180	1800	1.21	W

(a) Teledyne Brown Engineering reported result.

(b) 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.

(c) Ratio of Teledyne Brown Engineering to Analytics results.

(d) 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.

(2) NCR 16-26 was initiated

(3) NCR 16-35 was initiated

TABLE D-2 **DOE's MIXED ANALYTE PERFORMANCE EVALUATION PROGRAM (MAPEP)**
TELEDYNE BROWN ENGINEERING ENVIRONMENTAL SERVICES

Month/Year	Identification Number	Media	Nuclide	Units	Reported Value (a)	Known Value (b)	Acceptance Range	Evaluation (c)
March 2016	16-MaW34	Water	Am-241	Bq/L	0.008		(1)	A
			Ni-63	Bq/L	12.4	12.3	8.6-16.0	A
			Pu-238	Bq/L	1.4900	1.2440	0.871-1.617	A
			Pu-239/240	Bq/L	0.729	0.641	0.449-0.833	A
	16-MaS34	Soil	Ni-63	Bq/kg	1140	1250.0	875-1625	A
			Sr-90	Bq/kg	8.15		(1)	A
	16-RdF34	AP	U-234/233	Bq/sample	0.1620	0.1650	0.116-0.215	A
			U-238	Bq/sample	0.163	0.172	0.120-0.224	A
	16-GrF34	AP	Gr-A	Bq/sample	0.608	1.20	0.36-2.04	A
			Gr-B	Bq/sample	0.8060	0.79	0.40-1.19	A
	16-RdV34	Vegetation	Cs-134	Bq/sample	10.10	10.62	7.43-13.81	A
			Cs-137	Bq/sample	6.0	5.62	3.93-7.31	A
			Co-57	Bq/sample	13.3000	11.8	8.3-15.3	A
			Co-60	Bq/sample	0.013		(1)	A
			Mn-54	Bq/sample	0.0150		(1)	A
			Sr-90	Bq/sample	0.301		(1)	N(4)
			Zn-65	Bq/sample	10.500	9.6	6.7-12.5	A
September 2016	16-MaW35	Water	Am-241	Bq/L	0.626	0.814	.570-1058	W
			Ni-63	Bq/L	12.4	17.2	12.0-22.4	A
			Pu-238	Bq/L	1.23	1.13	0.79-1.47	W
			Pu-239/240	Bq/L	0.0318	0.013	(1)	A
	16-MaS35	Soil	Ni-63	Bq/kg	724	990	693-1287	A
			Sr-90	Bq/kg	747	894	626-1162	A
	16-RdF35	AP	U-234/233	Bq/sample	0.160	0.15	0.105-0.195	A
			U-238	Bq/sample	0.157	0.156	0.109-0.203	A
	16-RdV35	Vegetation	Cs-134	Bq/sample	-0.103		(1)	A
			Cs-137	Bq/sample	5.64	5.54	3.88-7.20	A
			Co-57	Bq/sample	7.38	6.81	4.77-8.85	A
			Co-60	Bq/sample	4.81	4.86	3.40-6.32	A
			Mn-54	Bq/sample	7.4	7.27	5.09-9.45	A
			Sr-90	Bq/sample	0.774	0.80	0.56-1.04	A
			Zn-65	Bq/sample	5.46	5.4	3.78-7.02	A

(1) False positive test.

(a) Teledyne Brown Engineering reported result.

(b) 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.

(c) DOE/MAPEP evaluation: A=acceptable, W=acceptable with warning, N=not acceptable.

(4)NCR 16-14 was initiated

TABLE D-3

ERA ENVIRONMENTAL RADIOACTIVITY CROSS CHECK PROGRAM
TELEDYNE BROWN ENGINEERING ENVIRONMENTAL SERVICES
(PAGE 1 OF 1)

Month/Year	Identification Number	Media	Nuclide	Units	Reported Value (a)	Known Value (b)	Acceptance Limits	Evaluation (c)
May 2016	RAD-105	Water	Sr-89	pCi/L	48.9	48.2	37.8 - 55.6	A
			Sr-90	pCi/L	25.0	28.5	20.7 - 33.1	A
			Ba-133	pCi/L	53.1	58.8	48.7 - 64.9	A
			Cs-134	pCi/L	40.9	43.3	34.6 - 47.6	A
			Cs-137	pCi/L	84.8	78.4	70.6 - 88.9	A
			Co-60	pCi/L	108	102	91.8 - 114	A
			Zn-65	pCi/L	226	214	193 - 251	A
			Gr-A	pCi/L	38.9	62.7	32.9 - 77.8	A
			Gr-B	pCi/L	41.9	39.2	26.0 - 46.7	A
			I-131	pCi/L	24.1	26.6	22.1 - 31.3	A
			U-Nat	pCi/L	4.68	4.64	3.39 - 5.68	A
			H-3	pCi/L	7720	7840	6790 - 8620	A
November 2016	RAD-107	Water	Sr-89	pCi/L	43.0	43.3	33.4-50.5	A
			Sr-90	pCi/L	30.0	33.6	24.6-38.8	A
			Ba-133	pCi/L	47.8	54.9	45.4-60.7	A
			Cs-134	pCi/L	72.9	81.8	67.0-90.0	A
			Cs-137	pCi/L	189	210	189-233	A
			Co-60	pCi/L	58.4	64.5	58.0-73.4	A
			Zn-65	pCi/L	243	245	220-287	A
			Gr-A	pCi/L	37.2	68.4	35.9-84.5	A
			Gr-B	pCi/L	35.1	33.9	22.1-41.6	A
			I-131	pCi/L	23.5	26.3	21.9-31.0	A
			U-Nat	pCi/L	49.2	51.2	41.6-56.9	A
			H-3	pCi/L	918	9820	8540-10800	N(5)
	MRAD-25	AP	Gr-A	pCi/Filter	56.8	71.2	23.9-111	A

(a) Teledyne Brown Engineering reported result.

(b) 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.

(c) ERA evaluation: A=acceptable. Reported result falls within the Warning Limits. N=not acceptable. Reported result falls outside of the Control Limits. CE=check for Error. Reported result falls within the Control Limits and outside of the Warning Limit.

(5) NCR 16-34 was initiated

TABLE D-4 **ERA STATISTICAL SUMMARY PROFICIENCY TESTING PROGRAM[a]**

MRAD Study, ENVIRONMENTAL, INC., 2016

			Concentration [a]			
Lab Code [b]	Date	Analysis	Laboratory Result	ERA Result	Control Limits	Acceptance
ERAP-1101	3/14/2016	Am-241	37.3	45.9	28.3 - 62.1	Pass
ERAP-1101	3/14/2016	Co-60	637	623	482 - 778	Pass
ERAP-1101	3/14/2016	Cs-134	251	304	193 - 377	Pass
ERAP-1101	3/14/2016	Cs-137	1,273	1,150	864 - 1,510	Pass
ERAP-1101	3/14/2016	Fe-55	< 162	126	39.1 - 246	Pass
ERAP-1101	3/14/2016	Mn-54	< 2.64	< 50.0	0.00 - 50.0	Pass
ERAP-1101	3/14/2016	Pu-238	68.0	70.5	48.3 - 92.7	Pass
ERAP-1101	3/14/2016	Pu-239/240	54.1	54.8	39.70 - 71.60	Pass
ERAP-1101	3/14/2016	Sr-90	139	150	73.3 - 225.0	Pass
ERAP-1101	3/14/2016	U-233/234	59.3	64.8	40.2 - 97.7	Pass
ERAP-1101	3/14/2016	U-238	55.5	64.2	41.5 - 88.8	Pass
ERAP-1101	3/14/2016	Zn-65	428	356	255 - 492	Pass
ERAP-1101	3/14/2016	Gr. Alpha	98.0	70.1	23.5 - 109	Pass
ERAP-1101	3/14/2016	Gr. Beta	78.6	54.4	34.4 - 79.3	Pass
ERSO-1105	3/14/2016	Am-241	1,030	1,360	796 - 1,770	Pass
ERSO-1105	3/14/2016	Ac-228	1,540	1,240	795 - 1,720	Pass
ERSO-1105	3/14/2016	Bi-212	1,550	1,240	330 - 1,820	Pass
ERSO-1105	3/14/2016	Bi-214	3,100	3,530	2,130 - 5,080	Pass
ERSO-1105	3/14/2016	Co-60	5,600	5,490	3,710 - 7,560	Pass
ERSO-1105	3/14/2016	Cs-134	3,030	3,450	2,260 - 4,140	Pass
ERSO-1105	3/14/2016	Cs-137	4,440	4,310	3,300 - 5,550	Pass
ERSO-1105	3/14/2016	K-40	10,300	10,600	7,740 - 14,200	Pass
ERSO-1105	3/14/2016	Mn-54	< 50.8	< 1000	0.0 - 1,000	Pass
ERSO-1105	3/14/2016	Pb-212	1,140	1,240	812 - 1,730	Pass
ERSO-1105	3/14/2016	Pb-214	3,190	3,710	2,170 - 5,530	Pass
ERSO-1105	3/14/2016	Pu-238	680	658	396 - 908	Pass
ERSO-1105	3/14/2016	Pu-239/240	460	496	324 - 0,685	Pass
ERSO-1105	3/14/2016	Sr-90	7,740	8,560	3,260 - 13,500	Pass
ERSO-1105	3/14/2016	Th-234	3,630	3,430	1,080 - 6,450	Pass
ERSO-1105	3/14/2016	U-233/234	3,090	3,460	2,110 - 4,430	Pass
ERSO-1105	3/14/2016	U-238	3,280	3,430	2,120 - 4,350	Pass
ERSO-1105	3/14/2016	Zn-65	2,940	2,450	1,950 - 3,260	Pass
ERW-1115	3/14/2016	Gr. Alpha	105.0	117.0	41.5 - 181.0	Pass
ERW-1115	3/14/2016	Gr. Beta	76.2	75.5	43.2 - 112.0	Pass
ERW-1117	3/14/2016	H-3	8,870	8,650	5,800 - 12,300	Pass
ERVE-1108	3/14/2016	Am-241	1,930	2,120	1,300 - 2,820	Pass
ERVE-1108	3/14/2016	Cm-244	1,294	1,560	764 - 2,430	Pass
ERVE-1108	3/14/2016	Co-60	1,164	1,100	759 - 1,540	Pass
ERVE-1108	3/14/2016	Cs-134	1,056	1,070	687 - 1,390	Pass
ERVE-1108	3/14/2016	Cs-137	930	838	608 - 1,170	Pass
ERVE-1108	3/14/2016	K-40	32,200	31,000	22,400 - 43,500	Pass
ERVE-1108	3/14/2016	Mn-54	< 24.5	< 300	0.00 - 300	Pass
ERVE-1108	3/14/2016	Zn-65	3,320	2,820	2,030 - 3,960	Pass

TABLE D-4 **ERA STATISTICAL SUMMARY PROFICIENCY TESTING PROGRAM[a]**

MRAD Study, ENVIRONMENTAL, INC., 2016

			Concentration [a]			
Lab Code [b]	Date	Analysis	Laboratory Result	ERA Result	Control Limits	Acceptance
ERVE-1108	3/14/2016	Pu-238	3,410	2,810	1,680 - 3,850	Pass
ERVE-1108	3/14/2016	Pu-239/240	4,120	3,640	2,230 - 5,010	Pass
ERVE-1108	3/14/2016	Sr-90	8,120	8,710	4,960 - 11,500	Pass
ERVE-1108	3/14/2016	U-233/234	4,350	4,160	2,740 - 5,340	Pass
ERVE-1108	3/14/2016	U-238	4,220	4,120	2,750 - 5,230	Pass
ERW-1111	3/14/2016	Am-241	113	121	81.5 - 162	Pass
ERW-1111	3/14/2016	Co-60	1,120	1,050	912 - 1,230	Pass
ERW-1111	3/14/2016	Cs-134	806	842	618 - 968	Pass
ERW-1111	3/14/2016	Cs-137	1,190	1,100	934 - 1,320	Pass
ERW-1111	3/14/2016	Mn-54	< 5.89	< 100	0.00 - 100	Pass
ERW-1111	3/14/2016	Pu-238	159	138	102 - 172	Pass
ERW-1111	3/14/2016	Pu-239/240	113	98.7	76.6 - 124	Pass
ERW-1111	3/14/2016	U-233/234	46.9	52.7	39.6 - 68.0	Pass
ERW-1111	3/14/2016	U-238	50.4	52.3	39.9 - 64.2	Pass
ERW-1111	3/14/2016	Zn-65	1,160	1,010	842 - 1,270	Pass
ERW-1111	3/14/2016	Fe-55	1,600	1,650	984 - 2,240	Pass
ERW-1111	3/14/2016	Sr-90	430	434	283 - 574	Pass

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

[b] Laboratory codes as follows: ERW (water), ERAP (air filter), ERSO (soil), ERVE (vegetation). Results are reported in units of pCi/L, except for air filters (pCi/Filter), vegetation and soil (pCi/kg).

[c] Results are presented as the known values, expected laboratory precision (1 sigma, 1 determination) and control limits as provided by ERA.

TABLE D-5 **DOE's Mixed Analyte Performance Evaluation Program (MAPEP)**
ENVIRONMENTAL, INC., 2016

			Concentration [a]			
Lab Code [b]	Reference Date	Analysis	Laboratory result	Known Activity	Control Limits [c]	Acceptance
MASO-1053	2/1/2016	Ni-63	1,206 ± 20	1250	875 - 1625	Pass
MASO-1053	2/1/2016	Sr-90	0.65 ± 1.27	0.00	NA [c]	Pass
MASO-1053	2/1/2016	Tc-99	0.1 ± 5.5	0.0	NA [c]	Pass
MASO-1053	2/1/2016	Cs-134	908 ± 26	1030	721 - 1339	Pass
MASO-1053	2/1/2016	Cs-137	0.10 ± 6.20	0.00	NA [c]	Pass
MASO-1053	2/1/2016	Co-57	1058 ± 26	992	694 - 1290	Pass
MASO-1053	2/1/2016	Co-60	1229 ± 28	1190	833 - 1547	Pass
MASO-1053	2/1/2016	Mn-54	1235 ± 43	1160	812 - 1508	Pass
MASO-1053	2/1/2016	Zn-65	753 ± 64	692	484 - 900	Pass
MASO-1053	2/1/2016	K-40	753 ± 140	607	425 - 789	Pass
MASO-1053	2/1/2016	Am-241	79 ± 6	103	72 - 134	Pass
MASO-1053	2/1/2016	Pu-238	73.9 ± 9.2	63.6	44.5 - 82.7	Pass
MASO-1053	2/1/2016	Pu-239/240	0.76 ± 1.34	0.21	NA [d]	Pass
MASO-1053	2/1/2016	U-234/233	45.0 ± 5.1	45.9	32.1 - 59.7	Pass
MASO-1053	2/1/2016	U-238	129 ± 9	146	102 - 190	Pass
MAW-989	2/1/2016	Am-241	0.018 ± 0.015	0.00	NA [c]	Pass
MAW-989	2/1/2016	H-3	0.2 ± 2.8	0.0	NA [c]	Pass
MAW-989	2/1/2016	Ni-63	12.8 ± 2.7	12.3	8.6 - 16.0	Pass
MAW-989	2/1/2016	Sr-90	8.70 ± 1.20	8.74	6.12 - 11.36	Pass
MAW-989	2/1/2016	Tc-99	-1.1 ± 0.6	0.0	NA [c]	Pass
MAW-989	2/1/2016	Cs-134	15.5 ± 0.3	16.1	11.3 ± 20.9	Pass
MAW-989	2/1/2016	Cs-137	23.7 ± 0.5	21.2	14.8 - 27.6	Pass
MAW-989[e]	2/1/2016	Co-57	1.38 ± 0.12	0.00	NA [c]	Fail
MAW-989	2/1/2016	Co-60	12.5 ± 0.3	11.8	8.3 - 15.3	Pass
MAW-989	2/1/2016	Mn-54	12.2 ± 0.4	11.1	7.8 - 14.4	Pass
MAW-989	2/1/2016	Zn-65	15.7 ± 0.7	13.6	9.5 - 17.7	Pass
MAW-989	2/1/2016	K-40	288 ± 5	251	176 - 326	Pass
MAW-989	2/1/2016	Fe-55	17.3 ± 7.0	16.2	11.3 - 21.1	Pass
MAW-989	2/1/2016	Ra-226	0.710 ± 0.070	0.718	0.503 - 0.933	Pass
MAW-989	2/1/2016	Pu-238	1.280 ± 0.110	1.244	0.871 ± 1.617	Pass
MAW-989	2/1/2016	Pu-239/240	0.640 ± 0.080	0.641	0.449 - 0.833	Pass
MAW-989	2/1/2016	U-234/233	1.39 ± 0.12	1.48	1.04 - 1.92	Pass
MAW-989	2/1/2016	U-238	1.43 ± 0.12	1.53	1.07 - 1.99	Pass
MAW-893	2/1/2016	Gross Alpha	0.600 ± 0.050	0.673	0.202 - 1.144	Pass
MAW-893	2/1/2016	Gross Beta	2.10 ± 0.06	2.15	1.08 - 3.23	Pass
MAW-896	2/1/2016	I-129	3.67 ± 0.20	3.85	2.70 - 5.01	Pass
MAAP-1056	2/1/2016	Gross Alpha	0.39 ± 0.05	1.20	0.36 - 2.04	Pass
MAAP-1056	2/1/2016	Gross Beta	1.03 ± 0.07	0.79	0.40 - 1.19	Pass
MAAP-1057	2/1/2016	Sr-90	1.34 ± 0.15	1.38	0.97 ± 1.79	Pass
MAAP-1057	2/1/2016	Cs-134	-0.01 ± 0.03	0.00	NA [c]	Pass
MAAP-1057	2/1/2016	Cs-137	2.57 ± 0.10	2.30	1.61 - 2.99	Pass

TABLE D-5 **DOE's Mixed Analyte Performance Evaluation Program (MAPEP)**
ENVIRONMENTAL, INC., 2016

			Concentration [a]			
Lab Code [b]	Reference Date	Analysis	Laboratory result	Known Activity	Control Limits [c]	Acceptance
MAAP-1057	2/1/2016	Co-57	3.01 ± 0.06	2.94	2.06 - 3.82	Pass
MAAP-1057	2/1/2016	Co-60	4.28 ± 0.10	4.02	2.81 - 5.23	Pass
MAAP-1057	2/1/2016	Mn-54	4.90 ± 0.13	4.53	3.17 - 5.89	Pass
MAAP-1057	2/1/2016	Zn-65	4.09 ± 0.18	3.57	2.50 - 4.64	Pass
MAAP-1057	2/1/2016	Am-241	0.059 ± 0.015	0.0805	0.0564 - 0.1047	Pass
MAAP-1057	2/1/2016	Pu-238	0.066 ± 0.020	0.0637	0.0446 - 0.0828	Pass
MAAP-1057	2/1/2016	Pu-239/240	0.074 ± 0.020	0.099	NA [d]	Pass
MAAP-1057	2/1/2016	U-234/233	0.151 ± 0.026	0.165	0.116 - 0.215	Pass
MAAP-1057	2/1/2016	U-238	0.160 ± 0.026	0.172	0.120 - 0.224	Pass
MAVE-1050	2/1/2016	Cs-134	9.83 ± 0.19	10.62	7.43 - 13.81	Pass
MAVE-1050	2/1/2016	Cs-137	6.06 ± 0.19	5.62	3.93 - 7.31	Pass
MAVE-1050	2/1/2016	Co-57	13.8 ± 0.2	11.8	8.3 - 15.3	Pass
MAVE-1050	2/1/2016	Co-60	0.022 ± 0.040	0.00	NA [c]	Pass
MAVE-1050	2/1/2016	Mn-54	0.009 ± 0.044	0.000	NA [c]	Pass
MAVE-1050	2/1/2016	Zn-65	10.67 ± 0.39	9.60	6.70 - 12.50	Pass
MASO-4780[f]	8/1/2016	Ni-63	648 ± 14	990	693 - 1287	Fail
MASO-4780[g]	8/1/2016	Ni-63	902 ± 46	990	693 - 1287	Pass
MASO-4780	8/1/2016	Sr-90	757 ± 16	894	626 - 1162	Pass
MASO-4780	8/1/2016	Tc-99	559 ± 12	556	389 - 723	Pass
MASO-4780	8/1/2016	Cs-134	0.93 ± 2.92	0.00	NA [c]	Pass
MASO-4780	8/1/2016	Cs-137	1061 ± 12	1067	747 - 1387	Pass
MASO-4780	8/1/2016	Co-57	1178 ± 8	1190	833 - 1547	Pass
MASO-4780	8/1/2016	Co-60	841 ± 9	851	596 - 1106	Pass
MASO-4780	8/1/2016	Mn-54	0.69 ± 2.53	0.00	NA [c]	Pass
MASO-4780	8/1/2016	Zn-65	724 ± 19	695	487 - 904	Pass
MASO-4780	8/1/2016	K-40	566 ± 52	588	412 - 764	Pass
MASO-4780	8/1/2016	Am-241	0.494 ± 0.698	0.000	NA [c]	Pass
MASO-4780	8/1/2016	Pu-238	69.7 ± 7.4	70.4	49.3 - 91.5	Pass
MASO-4780	8/1/2016	Pu-239/240	53.9 ± 6.3	53.8	37.7 - 69.9	Pass
MASO-4780[h]	8/1/2016	U-233/234	46.8 ± 3.9	122	85 - 159	Fail
MASO-4780[h]	8/1/2016	U-238	46.6 ± 3.9	121	85 - 157	Fail
MAW-4776	8/1/2016	I-129	4.40 ± 0.20	4.54	3.18 - 5.90	Pass
MAVE-4782	8/1/2016	Cs-134	-0.01 ± 0.05	0.00	NA [c]	Pass
MAVE-4782	8/1/2016	Cs-137	6.18 ± 0.20	5.54	3.88 - 7.20	Pass
MAVE-4782	8/1/2016	Co-57	8.13 ± 0.16	6.81	4.77 - 8.85	Pass
MAVE-4782	8/1/2016	Co-60	5.30 ± 0.15	4.86	3.40 - 6.32	Pass
MAVE-4782	8/1/2016	Mn-54	8.08 ± 0.24	7.27	5.09 - 9.45	Pass
MAVE-4782	8/1/2016	Zn-65	6.24 ± 0.36	5.40	3.78 - 7.02	Pass
MAAP-4784	8/1/2016	Sr-90	1.18 ± 0.10	1.03	0.72 - 1.34	Pass
MAAP-4784	8/1/2016	Cs-134	1.58 ± 0.08	2.04	1.43 - 2.65	Pass

TABLE D-5 **DOE's Mixed Analyte Performance Evaluation Program (MAPEP)**
ENVIRONMENTAL, INC., 2016

			Concentration [a]			
Lab Code [b]	Reference Date	Analysis	Laboratory result	Known Activity	Control Limits [c]	Acceptance
MAAP-4784	8/1/2016	Cs-137	1.85 ± 0.09	1.78	1.25 - 2.31	Pass
MAAP-4784	8/1/2016	Co-57	2.39 ± 0.52	2.48	1.74 - 3.22	Pass
MAAP-4784	8/1/2016	Co-60	3.22 ± 0.08	3.26	2.28 - 4.24	Pass
MAAP-4784	8/1/2016	Mn-54	2.82 ± 0.12	2.75	1.93 - 3.58	Pass
MAAP-4784	8/1/2016	Zn-65	-0.015 ± 0.062	0.00	NA [c]	Pass
MAAP-4784	8/1/2016	Am-241	-0.001 ± 0.006	0.00	NA [c]	Pass
MAAP-4784	8/1/2016	Pu-238	0.075 ± 0.022	0.069	0.049 - 0.090	Pass
MAAP-4784	8/1/2016	Pu-239/240	0.048 ± 0.015	0.054	0.038 - 0.070	Pass
MAAP-4784	8/1/2016	U-234/233	0.151 ± 0.036	0.150	0.105 - 0.195	Pass
MAAP-4784	8/1/2016	U-238	0.147 ± 0.034	0.156	0.109 - 0.203	Pass
MAW-4778	8/1/2016	H-3	365 ± 11	334	234 - 434	Pass
MAW-4778	8/1/2016	Fe-55	23.6 ± 16.3	21.5	15.1 ± 28.0	Pass
MAW-4778	8/1/2016	Ni-63	17.0 ± 2.8	17.2	12.0 ± 22.4	Pass
MAW-4778	8/1/2016	Sr-90	0.17 ± 0.28	0.00	NA [c]	Pass
MAW-4778	8/1/2016	Tc-99	9.50 ± 0.41	11.60	8.10 - 15.10	Pass
MAW-4778	8/1/2016	Cs-134	22.6 ± 0.4	23.9	16.7 - 31.1	Pass
MAW-4778	8/1/2016	Cs-137	0.018 ± 0.117	0.00	NA [c]	Pass
MAW-4778	8/1/2016	Co-57	27.6 ± 0.2	27.3	19.1 ± 35.5	Pass
MAW-4778	8/1/2016	Co-60	0.018 ± 0.090	0.00	NA [c]	Pass
MAW-4778	8/1/2016	Mn-54	16.2 ± 0.4	14.8	10.4 - 19.2	Pass
MAW-4778	8/1/2016	Zn-65	19.3 ± 0.7	17.4	12.2 - 22.6	Pass
MAW-4778	8/1/2016	K-40	286 ± 6	252	176 - 328	Pass
MAW-4778	8/1/2016	Ra-226	1.48 ± 0.09	1.33	0.93 - 1.73	Pass
MAW-4778	8/1/2016	Pu-238	1.09 ± 0.13	1.13	0.79 - 1.47	Pass
MAW-4778	8/1/2016	Pu-239/240	0.003 ± 0.011	0.016	NA [d]	Pass
MAW-4778	8/1/2016	U-234/233	1.80 ± 0.13	1.86	1.30 - 2.42	Pass
MAW-4778	8/1/2016	U-238	1.77 ± 0.13	1.92	1.34 - 2.50	Pass
MAW-4778	8/1/2016	Am-241	0.678 ± 0.086	0.814	0.570 ± 1.058	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), MAAP (air filter), MASO (soil), 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 control limits.

[d] Provided in the series for "sensitivity evaluation". MAPEP does not provide control limits.

[e] The laboratory properly identified the Sn-75 interfering peak in the vicinity of Co-57 and stated so in the comment field. MAPEP requires results to be reported as an activity with an uncertainty. Since the calculated uncertainty was less than the activity MAPEP interpreted the submitted result as a "false positive" resulting in a failure.

[f] Original analysis for Ni-63 failed.

[g] Reanalysis with a smaller aliquot resulted in acceptable results. An investigation is in process to identify better techniques for analyzing samples with complex matrices.

[h] MAPEP states that samples contain two fractions of Uranium; one that is soluble in concentrated HNO^3 and HCl acid and one that is "fundamentally insoluble in these acids". They also state that HF treatment can not assure complete dissolution. Results are consistent with measuring the soluble form.

TABLE D-6 Interlaboratory Comparison Crosscheck Program, Environmental Resource Associates (ERA)[a]
RAD Study, ENVIRONMENTAL, INC., 2016

Lab Code	Date	Analysis	Concentration (pCi/L) Laboratory Result	ERA Result	Control Limits	Acceptance
ERW-1392	4/4/2016	Sr-89	43.5 ± 4.3	48.2	37.8 - 55.6	Pass
ERW-1392	4/4/2016	Sr-90	27.5 ± 1.9	28.5	20.7 - 33.1	Pass
ERW-1394 [b]	4/4/2016	Ba-133	65.2 ± 3.8	58.8	48.7 - 64.9	Fail
ERW-1394 [c]	4/4/2016	Ba-133	57.8 ± 5.3	58.8	48.7 - 64.9	Pass
ERW-1394	4/4/2016	Cs-134	43.7 ± 3.0	43.3	34.6 - 47.6	Pass
ERW-1394	4/4/2016	Cs-137	86.1 ± 5.3	78.4	70.6 - 88.9	Pass
ERW-1394	4/4/2016	Co-60	108 ± 44	102	91.8 - 114	Pass
ERW-1394	4/4/2016	Zn-65	240 ± 13	214	193 - 251	Pass
ERW-1397	4/4/2016	Gr. Alpha	52.0 ± 2.2	62.7	32.9 - 77.8	Pass
ERW-1397	4/4/2016	Gr. Beta	33.9 ± 1.2	39.2	26.0 - 46.7	Pass
ERW-1400	4/4/2016	I-131	24.7 ± 0.6	26.6	22.1 - 31.3	Pass
ERW-1402	4/4/2016	Ra-226	15.6 ± 0.5	15.2	11.3 - 17.4	Pass
ERW-1402	4/4/2016	Ra-228	5.28 ± 0.76	5.19	3.12 - 6.93	Pass
ERW-1403	4/4/2016	Uranium	4.02 ± 0.42	4.64	3.39 - 5.68	Pass
ERW-1405	4/4/2016	H-3	8,150 ± 270	7,840	6,790 - 8,620	Pass
SPW-2845	7/7/2015	Ba-133	60.3 ± 5.7	64.7	53.9 - 71.2	Pass
SPW-2845	7/7/2015	Cs-134	48.8 ± 9.3	50.1	40.3 - 55.1	Pass
SPW-2845	7/7/2015	Cs-137	101 ± 8	89.8	80.8 - 101	Pass
SPW-2845	7/7/2015	Co-60	65.1 ± 5.8	59.9	53.9 - 68.4	Pass
SPW-2845	7/7/2015	Zn-65	288 ± 29	265	238 - 310	Pass
ERW-3485	7/11/2016	Sr-89	43.3 ± 6.5	53.3	42.3 - 60.9	Pass
ERW-3485	7/11/2016	Sr-90	39.0 ± 2.8	39.2	28.8 - 45.1	Pass
ERW-3487	7/11/2016	Ba-133	83.3 ± 4.9	82.9	69.7 - 91.2	Pass
ERW-3487	7/11/2016	Cs-134	62.5 ± 4.4	65.3	53.1 - 71.8	Pass
ERW-3487	7/11/2016	Cs-137	98.1 ± 5.6	95.2	85.7 - 107	Pass
ERW-3487	7/11/2016	Co-60	122 ± 5	117	105 - 131	Pass
ERW-3487	7/11/2016	Zn-65	124 ± 9	113	102 - 134	Pass
ERW-3490	7/11/2016	Gr. Alpha	46.6 ± 2.2	48.1	25.0 - 60.5	Pass
ERW-3490	7/11/2016	Gr. Beta	26.8 ± 1.1	28.6	18.2 - 36.4	Pass
ERW-3492	7/11/2016	I-131	23.7 ± 1.0	24.9	20.7 - 29.5	Pass
ERW-3493	7/11/2016	Ra-226	12.9 ± 0.4	12.3	9.2 - 14.2	Pass
ERW-3493	7/11/2016	Ra-228	5.8 ± 0.8	5.8	3.5 - 7.6	Pass
ERW-3493	7/11/2016	Uranium	32.8 ± 0.8	25.2	28.4 - 39.3	Pass
ERW-3495	7/11/2016	H-3	12,400 ± 334	12,400	10,800 - 13,600	Pass

[a] Results obtained by Environmental, Inc., Midwest Laboratory as a participant in the crosscheck program for proficiency testing in drinking water conducted by Environmental Resources Associates (ERA).

[b] No reason determined for failure of Ba-133 result.

[c] The result of reanalysis (Compare to original result, footnoted "b" above).

APPENDIX E

EFFLUENT DATA

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INTRODUCTION

Units 1 and 2 of the Zion Station, located in Zion, Illinois adjacent to Lake Michigan, were 1100 MWe (3520 MWt) Westinghouse pressurized water reactors. The plant permanently ceased operation in February of 1998 and has been permanently defueled. The station is in an advanced state of decommissioning.

The station was designed to keep releases to the environment at levels below those specified in the regulations. Historical data has been established that Zion, as a fully operational facility, did not contribute appreciable doses to the surrounding public. Sampling results for 2016 showed minimal releases above background for a variety of monitored pathways, e.g. water, vegetation, air samples and TLD.

Liquid effluents from Zion Station are released to Lake Michigan in controlled batches after radioassay of each batch and continuously through a monitored pathway. There are no routine noble gas releases. Due to decay, iodine is no longer present. The only noble gas that remained prior to January 2015 was Kr-85 captured in the spent fuel assemblies stored in the fuel pool in the fuel building. During January 2015, the last fuel assembly was removed from the fuel building and Kr-85 is no longer present in the fuel handling building. The results of effluent analyses are summarized on a monthly basis and reported to the Nuclear Regulatory Commission as required per Quality Assurance Project Plan which replaced the Technical Specifications after spent fuel was transferred to the ISFSI. Airborne concentrations of noble gases and particulate radioactivity in offsite areas are calculated using effluent and historical meteorological data.

Currently Zion Station is undergoing decommissioning. During the decommissioning process, containerized waste is temporarily maintained at designated locations onsite. The designated locations are located in a manner to minimize the direct radiation exposure to the public at or near the site boundary.

Environmental monitoring was conducted by sampling at indicator and control (background) locations in the vicinity of the Zion Station to measure changes in radiation or radioactivity levels that may be attributable to the station. If significant changes attributable to Zion Station are measured, these changes are correlated with effluent releases or direct radiation from containerized waste.

ISFSI operations were conducted in 2016 which attributed direct radiation dose in the form of gamma and neutron radiation to members of the public. The results of the calculated dose from direct radiation from the ISFSI have been calculated and included in this report. In addition to the dose contributed to members of the public, a special case exists for members of the public working

onsite in the switchyard area. Switchyard worker dose results are also included in this report.

SUMMARY

Gaseous, liquid and solid waste effluents for the period contributed to only a small fraction of the Station Technical Specification limits. Calculations of environmental concentrations based on effluent and historical meteorological data for the period indicate that consumption by the public of radionuclides attributable to the Zion Station does not exceed regulatory limits. Radiation exposure from direct radiation from the ISFSI and containerized waste at the site boundary represented the critical pathway for the period with a maximum individual total body dose estimated to be 1.49E+01 mrem for the year, where a factor to analyze exposure based on habits of the real individual of 3.38-01 was applied at the maximally exposed receptor. The assessment of radiation doses is performed in accordance with the Zion Station Offsite Dose Calculation Manual (ODCM). The results of analysis confirm that the station is operating in compliance with 10 CFR 50 Appendix I, 10 CFR 20, 10 CFR 72 and 40 CFR 190.

1.0 EFFLUENTS

1.1 Gaseous Effluents to the Atmosphere

Measured concentrations and isotopic composition of noble gases and particulate radioactivity released to the atmosphere were monitored during the year. A total of 0.00E+00 microcuries (µCi) of fission and activation gases was released with a maximum average release rate of 0.00E+00 µCi/sec during any one quarter period.

A total of 4.51E-04 curies of beta-gamma emitters was released as airborne particulate matter with a maximum average quarterly release rate of 1.43E-05 µCi/sec. Alpha-emitting radionuclides were less than measurable detection limits. 0.00E+00 curies of tritium were released with a maximum average quarterly release rate of 0.00E+00 µCi/sec.

1.2 Liquids Released to Lake Michigan

A total of 1.54E+07 liters of liquid waste containing 2.82E-02 curies of fission and activation products, 1.06E+00 curies of tritium, and 1.87E-05 Ci of Alpha was discharged from the station via an approved pathway after dilution with a total of 9.96E+09 liters of water. These wastes were released at a maximum quarterly average concentration of 3.59E-08 µCi/ml. Monthly release estimates and principal radionuclides in liquid effluents are reported in the Zion Nuclear Power Station Radioactive Effluent Report for 2016.

2.0 SOLID RADIOACTIVE WASTE

There were 191 solid radioactive waste shipments in 2016. For more detail, refer to the Zion Station 2016 Annual Radioactive Effluent Release Report.

3.0 DOSE TO MAN

3.1 Gaseous Effluent Pathways

Table 3.1-1 summarizes the doses resulting from releases of airborne radioactivity via the different exposure pathways.

3.1.1 Gaseous Releases

3.1.1.1 Gamma Dose Rates

Offsite Gamma air and whole (total) body dose rates are shown in Table 3.1-1 and were calculated based on measured release rates, isotopic composition of the gases, and meteorological data for the period. Based on measured effluents and historical meteorological data, the maximum total body dose to an individual would be 2.96E-02 mrem (adult) for the year (Table 3.5-1), with an occupancy or shielding factor of 0.7 included. The maximum gamma air dose was 0.00E+00 mrad based on measured effluents and average historical meteorological data (Table 3.5-1).

3.1.1.2 Beta Air and Skin Dose Rates

The range of beta particles in air is relatively small (on the order of a few meters or less); consequently, plumes of gaseous effluents may be considered "infinite" for purpose of calculating the dose from beta radiation incident on the skin. However, the actual dose to sensitive skin tissues is difficult to calculate due to the effect of the beta particle energies, thickness of inert skin and clothing covering sensitive tissues. For purposes of this report the skin is taken to have a thickness of 7.0 mg/cm^2 and an occupancy factor of 1.0 is used. The skin dose from beta and gamma radiation for the year 0.00E+00 mrem based on measured effluents and historical meteorological data (Table 3.5-1).

The maximum offsite beta air dose for the year was 0.00E+00 mrad based on measured effluents and historical meteorological data (Table 3.5-1).

3.1.2 Radioactive Iodine

The human thyroid exhibits a significant capacity to concentrate ingested or inhaled iodine. The radioiodine, 1-131, released during routine operation of the station, may

be made available to man resulting in a dose to the thyroid. The principal pathway of interest for this radionuclide is ingestion of radioiodine in milk. As Zion Station is not operational and I-131 has decayed away, the maximum offsite concentration is estimated to be zero, as expected.

3.1.3 Dose to Thyroid

The hypothetical thyroid dose to a maximum exposed individual living near the station via ingestion of milk was calculated. As Zion Station is not operational and 1-131 has decayed away, the maximum offsite concentration is estimated to be zero, as expected.

3.2 Liquid Effluent Pathways

The three principal pathways through the aquatic environment for potential doses to man from liquid waste are ingestion of potable water, eating aquatic foods, and exposure while on the shoreline. Not all of these pathways are significant or applicable at a given time but a reasonable approximation of the dose can be made by adjusting the dose formula for season of the year or type and degree of use of the aquatic environment. NRC developed equations* were used to calculate the doses to the whole body, lower GI tracts, thyroid, bone, skin; specific parameters for use in the equations are given in the Zion Station Offsite Dose Calculation Manual. The maximum whole body dose (total body) for the year was 8.73E-03 mrem and no organ dose exceeded 3.10E-02 mrem (Table 3.2-1).

3.3 Direct Radiation

During the period January to December 2016, Zion Station during decommissioning has stored containerized radioactive waste combined with direct radiation from the ISFSI (including gamma plus neutron) that contributed a total of 1.49E+01 mrem to the whole body of a maximally exposed individual at site boundary taking into account the occupancy factor of 3.38E-01 calculated in Zion Station ES&H Technical Support Document (TSD) 13-009 "Member of the Public Dose from All Onsite Sources." The maximally exposed member of the public working in the switchyard onsite was calculated to receive 9.98E+01 mrem to the whole body at the south switchyard boundary. This value takes into account the occupancy factor of 2.38E-01 as described in ES&H TSD 13-009 referenced above. During Quarters 1-3 of 2016 the historical Harshaw TLD100

dosimeters were used to estimate dose. The Harshaw TLD100 gamma readings are known to over-respond in the presence of neutrons. During Quarter 4 of 2016, a study on TLD over-response was completed and the Harshaw TLD100s were replaced with Panasonic TLD814 Environmental TLDs which do not over-respond in the presence of neutrons. No correction has been made for the over-response in the above dose values as the values above demonstrate regulatory compliance.

3.4 Assessment of Dose to Member of Public

During the period January to December, 2016, Zion Station did not exceed the below limits as shown in Table 3.1-1 and Table 3.2-1 (based on yearly average meteorological data), and Table 3.3 (based on TLD results):

- The RETS limits on dose or dose commitment to an individual due to radioactive materials in liquid effluents from each reactor unit (3 mrem to the whole body or 10 mrem to any organ during any calendar year).

- The RETS limits on air dose in noble gases released in gaseous effluents to a member of the public from each reactor unit (10 mrads for gamma radiation or 20 mrad for beta radiation during any calendar year).

- The RETS limits on dose to a member of the public due to iodine-131, iodine-133, tritium, and radionuclides in particulate form 'with half-lives greater than eight days in gaseous effluents released from each reactor unit (15 mrem to any organ during any calendar year).

- The 10CFR20 limit on Total Effective Dose Equivalent to individual members of the public (100 mrem).

- The 10CFR72.104 limit on Total Effective Dose Equivalent to individual members of the public from combined effluents and radioactive material including ISFSI(25 mrem).

4.0 SITE METEOROLOGY

A summary of the site meteorological measurements taken during the period of operation of the meteorological tower is given in Appendix 11. After fuel was removed from the fuel building, the meteorological tower was no longer required and the tower was removed. A new historical average of the meteorological data

was created to reflect current parameters and the data are presented as cumulative joint frequency which represents a time period from January 1 2009 to December 31 2014.

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*Nuclear Regulatory Commission, Regulatory Guide 1.109 (Rev. 1) distributions of the wind direction for the 250' level and wind speed class by atmospheric stability class determined from the temperature difference between the 250' and 35' levels. Data recovery for these measurements was 99.6% during 2016 (Table 3.5-1).

APPENDIX E-1

DATA TABLES AND FIGURES

Table 3.1-1
Maximum Dose Resulting from Airborne Releases
Zion Station 2016

GASEOUS EFFLUENTS - SUMMATION OF ALL RELEASES
Unit 1 Vent Stack - GROUND RELEASES

REPORT FOR 2016	Units	QTR 1	QTR 2	QTR 3	QTR 4	YEAR
Fission and Activation Gases						
1. Total Release	Ci	<LLD	<LLD	<LLD	<LLD	<LLD
2. Avg. Release Rate	µCi/sec	<LLD	<LLD	<LLD	<LLD	<LLD
Iodine-131						
1. Total Release	Ci	<LLD	<LLD	<LLD	<LLD	<LLD
2. Avg. Release Rate	µCi/sec	<LLD	<LLD	<LLD	<LLD	<LLD
Particulates Half Life >= 8 days						
1. Total Release	Ci	6.39E-06	1.82E-05	7.03E-06	9.28E-07	3.25E-05
2. Avg. Release Rate	µCi/sec	8.22E-07	2.31E-06	8.84E-07	1.17E-07	1.03E-06
Tritium						
1. Total Release	Ci	<LLD	<LLD	<LLD	<LLD	<LLD
2. Avg. Release Rate	µCi/sec	<LLD	<LLD	<LLD	<LLD	<LLD
Gross Alpha Radioactivity						
1. Total Release	Ci	<LLD	<LLD	<LLD	<LLD	<LLD
2. Avg. Release Rate	µCi/sec	<LLD	<LLD	<LLD	<LLD	<LLD

GASEOUS EFFLUENTS - GROUND RELEASES - CONTINUOUS MODE

REPORT FOR 2016	Units	QTR 1	QTR 2	QTR 3	QTR 4	YEAR
Fission and Activation Gases		<LLD	<LLD	<LLD	<LLD	<LLD
Iodines		<LLD	<LLD	<LLD	<LLD	<LLD
Particulates Half Life >= 8 days						
CO-60	Ci	2.06E-06	7.86E-06	3.30E-06	0.00E+00	1.32E-05
CS-137	Ci	4.21E-06	1.03E-05	3.73E-06	0.00E+00	1.83E-05
NI-63	Ci	3.51E-09	0.00E+00	0.00E+00	0.00E+00	3.51E-09
Totals for Period...	Ci	6.27E-06	1.82E-05	7.03E-06	0.00E+00	3.15E-05
Tritium		<LLD	<LLD	<LLD	<LLD	<LLD
Gross Alpha Radioactivity		<LLD	<LLD	<LLD	<LLD	<LLD

Table 3.1-1(continued)
Maximum Dose Resulting from Airborne Releases
Zion Station 2016

GASEOUS EFFLUENTS - SUMMATION OF ALL RELEASES
Unit 2 Vent Stack - GROUND RELEASES

REPORT FOR 2016	Units	QTR 1	QTR 2	QTR 3	QTR 4	YEAR
Fission and Activation Gases						
1. Total Release	Ci	<LLD	<LLD	<LLD	<LLD	<LLD
2. Avg. Release Rate	µCi/sec	<LLD	<LLD	<LLD	<LLD	<LLD
Iodine-131						
1. Total Release	Ci	<LLD	<LLD	<LLD	<LLD	<LLD
2. Avg. Release Rate	µCi/sec	<LLD	<LLD	<LLD	<LLD	<LLD
Particulates Half Life >= 8 days						
1. Total Release	Ci	4.03E-04	1.14E-05	5.48E-06	<LLD	4.20E-04
2. Avg. Release Rate	uCi/sec	5.18E-05	1.44E-06	6.90E-07	<LLD	1.33E-05
Tritium						
1. Total Release	Ci	<LLD	<LLD	<LLD	<LLD	<LLD
2. Avg. Release Rate	µCi/sec	<LLD	<LLD	<LLD	<LLD	<LLD
Gross Alpha Radioactivity						
1. Total Release	Ci	<LLD	<LLD	<LLD	<LLD	<LLD
2. Avg. Release Rate	µCi/sec	<LLD	<LLD	<LLD	<LLD	<LLD

GASEOUS EFFLUENTS - GROUND RELEASES - CONTINUOUS MODE

REPORT FOR 2016	Units	QTR 1	QTR 2	QTR 3	QTR 4	YEAR
Fission and Activation Gases		<LLD	<LLD	<LLD	<LLD	<LLD
Iodines		<LLD	<LLD	<LLD	<LLD	<LLD
Particulates Half Life >= 8 days						
CO-60	Ci	2.37E-04	6.26E-06	1.67E-06	<LLD	2.45E-04
CS-137	Ci	1.66E-04	5.09E-06	3.81E-06	<LLD	1.75E-04
Totals for Period...	Ci	4.03E-04	1.14E-05	5.48E-06	<LLD	4.20E-04
Tritium		<LLD	<LLD	<LLD	<LLD	<LLD
Gross Alpha Radioactivity		<LLD	<LLD	<LLD	<LLD	<LLD

Table 3.1-1 (continued)
Maximum Dose Resulting from Airborne Releases
Zion Station 2016

40 CFR 190 URANIUM FUEL CYCLE DOSE REPORT

GAS ANNUAL DOSE SUMMARY

Year.....: 2016
From Unit.....: 1
To Unit.....: 2
Coefficient Type.....: Historical
Gas Receptor.....: 5 Composite Crit. Receptor - IP
Distance (meters).....: 0.00
Compass Point.....: NA

=== MAXIMUM PERIOD DOSE TO LIMIT (Any Organ) ===

Dose Period	Age Group	Organ	Dose (mrem)	Limit Period	Admin Limit	Admin % of Limit	T.Spec Limit	T.Spec % of Limit
Quarter 1	INFANT	LIVER	9.03E-02	Quarter	5.63E+00	1.61E+00	7.50E+00	1.20E+00
Quarter 2	INFANT	LIVER	7.84E-03	Quarter	5.63E+00	1.39E-01	7.50E+00	1.05E-01
Quarter 3	INFANT	LIVER	3.75E-03	Quarter	5.63E+00	6.67E-02	7.50E+00	5.00E-02
Quarter 4	INFANT	LIVER	3.78E-04	Quarter	5.63E+00	6.72E-03	7.50E+00	5.04E-03
Annual	INFANT	LIVER	1.02E-01	Annual	1.13E+01	9.09E-01	1.50E+01	6.82E-01

=== MAXIMUM PERIOD DOSE TO LIMIT (Tot Body)) ===

Dose Period	Age Group	Organ	Dose (mrem)	Limit Period	Admin Limit	Admin % of Limit	T.Spec Limit	T.Spec % of Limit
Quarter 1	ADULT	TBODY	2.65E-02	Quarter	5.25E+00	5.04E-01	7.50E+00	3.53E-01
Quarter 2	ADULT	TBODY	2.05E-03	Quarter	5.25E+00	3.91E-02	7.50E+00	2.74E-02
Quarter 3	ADULT	TBODY	9.16E-04	Quarter	5.25E+00	1.75E-02	7.50E+00	1.22E-02
Quarter 4	ADULT	TBODY	7.89E-05	Quarter	5.25E+00	1.50E-03	7.50E+00	1.05E-03
Annual	ADULT	TBODY	2.95E-02	Annual	1.05E+01	2.81E-01	1.50E+01	1.97E-01

Maximum Dose Resulting from Airborne Releases
Zion Station 2016

GASEOUS RELEASE AND DOSE SUMMARY REPORT
(Composite Critical Receptor - Limited Analysis)

Release ID.....: 1 All Gas Releases
Period Start Date....: 01/01/2016 00:00
Period End Date.....: 01/01/2016 00:00
Period Duration (min): 5.256E+05
Coefficient Type.....: Historical
From Unit.....: 0
To Unit.....: 2
Receptor.....: 5 Composite Crit. Receptor - IP
Distance (meters)....: 0.0
Compass Point.....: 0.0

=== MAXIMUM PERIOD DOSE TO LIMIT (Any Organ) ==========

Dose Period	Age Group	Organ	Dose (mrem)	Limit Period	Admin Limit	Admin % of Limit	T.Spec Limit	T.Spec % of Limit
Strt->End	INFANT	LIVER	1.35E-01	31-day	2.25E-01	6.00E+01	3.00E-01	4.50E+01
				Quarter	5.63E+00	2.40E+00	7.50E+00	1.80E+00
				Annual	1.13E+01	1.20E+00	1.50E+01	9.01E-01

Critical Pathway.....: 3 Grs/Goat/Milk (GMILK)
Major Contributors.....: 0.0 % or greater to total

Nuclide	Percentage
MN-56	5.48E-02
CO-60	2.89E+01
CS-137	7.10E+01

=== MAXIMUM PERIOD DOSE TO LIMIT (Tot Body)) ==========

Dose Period	Age Group	Organ	Dose (mrem)	Limit Period	Admin Limit	Admin % of Limit	T.Spec Limit	T.Spec % of Limit
Strt->End	ADULT	TBODY	5.87E-02	31-day	1.50E-01	3.92E+01	2.00E-01	2.94E+01
				Quarter	5.25E+00	1.12E+00	7.50E+00	7.83E-01
				Annual	1.05E+01	5.59E-01	1.50E+01	3.92E-01

Critical Pathway.....: 0 Ground Plane Deposition (GPD)
Major Contributors.....: 0.0 % or greater to total

Nuclide	Percentage
MN-56	1.26E-01
CO-60	6.79E+01
CS-137	3.20E+01

Table 3.2-1
Maximum Dose Resulting from Liquid Effluents
Zion Station 2016

LIQUID EFFLUENTS - SUMMATION OF ALL RELEASES (Unit 1 & Unit 2 combined)

REPORT FOR 2016	Units	QTR 1	QTR 2	QTR 3	QTR 4	YEAR
Fission and Activation Products						
AG-108M	Ci	0.00E+00	0.00E+00	1.04E-05	2.51E-06	1.29E-05
C-14	Ci	4.41E-06	3.85E-04	3.50E-04	1.86E-04	9.25E-04
CO-60	Ci	1.00E-05	8.09E-04	7.82E-04	4.15E-04	2.02E-03
CS-137	Ci	0.00E+00	1.28E-05	9.54E-06	1.30E-05	3.54E-05
FE-55	Ci	1.57E-06	1.13E-04	1.08E-04	5.73E-05	2.79E-04
NI-59	Ci	3.01E-06	2.11E-04	1.06E-04	5.65E-05	3.77E-04
NI-63	Ci	1.31E-04	1.08E-02	8.83E-03	4.69E-03	2.45E-02
PU-241	Ci	1.03E-07	9.00E-06	8.75E-06	4.65E-06	2.25E-05
SR-90	Ci	1.69E-06	9.47E-05	4.31E-06	2.29E-06	1.03E-04
Totals for Period...	Ci	1.52E-04	1.24E-02	1.02E-02	5.43E-03	2.82E-02
Tritium						
H-3	Ci	6.64E-03	2.57E-01	2.57E-01	5.43E-01	1.06E+00
Totals for Period...	Ci	6.64E-03	2.57E-01	2.57E-01	5.43E-01	1.06E+00
Dissolved and Entrained Gases						
1. Total Release	Ci	<LLD	<LLD	<LLD	<LLD	<LLD
Gross Alpha Radioactivity						
ALPHA	Ci	0.00E+00	7.22E-06	4.90E-06	6.55E-06	1.87E-05
Totals for Period...	Ci	0.00E+00	7.22E-06	4.90E-06	6.55E-06	1.87E-05
Volume of liquid waste	liters	1.27E+06	1.82E+06	2.23E+06	1.01E+07	1.54E+07
Volume of dil. water	liters	1.23E+09	1.24E+09	2.48E+09	5.01E+09	9.96E+09

LIQUID EFFLUENTS - CONTINUOUS MODE (Unit 1 & Unit 2 combined)

REPORT FOR 2016	Units	QTR 1	QTR 2	QTR 3	QTR 4	YEAR
Fission and Activation Products		<LLD	<LLD	<LLD	<LLD	<LLD
Tritium		<LLD	<LLD	<LLD	<LLD	<LLD
Dissolved and Entrained Gases		<LLD	<LLD	<LLD	<LLD	<LLD
Gross Alpha Radioactivity		<LLD	<LLD	<LLD	<LLD	<LLD

Table 3.2-1 (continued)
Maximum Dose Resulting from Liquid Effluents
Zion Station 2016

LIQUID EFFLUENTS - BATCH MODE (Unit 1 & Unit 2 combined)

REPORT FOR 2016	Units	QTR 1	QTR 2	QTR 3	QTR 4	YEAR
Fission and Activation Products						
C-14	Ci	3.64E-04	N/A	2.61E-05	2.44E-06	3.92E-04
CO-60	Ci	8.11E-04	N/A	1.99E-04	1.86E-05	1.03E-03
CS-137	Ci	1.82E-04	N/A	2.26E-04	1.40E-04	5.48E-04
FE-55	Ci	1.12E-04	N/A	<LLD	<LLD	1.12E-04
NI-59	Ci	1.10E-04	N/A	<LLD	<LLD	1.10E-04
NI-63	Ci	9.16E-03	N/A	2.53E-04	2.36E-05	9.43E-03
PU-241	Ci	9.08E-06	N/A	<LLD	<LLD	9.08E-06
SR-90	Ci	4.47E-06	N/A	1.56E-05	1.46E-06	2.15E-05
Totals for Period...	Ci	1.07E-02	N/A	7.19E-04	1.86E-04	1.17E-02
Tritium						
H-3	Ci	6.52E-02	N/A	9.31E-02	6.63E-03	1.65E-01
Totals for Period...	Ci	6.52E-02	N/A	9.31E-02	6.63E-03	1.65E-01
Dissolved and Entrained Gases		<LLD	N/A	<LLD	<LLD	<LLD
Gross Alpha Radioactivity						
ALPHA	Ci	4.86E-06	N/A	8.27E-06	<LLD	1.31E-05
Totals for Period...	Ci	4.86E-06	N/A	8.27E-06	<LLD	1.31E-05

SUPPLEMENTAL INFORMATION
LIQUID EFFLUENTS - BATCH MODE

REPORT FOR 2016	Units	QTR 1	QTR 2	QTR 3	QTR 4	YEAR
Number of releases		14	0	12	5	31
Total release time	minutes	3.32E+04	0.00E+00	8.76E+03	5.83E+02	4.26E+04
Maximum release time	minutes	3.32E+03	0.00E+00	6.67E+03	1.59E+02	6.67E+03
Average release time	minutes	2.37E+03	0.00E+00	7.30E+02	1.17E+02	1.37E+03
Minimum release time	minutes	2.40E+02	0.00E+00	1.12E+02	5.90E+01	5.90E+01
Permit dilution vol	ltr	1.26E+09	0.00E+00	1.28E+08	2.23E+07	1.41E+09
Permit dilution flow	gpm	1.00E+04	0.00E+00	3.85E+03	1.01E+04	8.74E+03
Permit max total diluted concentration (no H-3)	µCi/ml	3.23E-08	0.00E+00	3.59E-08	2.41E-08	3.59E-08
Period dilution vol	ltr	4.96E+09	4.96E+09	5.01E+09	5.01E+09	2.00E+10
Period dilution flow	gpm	1.00E+04	1.00E+04	1.00E+04	1.00E+04	1.00E+04

Table 3.2-1 (continued)
Maximum Dose Resulting from Liquid Effluents
Zion Station 2016

40 CFR 190 URANIUM FUEL CYCLE DOSE REPORT

LIQUID ANNUAL DOSE SUMMARY

Year.....: 2016
From Unit.....: 1
To Unit.....: 2
Liquid Receptor.....: 0 Liquid Receptor

=== MAXIMUM PERIOD DOSE TO LIMIT (Any Organ) ===

Dose Period	Age Group	Organ	Dose (mrem)	Limit Period	Admin Limit	Admin % of Limit	T.Spec Limit	T.Spec % of Limit
Quarter 1	CHILD	BONE	2.16E-02	Quarter	2.50E+00	8.66E-01	2.50E+00	8.66E-01
Quarter 2	ADULT	BONE	0.00E+00	Quarter	2.50E+00	0.00E+00	2.50E+00	0.00E+00
Quarter 3	CHILD	BONE	6.04E-03	Quarter	2.50E+00	2.42E-01	2.50E+00	2.42E-01
Quarter 4	TEEN	LIVER	3.36E-03	Quarter	2.50E+00	1.34E-01	2.50E+00	1.34E-01
Annual	CHILD	BONE	3.10E-02	Annual	5.00E+00	6.19E-01	5.00E+00	6.19E-01

=== MAXIMUM PERIOD DOSE TO LIMIT (Tot Body)) ===

Dose Period	Age Group	Organ	Dose (mrem)	Limit Period	Admin Limit	Admin % of Limit	T.Spec Limit	T.Spec % of Limit
Quarter 1	ADULT	TBODY	3.19E-03	Quarter	1.50E+00	2.13E-01	1.50E+00	2.13E-01
Quarter 2	ADULT	TBODY	0.00E+00	Quarter	1.50E+00	0.00E+00	1.50E+00	0.00E+00
Quarter 3	ADULT	TBODY	3.42E-03	Quarter	1.50E+00	2.28E-01	1.50E+00	2.28E-01
Quarter 4	ADULT	TBODY	2.12E-03	Quarter	1.50E+00	1.41E-01	1.50E+00	1.41E-01
Annual	ADULT	TBODY	8.73E-03	Annual	3.00E+00	2.91E-01	3.00E+00	2.91E-01

Table 3.3-1
Maximum Dose Resulting from Direct Radiation
Zion Station 2016

Maximally exposed sector: J (25mrem/year limit)

Unit	Qtr 1 (mrem)	Qtr 2 (mrem)	Qtr 3 (mrem)	Qtr 4 (mrem)	2016 (mrem)
Unit 1	1.93E+00	1.20E+00	6.33E-01	7.33E-01	4.50E+00
Unit 2	1.93E+00	1.20E+00	6.33E-01	7.33E-01	4.50E+00
ISFSI – gamma	1.93E+00	1.20E+00	6.33E-01	7.33E-01	4.50E+00
ISFSI – neutron	6.00E-01	3.00E-01	3.00E-01	2.00E-01	1.40E+00
Sum:	6.40E+00	3.90E+00	2.20E+00	2.40E+00	1.49E+01

Maximally exposed switchyard: Switchyard South (100mrem/year limit)

Switchyard	Qtr 1 (mrem)	Qtr 2 (mrem)	Qtr 3 (mrem)	Qtr 4 (mrem)	2016 (mrem)
Gamma	2.44E+01	2.97E+01	2.47E+01	1.16E+01	9.04E+01
Neutron	2.40E+00	2.40E+00	3.40E+00	1.20E+00	9.40E+00
Sum	2.68E+01	3.21E+01	2.82E+01	1.28E+01	9.98E+01

Table 3.4-1
ZION STATION
2016
Unit 1
10 CFR 20 Compliance Assessment

1. 10 CFR 20.1301 (a) (1) Compliance

   Total Effective Dose Equivalent **4.52E+00 mrem/year**

   10 CFR 20.1301 (a) (1) limit 100 mrem/year

   % of the limit **4.52E+00 %**

2. Compliance Summary 10 CFR 20

	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr	% of Limit
TEDE	**1.94E+00**	**1.20E+00**	**6.35E-01**	**7.34E-01**	**4.52E+00%**

Table 3.4-1 (continued)
ZION STATION
2016
Unit 2
10 CFR 20 Compliance Assessment

1. 10 CFR 20.1301 (a) (1) Compliance

   Total Effective Dose Equivalent **4.52E+00 mrem/year**

   10 CFR 20.1301 (a) (1) limit 100 mrem/year

   % of the limit **4.52E+00 %**

2. Compliance Summary 10 CFR 20

	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr	% of Limit
TEDE	**8.25E-01**	**1.57E+00**	**1.86E+00**	**1.57E+00**	**5.83E+00%**

Table 3.4-1 (continued)
ZION STATION
2016
Switchyard
10 CFR 20 Compliance Assessment

1. 10 CFR 20.1301 (a) (1) Compliance

   Total Effective Dose Equivalent **9.98E+01 mrem/year**

   10 CFR 20.1301 (a) (1) limit 100 mrem/year

   % of the limit **9.98E+01%**

2. Compliance Summary 10 CFR 20

	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr	% of Limit
TEDE	**2.68E+01**	**3.21E+01**	**2.82E+01**	**1.28E+01**	**9.98E+01%**

*Note: Qtr 1,2,3 Harshaw TLD100 represents 30% gamma over-response. Qtr 4 TLD changed to Panasonic TLD 814 which does not over-respond when in presence of neutrons

Table 3.4-1 (continued)
ZION STATION
2016
ISFSI
10 CFR 72.104 Compliance Assessment

1. 10 CFR 72.104 (a) (2) Compliance

   Total Effective Dose Equivalent **5.90E+00 mrem/year**

   10 CFR 72.104 (a) limit 25 mrem/year

   % of the limit **2.36E+01%**

2. Compliance Summary 10 CFR 20

	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr	% of Limit
TEDE	**2.53E+00**	**1.23E+00**	**9.33E-01**	**9.33E-01**	**2.36E+01%**

Table 3.5-1

Doses Resulting from Airborne Releases

The following are the maximum annual calculated cumulative offsite doses resulting from Zion Station airborne releases.

Unit 1:

Dose	*Maximum Value*	*Sector Affected*
gamma air [1]	0.00E+00 mrad	
beta air [2]	0.00E+00 mrad	
whole body [3]	1.48E-02 mrem	East
skin [4]	0.00E+00 mrem	East
organ [5] (infant liver)	5.10E-02 mrem	East

Unit 2:

Dose	*Maximum Value*	*Sector Affected*
gamma air [1]	0.00E+00 mrad	
beta air [2]	0.00E+00 mrad	
whole body [3]	9.86E-02 mrem	East
skin [4]	0.00E+00 mrem	East
organ [5] (infant liver)	3.40E-01 mrem	East

All values based on historical values of atmospheric dispersion coefficients and XOQDOQ values reflecting the time period from Jan. 1, 2009 to Dec. 31 2014. Meteorological Tower was removed March 2015.

Data recovery: 98.71%

(1) Gamma Air Dose – GASPAR II, NUREG-0597
(2) Beta Air Dose – GASPAR II, NUREG-0597
(3) Whole Body Dose – GASPAR II, NUREG-0597
(4) Skin Dose – GASPAR II, NUREG-0597
(5) Inhalation and Food Pathways Dose – GASPAR II, NUREG-0597

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APPENDIX F

METEOROLOGICAL DATA

1. Introduction

The purpose of the meteorological program conducted at Zion Station site was to provide information sufficient to assess the local weather conditions and was used to determine the degree of atmospheric dispersion of airborne radioactive effluent from the station.

During the first quarter of 2015, all fuel had been removed to the ISFSI location and continuous meteorological monitoring was no longer required. The previous 6 years of data from Jan. 1, 2009 to Dec. 31, 2014 was queried to generate the historic average wind rose and atmospheric dispersion parameters for future airborne effluents from Zion Station.

The method of dose calculation that will be used going forward is ground level release and relevant information that is applicable to this method of effluent dose calculation has been included in this report.

The meteorological tower that was used in calculation of these historical averages was 250 ft. in elevation and was instrumented at two levels. Wind speed and direction measured at 35 ft. and 250 ft. Ambient temperature was measured at 35 ft. Differential temperature, referenced to 35 ft. was measured at 250 ft. Dew point temperature was measured approximately ten feet from the tower at an elevation of 5 ft. Precipitation was measured by a rain gauge located on the roof of the meteorological shelter building.

Joint frequency stability wind rose tables of wind direction, wind speed, and stability were routinely tabulated from hourly measurements during the six year period of this historical average. The six year historical average data tables are included in this report.

2. Summary

Zion Station meteorological monitoring program produced 51,918 total hours valid for the instruments used in generating the historical average out of a possible 52596 total hours in the 6 year monitoring period from Jan. 1, 2009 to Dec. 31, 2014. (365.25 days X 6 years X 24 hours/day). 678 total hours of data were lost representing a 98.71% data recovery rate.

The stability wind rose tables included in this report have been generated using the 35 ft. wind data with the 250-35 ft. differential temperature data.

3. Data Acquisition

Information regarding Data Acquisition, Data Analysis and instruments used can be found in the meteorological monitoring sections of prior Zion Stations Annual Radioactive Environmental Monitoring Reports from 2009 to 2014.

Table 1

Wind Direction Classes

Wind Direction Class	Compass Direction the Wind is Coming From		
N	348.75^0	< WD ≤	11.25^0
NNE	11.25^0	< WD ≤	11.25^0
NE	33.75^0	< WD ≤	33.75^0
ENE	56.25^0	< WD ≤	56.25^0
E	78.75^0	< WD ≤	78.75^0
ESE	101.25^0	< WD ≤	101.25^0
SE	123.75^0	< WD ≤	123.75^0
SSE	146.25^0	< WD ≤	146.25^0
S	168.75^0	< WD ≤	168.75^0
SSW	191.25^0	< WD ≤	191.25^0
SW	213.75^0	< WD ≤	213.75^0
WSW	236.25^0	< WD ≤	236.25^0
W	258.75^0	< WD ≤	258.75^0
WNW	281.25^0	< WD ≤	281.25^0
NW	303.75^0	< WD ≤	303.75^0
NNW	326.25^0	< WD ≤	348.75^0

Table 2

Wind Speed Classes

Wind Speed Class	Wind Speeds are in miles per hour (mph)		
1	0.0	< WS ≤	0.7
2	0.7	< WS ≤	3.5
3	3.5	< WS ≤	7.5
4	7.5	< WS ≤	12.5
5	12.5	< WS ≤	18.5
6	18.5	< WS ≤	24.5
7	24.5	< WS	

Table 3

Atmospheric Stability Classes

Class	Differential Temperature Interval (in $^{o}C/100m$)[1]	Differential Temperature Interval (in ^{o}F over the 250-35 ft. interval)[2]
A – Extremely Unstable	$\Delta T \leq -1.9$	$\Delta T \leq -2.3$
B – Moderately Unstable	$-1.9 < \Delta T \leq -1.7$	$-2.3 < \Delta T \leq -2.1$
C – Slightly Unstable	$-1.7 < \Delta T \leq -1.5$	$-2.1 < \Delta T \leq -1.8$
D – Neutral	$-1.5 < \Delta T \leq -0.5$	$-1.8 < \Delta T \leq -0.6$
E – Slightly Stable	$-0.5 < \Delta T \leq 1.5$	$-0.6 < \Delta T \leq 1.7$
F – Moderately Stable	$1.5 < \Delta T \leq 4.0$	$1.7 < \Delta T \leq 4.7$
G – Extremely Stable	$4.0 < \Delta T$	$4.7 < \Delta T$

(1) From ANSI/ANS 2.5

(2) ANSI/ANS 2.5 intervals scaled for instrument heights on the Zion meteorological tower.

4. The following two programs were used to calculate doses resulting from radioactive releases:

   a. XOQDOQ: Computer Program for the Meteorological Evaluation of Routine Effluent Releases at Nuclear Power Stations (NUREG/CR-2919)

      The program is based on the theory that material released to the atmosphere will be normally distributed (Gaussian) about the plume centerline. A straight-line trajectory is assumed between the point of release and all receptors.

      The program implements the assumptions outlined in Section C of NRC Regulatory Guide 1.111. In evaluating routine releases from nuclear power plants, it primarily is designed to calculate annual relative effluent concentrations, X/Q values and annual average relative deposition, D/Q values.

      The historical average output from the XOQDOQ program from 2009-2014 was used to develop the input to the RETDAS program.

   b. RETDAS: Radiological Effluent Tracking and Dose Assessment Software.

      RETDAS is a program written for the evaluation of radiological impacts due to the release of radioactive material to the environment during normal operation of reactors. The RETDAS code implements the radiological impact models of NRC Regulatory Guide 1.109 Rev. 1, for atmospheric releases. The program is used to estimate the maximum individual doses at the maximally exposed location in the vicinity of the plant.

5. Detailed information regarding the meteorological maintenance and calibration information of the meteorological tower and instruments used during the historical average evaluation time period can be found in prior Zion Station Annual Radioactive Environmental Operating Reports from 2009 to 2014.

6. Stability Wind Rose Data

The historical stability wind roses are given in Tables 4 through 8. For the year, winds measured at 35ft. most frequently came from the West (10.86%) and fell into the 3.6 to 7.5 mph wind speed class (34.94%). Calms (wind speeds at or below 1mph were measured at 0.16% of the time and speeds greater than 24.5 mph were measured 0.09% of the time.

Stability based on the 250-35 ft. differential temperature most frequently fell into the neutral classification (39.58%)

Table 4

Percent of time at each Wind Speed and Direction

Period of Record: Jan. 1, 2009 to Dec. 31, 2014

Stability Class: A - Extremely Unstable

Elevation: Ground Level Release

	Wind Speed (mph) at 10m Level							
Wind Direction	<1	1 - 3.5	3.6 - 7.5	7.6 - 12.5	12.6 - 18.5	18.6 - 24.5	>24.5	Total:
N	0	0	0.031	0.156	0.254	0.04	0.002	0.48
NNE	0	0	0.176	0.98	0.287	0.006	0	1.45
NE	0	0.002	0.391	0.559	0.075	0.004	0	1.03
ENE	0	0.002	0.368	0.22	0.019	0.002	0	0.61
E	0	0.004	0.412	0.133	0.023	0	0	0.57
ESE	0	0.002	0.379	0.141	0	0	0	0.52
SE	0	0	0.272	0.219	0.01	0	0	0.5
SSE	0	0	0.05	0.249	0.035	0	0	0.33
S	0	0	0.01	0.046	0.019	0	0	0.08
SSW	0	0.002	0.015	0.068	0.144	0.01	0	0.24
SW	0	0.002	0.041	0.319	0.331	0.015	0.006	0.71
WSW	0	0	0.133	0.516	0.366	0.021	0.004	1.04
W	0	0	0.12	0.577	0.401	0.01	0	1.11
WNW	0	0	0.089	0.492	0.187	0.002	0	0.77
NW	0	0.006	0.068	0.404	0.112	0	0	0.59
NNW	0	0	0.039	0.058	0.037	0	0	0.13
Total:	0	0.019	2.591	5.137	2.3	0.11	0.012	10.17

Percent of time at each Wind Speed and Direction

Period of Record: Jan. 1, 2009 to Dec. 31, 2014

Stability Class: B - Moderately Unstable

Elevation: Ground Level Release

	Wind Speed (mph) at 10m Level							
Wind Direction	<1	1 - 3.5	3.6 - 7.5	7.6 - 12.5	12.6 - 18.5	18.6 - 24.5	>24.5	Total:
N	0	0	0.039	0.102	0.119	0.015	0	0.28
NNE	0	0	0.112	0.196	0.058	0.004	0.002	0.37
NE	0	0.012	0.108	0.052	0.014	0.004	0	0.19
ENE	0	0.012	0.068	0.029	0.014	0	0	0.12
E	0	0.004	0.077	0.025	0.002	0	0	0.11
ESE	0	0.008	0.066	0.045	0	0	0	0.12
SE	0	0	0.097	0.041	0	0	0	0.14
SSE	0	0	0.06	0.164	0.025	0	0	0.25
S	0	0	0.01	0.052	0.008	0.002	0	0.07
SSW	0	0	0.013	0.058	0.098	0.008	0.002	0.18
SW	0	0.002	0.033	0.149	0.158	0.013	0.002	0.36
WSW	0	0	0.062	0.193	0.089	0.012	0.002	0.36
W	0	0.002	0.068	0.211	0.129	0.004	0	0.41
WNW	0	0	0.06	0.179	0.081	0.004	0	0.32
NW	0	0.004	0.049	0.191	0.052	0	0	0.29
NNW	0	0.002	0.021	0.054	0.027	0.002	0	0.11
Total:	0	0.044	0.938	1.739	0.872	0.067	0.008	3.67

Percent of time at each Wind Speed and Direction

Period of Record: Jan. 1, 2009 to Dec. 31, 2014

Stability Class: C - Slightly Unstable

Elevation: Ground Level Release

Wind Speed (mph) at 10m Level

Wind Direction	<1	1 - 3.5	3.6 - 7.5	7.6 - 12.5	12.6 - 18.5	18.6 - 24.5	>24.5	Total:
N	0	0.004	0.086	0.243	0.177	0.013	0.008	0.53
NNE	0	0.01	0.183	0.31	0.079	0.004	0	0.59
NE	0	0.023	0.15	0.102	0.031	0.01	0.006	0.32
ENE	0	0.023	0.1	0.044	0.021	0.012	0.002	0.2
E	0	0.01	0.146	0.025	0.018	0	0	0.2
ESE	0	0.019	0.115	0.037	0.014	0	0	0.18
SE	0	0.006	0.181	0.054	0.016	0	0	0.26
SSE	0	0.006	0.106	0.351	0.11	0.01	0	0.58
S	0	0.004	0.066	0.101	0.021	0	0	0.19
SSW	0	0.002	0.041	0.119	0.154	0.017	0.004	0.34
SW	0	0	0.094	0.244	0.189	0.023	0.006	0.56
WSW	0	0.004	0.11	0.252	0.139	0.01	0.002	0.52
W	0	0.008	0.133	0.277	0.165	0.008	0	0.59
WNW	0	0.008	0.127	0.308	0.079	0	0	0.52
NW	0	0.01	0.096	0.206	0.096	0	0	0.41
NNW	0	0.01	0.033	0.133	0.045	0.004	0	0.22
Total:	0	0.145	1.768	2.806	1.352	0.11	0.027	6.21

Percent of time at each Wind Speed and Direction

Period of Record: Jan. 1, 2009 to Dec. 31, 2014

Stability Class: D - Neutral

Elevation: Ground Level Release

	Wind Speed (mph) at 10m Level							
Wind Direction	<1	1 - 3.5	3.6 - 7.5	7.6 - 12.5	12.6 - 18.5	18.6 - 24.5	>24.5	Total:
N	0	0.102	0.597	1.392	1.05	0.21	0.06	3.41
NNE	0	0.142	0.758	1.123	0.769	0.042	0.031	2.87
NE	0	0.161	0.528	0.57	0.405	0.046	0.025	1.74
ENE	0.001	0.137	0.348	0.346	0.347	0.092	0.008	1.28
E	0	0.121	0.392	0.303	0.353	0.094	0.013	1.28
ESE	0	0.148	0.489	0.289	0.163	0.035	0.002	1.13
SE	0	0.127	0.567	0.378	0.149	0.008	0	1.23
SSE	0	0.075	0.523	1.258	0.944	0.168	0.054	3.02
S	0	0.106	0.686	0.805	0.314	0.015	0	1.93
SSW	0	0.128	0.641	0.994	0.774	0.087	0.008	2.63
SW	0	0.152	0.612	1.443	1.003	0.108	0.015	3.33
WSW	0.001	0.138	0.849	1.327	0.659	0.042	0.002	3.02
W	0	0.146	1.1	1.766	0.961	0.029	0.002	4
WNW	0	0.169	1.139	1.402	0.52	0.012	0	3.24
NW	0	0.164	1	1.404	0.489	0.021	0	3.08
NNW	0	0.098	0.655	1.21	0.387	0.039	0.006	2.39
Total:	0.006	2.117	10.886	16.01	9.286	1.048	0.225	39.58

Percent of time at each Wind Speed and Direction

Period of Record: Jan. 1, 2009 to Dec. 31, 2014

Stability Class: E - Slightly Stable

Elevation: Ground Level Release

	Wind Speed (mph) at 10m Level							
Wind Direction	<1	1 - 3.5	3.6 - 7.5	7.6 - 12.5	12.6 - 18.5	18.6 - 24.5	>24.5	Total:
N	0.005	0.302	0.672	0.53	0.173	0.021	0.012	1.72
NNE	0.004	0.245	0.564	0.447	0.058	0.013	0	1.33
NE	0.004	0.204	0.314	0.167	0.075	0.002	0	0.77
ENE	0.003	0.154	0.212	0.092	0.071	0.01	0	0.54
E	0.003	0.148	0.212	0.082	0.11	0.054	0.008	0.62
ESE	0.002	0.129	0.233	0.091	0.052	0.017	0	0.52
SE	0.003	0.163	0.456	0.273	0.079	0.004	0	0.98
SSE	0.004	0.192	0.452	0.84	0.291	0.029	0.019	1.83
S	0.005	0.292	1.375	0.839	0.166	0.004	0	2.68
SSW	0.005	0.441	1.19	0.661	0.154	0.015	0	2.47
SW	0.006	0.324	0.855	0.607	0.183	0.013	0	1.99
WSW	0.004	0.277	1.008	0.503	0.069	0.002	0	1.86
W	0.005	0.353	1.349	0.649	0.117	0.006	0.002	2.48
WNW	0.005	0.38	1.136	0.599	0.05	0.002	0	2.17
NW	0.005	0.319	1.069	0.48	0.073	0	0	1.95
NNW	0.004	0.252	0.593	0.203	0.058	0	0	1.11
Total:	0.065	4.178	11.692	7.063	1.779	0.193	0.04	25.01

Percent of time at each Wind Speed and Direction

Period of Record: Jan. 1, 2009 to Dec. 31, 2014

Stability Class: F - Moderately Stable

Elevation: Ground Level Release

Wind Speed (mph) at 10m Level

Wind Direction	<1	1 - 3.5	3.6 - 7.5	7.6 - 12.5	12.6 - 18.5	18.6 - 24.5	>24.5	Total:
N	0.002	0.151	0.162	0.043	0	0	0	0.36
NNE	0.001	0.094	0.106	0.019	0	0	0	0.22
NE	0.001	0.083	0.086	0.025	0	0	0	0.2
ENE	0.001	0.076	0.064	0.024	0.014	0.002	0	0.18
E	0.001	0.079	0.077	0.027	0.01	0	0	0.19
ESE	0.001	0.077	0.111	0.045	0.016	0	0	0.25
SE	0.001	0.072	0.156	0.07	0.006	0	0	0.3
SSE	0.001	0.068	0.154	0.351	0.118	0.013	0	0.7
S	0.003	0.24	0.714	0.368	0.08	0.002	0	1.41
SSW	0.004	0.472	0.51	0.031	0.004	0	0	1.02
SW	0.005	0.454	0.334	0.023	0.002	0	0	0.82
WSW	0.005	0.495	0.368	0.015	0	0	0	0.88
W	0.005	0.416	0.637	0.015	0	0	0	1.07
WNW	0.003	0.307	0.458	0.008	0	0	0	0.78
NW	0.004	0.333	0.466	0.012	0	0	0	0.82
NNW	0.003	0.202	0.165	0.002	0.002	0	0	0.37
Total:	0.042	3.618	4.571	1.075	0.251	0.017	0	9.57

Percent of time at each Wind Speed and Direction

Period of Record: Jan. 1, 2009 to Dec. 31, 2014

Stability Class: G - Extremely Stable

Elevation: Ground Level Release

Wind Speed (mph) at 10m Level

Wind Direction	<1	1 - 3.5	3.6 - 7.5	7.6 - 12.5	12.6 - 18.5	18.6 - 24.5	>24.5	Total:
N	0.001	0.058	0.025	0	0	0	0	0.08
NNE	0.001	0.034	0.028	0	0	0	0	0.06
NE	0.001	0.03	0.01	0.008	0.002	0	0	0.05
ENE	0.001	0.029	0.018	0.008	0.012	0	0	0.07
E	0.001	0.033	0.029	0.02	0.008	0	0	0.09
ESE	0.001	0.039	0.058	0.021	0.004	0	0	0.12
SE	0.001	0.034	0.066	0.029	0.002	0	0	0.13
SSE	0.001	0.052	0.095	0.167	0.054	0	0	0.37
S	0.002	0.116	0.424	0.316	0.057	0	0	0.91
SSW	0.005	0.256	0.11	0.006	0	0	0	0.38
SW	0.005	0.258	0.189	0	0	0	0	0.45
WSW	0.006	0.481	0.316	0	0	0	0	0.8
W	0.008	0.586	0.609	0	0	0	0	1.2
WNW	0.007	0.353	0.401	0	0	0	0	0.76
NW	0.003	0.104	0.108	0	0	0	0	0.22
NNW	0.003	0.071	0.016	0	0	0	0	0.09
Total:	0.048	2.534	2.498	0.574	0.139	0	0	5.79

Table 5

Percent Wind Direction by Stability Class

Wind Direction	Stability Class							
	A	B	C	D	E	F	G	Total
N	0.48	0.28	0.53	3.4	1.72	0.36	0.08	6.86
NNE	1.45	0.37	0.59	2.9	1.33	0.22	0.06	6.89
NE	1.03	0.19	0.32	1.7	0.77	0.2	0.05	4.3
ENE	0.61	0.12	0.2	1.3	0.54	0.18	0.07	3
E	0.57	0.11	0.2	1.3	0.62	0.19	0.09	3.06
ESE	0.52	0.12	0.18	1.1	0.52	0.25	0.12	2.84
SE	0.5	0.14	0.26	1.2	0.98	0.3	0.13	3.54
SSE	0.33	0.25	0.58	3.0	1.83	0.7	0.37	7.08
S	0.08	0.07	0.19	1.9	2.68	1.41	0.91	7.27
SSW	0.24	0.18	0.34	2.6	2.47	1.02	0.38	7.26
SW	0.71	0.36	0.56	3.3	1.99	0.82	0.45	8.22
WSW	1.04	0.36	0.52	3.02	1.86	0.88	0.8	8.48
W	1.11	0.41	0.59	4	2.48	1.07	1.2	10.86
WNW	0.77	0.32	0.52	3.24	2.17	0.78	0.76	8.56
NW	0.59	0.29	0.41	3.08	1.95	0.82	0.22	7.36
NNW	0.13	0.11	0.22	2.39	1.11	0.37	0.09	4.42
TOTAL	10.17	3.67	6.21	39.58	25.01	9.57	5.79	100

Table 6

Percent Wind Direction by Wind Speed

Wind Direction	Wind Speed in mph							
	<1	1 - 3.5	3.6 - 7.5	7.6 - 12.5	12.6 - 18.5	18.6 - 24.5	>24.5	Total:
N	0.008	0.617	1.612	2.466	1.773	0.299	0.082	6.86
NNE	0.006	0.525	1.927	3.075	1.251	0.069	0.033	6.89
NE	0.006	0.515	1.587	1.483	0.602	0.066	0.031	4.3
ENE	0.006	0.433	1.178	0.763	0.498	0.118	0.01	3
E	0.005	0.399	1.345	0.615	0.524	0.148	0.021	3.06
ESE	0.004	0.422	1.451	0.669	0.249	0.052	0.002	2.84
SE	0.005	0.402	1.795	1.064	0.262	0.012	0	3.54
SSE	0.006	0.393	1.44	3.38	1.577	0.22	0.073	7.08
S	0.01	0.758	3.285	2.527	0.665	0.023	0	7.27
SSW	0.014	1.301	2.52	1.937	1.328	0.137	0.014	7.26
SW	0.016	1.192	2.158	2.785	1.866	0.172	0.029	8.22
WSW	0.016	1.395	2.846	2.806	1.322	0.087	0.01	8.48
W	0.018	1.511	4.016	3.495	1.773	0.057	0.004	10.86
WNW	0.015	1.217	3.41	2.988	0.917	0.02	0	8.56
NW	0.012	0.94	2.856	2.697	0.822	0.021	0	7.36
NNW	0.01	0.635	1.522	1.66	0.556	0.045	0.006	4.42
Total	0.161	12.655	34.944	34.404	15.979	1.545	0.312	100

Table 7
Percent Speed by Stability Class

Speed (mph)	Stability Class							
	A	B	C	D	E	F	G	Total
<1	0	0	0	0.006	0.065	0.042	0.048	0.161
1 - 3.5	0.227	0.177	0.524	4.22	6.601	4.625	3.303	19.677
3.6 - 7.5	2.591	0.938	1.768	10.886	11.692	4.571	2.498	34.944
7.6 - 12.5	5.137	1.739	2.806	16.01	7.063	1.075	0.574	34.404
12.6 - 18.5	2.3	0.872	1.352	9.286	1.779	0.251	0.139	15.979
18.6 - 24.5	0.11	0.067	0.11	1.048	0.193	0.017	0	1.545
>24.5	0.012	0.008	0.027	0.225	0.04	0	0	0.312
Total:	10.17	3.67	6.21	39.58	25.01	9.57	5.79	100

APPENDIX G

ANNUAL RADIOLOGICAL GROUNDWATER PROTECTION PROGRAM REPORT (ARGPPR)

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Docket No: 50-295
50-304
72-1037

ZION NUCLEAR POWER STATION
UNITS 1 and 2

Annual Radiological Groundwater Protection Program Report

1 January through 31 December 2016

Prepared By
Teledyne Brown Engineering
Environmental Services

ZionSolutions LLC
An EnergySolutions Company

Zion Nuclear Power Station
Zion, IL 60099

May 2017

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Appendices

I. Summary and Conclusions

In 2006, Exelon instituted a comprehensive program to evaluate the impact of station operations on groundwater and surface water in the vicinity of Zion Nuclear Power Station. This is the ninth in a series of annual reports on the status of the Radiological Groundwater Protection Program (RGPP) conducted at Zion Nuclear Power Station. This report covers both groundwater and surface water samples, collected from the environment, on station property in 2016. During that time period, 501 analyses were performed on 51 samples from 12 locations. Phase 1 of the monitoring was part of a comprehensive study initiated by Exelon to determine whether groundwater or surface water at and in the vicinity of Zion Nuclear Power Station had been adversely impacted by any releases of radionuclides. Phase 1 was conducted by Conestoga Rovers and Associates (CRA) and the conclusions were made available to state and federal regulators as well as the public in station specific reports.

Phase 2 of the RGPP was conducted by Zion*Solutions* (Exelon was responsible for the program up to 8/31/2010; Zion*Solutions* became the licensee on 9/1/2010, thus assuming responsibility for the RGPP) personnel to initiate follow up of Phase 1 and begin long-term monitoring at groundwater and surface water locations selected during Phase 1. All analytical results from Phase 2 monitoring are reported herein.

In assessing all the data gathered for this report, it was concluded that the operation of Zion Nuclear Power Station had no adverse radiological impact on the environment, and there are no known active releases into the groundwater at Zion Nuclear Power Station.

Naturally-occurring Potassium -40 (K-40) was detected in 2 groundwater samples. No other gamma-emitting radionuclides were detected at concentrations greater than their respective Lower Limits of Detection (LLDs) as specified in the Offsite Dose Calculation Manual (ODCM) in any of the groundwater or surface water samples. Strontium-90 was not detected in any of the samples analyzed in 2016.

Tritium was not detected in any groundwater or surface water samples analyzed in 2016. In the case of tritium, Zion*Solutions* specified that its laboratories achieve a lower limit of detection 10 times lower than that required by federal regulation.

Gross Alpha and Gross Beta analyses in the dissolved and suspended fractions were performed on surface water samples during all four quarters of sampling in 2016. Gross Alpha (dissolved) and Gross Alpha (suspended) was not detected in any of the surface water locations. Gross Beta (dissolved) was detected in any 4 samples at one surface water location. The concentrations ranged from

2.3 to 7.3 pCi/L. Gross Beta (suspended) was not detected in any surface water locations. Dissolved Gross Alpha and Dissolved Gross Beta are detectable in samples due to the presence of naturally-occurring isotopes.

Iron-55 (Fe-55), Ni-59 (Ni-59), and Nickel-63 (NI-63) analyses were performed in 2016 on 50 samples from 11 groundwater and 1 surface water location. All results were less than their respective LLDs.

II. Introduction

The Zion Nuclear Power Station (ZNPS), consisting of two 1,100 MWt pressurized water reactor was owned and operated by Exelon Corporation, 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. 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 Environmental Inc. (Midwest Labs) on samples collected in 2016.

A. Objective of the RGPP

The long-term objectives of the RGPP are as follows:

1. Identify suitable locations to monitor and evaluate potential impacts from station operations before significant radiological impact to the environment and potential drinking water sources.

2. Understand the local hydrogeologic regime in the vicinity of the station and maintain up-to-date knowledge of flow patterns on the surface and shallow subsurface.

3. Perform routine water sampling and radiological analysis of water from selected locations.

4. Report new leaks, spills, or other detections with potential radiological significance to stakeholders in a timely manner.

5. Regularly assess analytical results to identify adverse trends.

6. Take necessary corrective actions to protect groundwater resources.

7. The RGPP supports implementation of License Termination Plan (LTP) related requirements for groundwater characterization and ultimately groundwater compliance under the LTP for site release.

B. Implementation of the Objectives

The objectives identified have been implemented at Zion Nuclear Power Station as discussed below:

1. Exelon and its consultant identified locations as described in the Phase 1 study. Phase 1 studies were conducted by Conestoga

Rovers and Associates (CRA) and the results and conclusions were made available to state and federal regulators as well as the public in station specific reports.

2. The Zion Nuclear Power Station reports describe the local hydrogeologic regime. Periodically, the flow patterns on the surface and shallow subsurface are updated based on ongoing measurements. The 5-year hydrogeological report was conducted in 2016.

3. Zion Nuclear Power Station will continue to perform routine sampling and radiological analysis of water from selected locations.

4. Zion Nuclear Power Station has continued using established procedures to identify and report new leaks, spills, or other detections with potential radiological significance in a timely manner.

5. Zion Nuclear Power Station staff and consulting hydrogeologist assess analytical results on an ongoing basis to identify adverse trends.

C. Program Description

1. Sample Collection

Sample locations can be found in Table A–1 and Figure A–1, Appendix A.

Groundwater and Surface Water

Samples of water are collected, managed, transported and analyzed in accordance with approved procedures following EPA methods. Groundwater samples were collected. Sample locations, sample collection frequencies and analytical frequencies are controlled in accordance with approved station procedures. Contractor and/or station personnel are trained in the collection, preservation management, and shipment of samples, as well as in documentation of sampling events. Analytical laboratories are subject to internal quality assurance programs, industry cross-check programs, as well as nuclear industry audits. Station personnel review and evaluate all analytical data deliverables as data are received.

Analytical data results are reviewed by both station personnel and an independent hydrogeologist for adverse trends or changes to

hydrogeologic conditions.

D. Characteristics of Tritium (H-3)

Tritium (chemical symbol H-3) is a radioactive isotope of hydrogen. The most common form of tritium is tritium oxide, which is also called "tritiated water". The chemical properties of tritium are essentially those of ordinary hydrogen.

Tritiated water behaves the same as ordinary water in both the environment and the body. Tritium can be taken into the body by drinking water, breathing air, eating food, or absorption through skin. Once tritium enters the body, it disperses quickly and is uniformly distributed throughout the body. Tritium is excreted primarily through urine with a clearance rate characterized by an effective biological half-life of about 14 days. Within one month or so after ingestion, essentially all tritium is cleared. Organically bound tritium (tritium that is incorporated in organic compounds) can remain in the body for a longer period.

Tritium is produced naturally in the upper atmosphere when cosmic rays strike air molecules. Tritium is also produced during nuclear weapons explosions, as a by-product in reactors producing electricity, and in special production reactors, where the isotopes lithium-7 and/or boron-10 are activated to produce tritium. Like normal water, tritiated water is colorless and odorless. Tritiated water behaves chemically and physically like non-tritiated water in the subsurface, and therefore tritiated water will travel at the same velocity as the average groundwater velocity.

Tritium has a half-life of approximately 12.3 years. It decays spontaneously to Helium-3 (He-3). This radioactive decay releases a beta particle (low-energy electron). The radioactive decay of tritium is the source of the health risk from exposure to tritium. Tritium is one of the least dangerous radionuclides because it emits very weak radiation and leaves the body relatively quickly. Since tritium is almost always found as water, it goes directly into soft tissues and organs. The associated dose to these tissues is generally uniform and is dependent on the water content of the specific tissue.

III. Program Description

A. Sample Analysis

This section describes the general analytical methodologies used by TBE to analyze the environmental samples for radioactivity for the Zion Nuclear Power Station RGPP in 2016.

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

1. Concentrations of gamma emitters in groundwater and surface water

2. Concentrations of strontium in groundwater and surface water

3. Concentrations of tritium in groundwater and surface water

4. Concentration of gross alpha and gross beta in groundwater and surface water

5. Concentrations of Iron-55 in groundwater and surface water

6. Concentrations of Nickel-59 and Nickel-63 in groundwater and surface water

B. Data Interpretation

The radiological 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. 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 specified by federal regulation as a minimum sensitivity value that must be achieved routinely by the analytical parameter.

2. Laboratory Measurements Uncertainty

The estimated uncertainty in measurement of tritium in environmental samples is frequently on the order of 50% of the measurement value.

Statistically, the exact value of a measurement is expressed as a range with a stated level of confidence. The convention is to report results with a 95% level of confidence. The uncertainty comes from calibration standards, sample volume or weight measurements, sampling uncertainty and other factors. Zion*Solutions* reports the uncertainty of a measurement created by

statistical process (counting error) as well as all sources of error (Total Propagated Uncertainty or TPU). Each result has two values calculated. Zion*Solutions* reports the TPU by following the result with plus or minus ± the estimated sample standard deviation, as TPU, that is obtained by propagating all sources of analytical uncertainty in measurements.

Analytical uncertainties are reported at the 95% confidence level in this report for reporting consistency with the AREOR.

C. Background Analysis

A pre-operational Radiological Environmental Monitoring Program (pre-operational REMP) was conducted to establish background radioactivity levels prior to operation of the Station. The environmental media sampled and analyzed during the pre-operational REMP were atmospheric radiation, fall-out, domestic water, surface water, marine life, and foodstuffs. The results of the monitoring were detailed in the report entitled, Environmental Radiological Monitoring for Zion Nuclear Power Station, Commonwealth Edison Company, Annual Report 1973, issued May 1974.

The pre-operational REMP contained analytical results from samples collected from the surface water and groundwater.

Tritium levels in Lake Michigan water were studied in the vicinity of Zion Station throughout 1970. The concentration of tritium in the surface water samples from the Lake at Zion ranged from approximately 311 ± 20 pCi/L to 374 ± 34 pCi/L and averaged 340 pCi/L. There was no statistical difference in average tritium concentrations among the stations (eight stations from Kenosha to Waukegan).

Prior to 1998, surface water samples were collected at the following six locations along Lake Michigan:

- Kenosha, Wisconsin (intake located 10 miles north of the station)
- Lake County Public Water District (intake located 1.1 miles north of the Station)
- Waukegan, Illinois (intake located 6 miles south of the Station)
- North Chicago, Illinois (intake located 10 miles south of the Station)
- Great Lakes NTS (intake located 13 miles south of the Station)
- Lake Forest, Illinois (intake located 16.5 miles south of the Station)

After 1998, surface water samples were collected at the following four locations along Lake Michigan:

- Kenosha, Wisconsin (intake located 10 miles north of the station)
- Lake County Public Water District (intake located 1.1 miles north of the Station)
- Waukegan, Illinois (intake located 6 miles south of the Station)
- Lake Forest, Illinois (intake located 16.5 miles south of the Station)

Lake Michigan surface water data are collected as part of the REMP. Tritium concentrations in surface water samples from Lake Michigan taken between 1973 and 2012 have ranged from non-detect to 660 pCi/L.

Groundwater was collected from one off-site well on a quarterly basis. Gamma isotopic, Iron-55, Nickel-59, Nickel-63, Strontium-90 and tritium analyses were performed on all samples. Fe-55, Ni-59, Ni-63, Sr-90, tritium and gamma emitters were below their respective LLDs.

1. Background Concentrations of Tritium

   The purpose of the following discussion is to summarize background measurements of tritium in various media performed by others. Additional detail may be found by consulting references (CRA 2006).

   a. Tritium Production

      Tritium is created in the environment from naturally-occurring processes both cosmic and subterranean, as well as from anthropogenic (i.e., man-made) sources. In the upper atmosphere, "Cosmogenic" tritium is produced from the bombardment of stable nuclides and combines with oxygen to form tritiated water, which will then enter the hydrologic cycle. Below ground, "lithogenic" tritium is produced by the bombardment of natural lithium present in crystalline rocks by neutrons produced by the radioactive decay of naturally abundant uranium and thorium. Lithogenic production of tritium is usually negligible compared to other sources due to the limited abundance of lithium in rock. The lithogenic tritium is introduced directly to groundwater.

      A major anthropogenic source of tritium and Sr-90 comes from the former atmospheric testing of thermonuclear weapons. Levels of tritium in precipitation increased significantly during the 1950s and early 1960s, and later with additional testing, resulting in the release of significant

amounts of tritium to the atmosphere. The Canadian heavy water nuclear power reactors, other commercial power reactors, nuclear research and weapons production continue to influence tritium concentrations in the environment.

b. Precipitation Data

Precipitation samples are routinely collected at stations around the world for the analysis of tritium and other radionuclides. Two publicly available databases that provide tritium concentrations in precipitation are Global Network of Isotopes in Precipitation (GNIP) and USEPA's RadNet database. GNIP provides tritium precipitation concentration data for samples collected worldwide from 1960 to 2006. RadNet provides tritium precipitation concentration data for samples collected at stations throughout the U.S. from 1960 up to and including 2006. Based on GNIP data for sample stations located in the U.S. Midwest, tritium concentrations peaked around 1963. This peak, which approached 10,000 pCi/L for some stations, coincided with the atmospheric testing of thermonuclear weapons. Tritium concentrations in surface water showed a sharp decline up until 1975 followed by a gradual decline since that time. Tritium concentrations in Midwest precipitation have typically been below 100 pCi/L since around 1980. Tritium concentrations in wells may still be above the 200 pCi/L detection limit from the external causes described above. Water from previous years and decades is naturally captured in groundwater, so some well water sources today are affected by the surface water from the 1960s that were elevated in tritium.

c. Surface Water Data

Tritium concentrations are routinely measured in large surface water bodies, including Lake Michigan and the Mississippi River. Illinois surface water data were typically less than 100 pCi/L.

The USEPA RadNet surface water data typically has a reported 'Combined Standard Uncertainty' of 35 to 50 pCi/L. According to USEPA, this corresponds to a ± 70 to 100 pCi/L 95% confidence bound on each given measurement. Therefore, the typical background data provided may be subject to measurement uncertainty of approximately ± 70 to 100 pCi/L.

The radio-analytical laboratory is counting tritium results to an Exelon specified LLD of 200 pCi/L. Typically, the lowest positive measurement will be reported within a range of 40 – 240 pCi/L or 140 ± 100 pCi/L. Clearly, these sample results cannot be distinguished as different from background at this concentration.

IV. Results and Discussion

A. Groundwater and Surface Water Results

Groundwater and Surface Water

Samples were collected from on-site wells throughout the year in accordance with the station radiological groundwater protection program. Analytical results and anomalies are discussed below.

Tritium

Samples from all locations were analyzed for tritium activity (Table B–I.1, Appendix B) (Table B–II.1, Appendix B). Tritium was not detected in any groundwater or surface water samples analyzed. Zion Nuclear Power Station does not have any off-site wells.

Strontium

Sr-90 was not detected in any of the samples analyzed in 2016.

Iron

Iron-55 was not detected in any of the samples analyzed in 2016.

Nickel

Nickel-59 and Nickel-63 were not detected in any of the samples analyzed in 2016.

Gross Alpha and Gross Beta (Dissolved and Suspended)

Gross Alpha and Gross Beta analyses in the dissolved and suspended fractions were performed on groundwater water samples during all four quarters of sampling in 2016. Gross Alpha (dissolved) and Gross Alpha (suspended) was not detected at any of the locations. Gross Beta (dissolved) was detected at all 44 samples. The concentrations ranged

from 1.6 to 15.7 pCi/L. Gross Beta (suspended) was not detected in any of the groundwater locations.

Gross Alpha and Gross Beta analyses in the dissolved and suspended fractions were performed on surface water samples during all four quarters of sampling in 2016. Gross Alpha (dissolved) and Gross Alpha (suspended) was not detected in any of the surface water locations. Gross Beta (dissolved) was detected in four surface water samples at one surface water location. The concentrations ranged from 1.6 to 11.4 pCi/L. Gross Beta (suspended) was not detected in any of the surface water locations

Dissolved Gross Alpha and Dissolved Gross Beta are detectable in samples from background isotopes. A more detailed discussion on where these isotopes come from is explained later in this section. The concentration range of the isotopes can be found in (Table B–I.1, Appendix B) (Table B–II.1, Appendix B).

Gamma Emitters

Naturally-occurring K-40 was detected in 6 of 48 samples analyzed. The concentrations ranged from 37 to 162 pCi/L. All other gamma-emitting radionuclides were not detected in either groundwater or surface water samples analyzed (Table B–I.2, Appendix B) (Table B–II.1, Appendix B).

Other Naturally-occurring Isotopes

Gross Beta activity present in the environment may be detected from the following sources: Beryllium-7 (Be-7) and tritium (H-3) produced in the upper atmosphere when galactic rays strike nitrogen atoms, which then may reach the ground during precipitation. Gross Beta may also be detected from Cesium-137 (Cs-137) from past atomic bomb testing as it is still detectable in the environment. K-40 is a naturally-occurring radioactive isotope that occurs as a percentage of all stable isotopes of potassium. Gross alpha can occur as naturally-occurring uranium in soil undergoes decay to form radon gases and in this decay chain, many isotopes of alpha-emitting radionuclides are present.

B. Drinking Water Well Survey

A drinking water well survey was conducted during the summer 2006 by CRA (CRA 2006) around the Zion Nuclear Power Station.

C. Summary of Results – Inter-Laboratory Comparison Program

Inter-Laboratory Comparison Program results for TBE and Environmental

Inc. (Midwest Labs) are presented in the AREOR.

D. Leaks, Spills, and Releases

On 7/25/16 heavy rains accompanied by a roof drain pipe leaking into the fuel handling building truck bay caused water to run across the floor and some water leaked out from the floor pad of the truck bay and into the road base surrounding the truck bay. The overflow was less than reportable quantities. Nearby well samples were taken as follow-up. No indication of intrusion of contaminated water into the groundwater and the area is already in a zone marked for remediation after demolition of the fuel handling building.

E. Trends

There are no previously identified plumes; therefore, there are no trends.

F. Investigations

There are currently no investigations at this time.

G. Actions Taken

1. Compensatory Actions

   There have been no station events requiring compensatory actions at the Zion Nuclear Power Station.

2. Installation of Monitoring Wells

   No new wells were required to be installed.

3. Actions to Recover/Reverse Plumes

   There have been no station events requiring actions to recover/reverse any plumes.

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APPENDIX A

LOCATION & DIRECTION

TABLE A-1: Sampling Locations and Distance for the Radiological Groundwater Protection Program, Zion Station, 2016

Site	Site Type	Temporary/Permanent	Distance
MW-ZN-01S	Monitoring Well	Permanent	On-Site
MW-ZN-02S	Monitoring Well	Permanent	On-Site
MW-ZN-03S	Monitoring Well	Permanent	On-Site
MW-ZN-04S	Monitoring Well	Permanent	On-Site
MW-ZN-05S	Monitoring Well	Permanent	On-Site
MW-ZN-06S	Monitoring Well	Permanent	On-Site
MW-ZN-07S	Monitoring Well	Permanent	On-Site
MW-ZN-08S	Monitoring Well	Permanent	On-Site
MW-ZN-09S	Monitoring Well	Permanent	On-Site
MW-ZN-10S	Monitoring Well	Permanent	On-Site
MW-ZN-11S	Monitoring Well	Permanent	On-Site
SW-ZN-01	Surface Water	Lake Michigan	On-Site

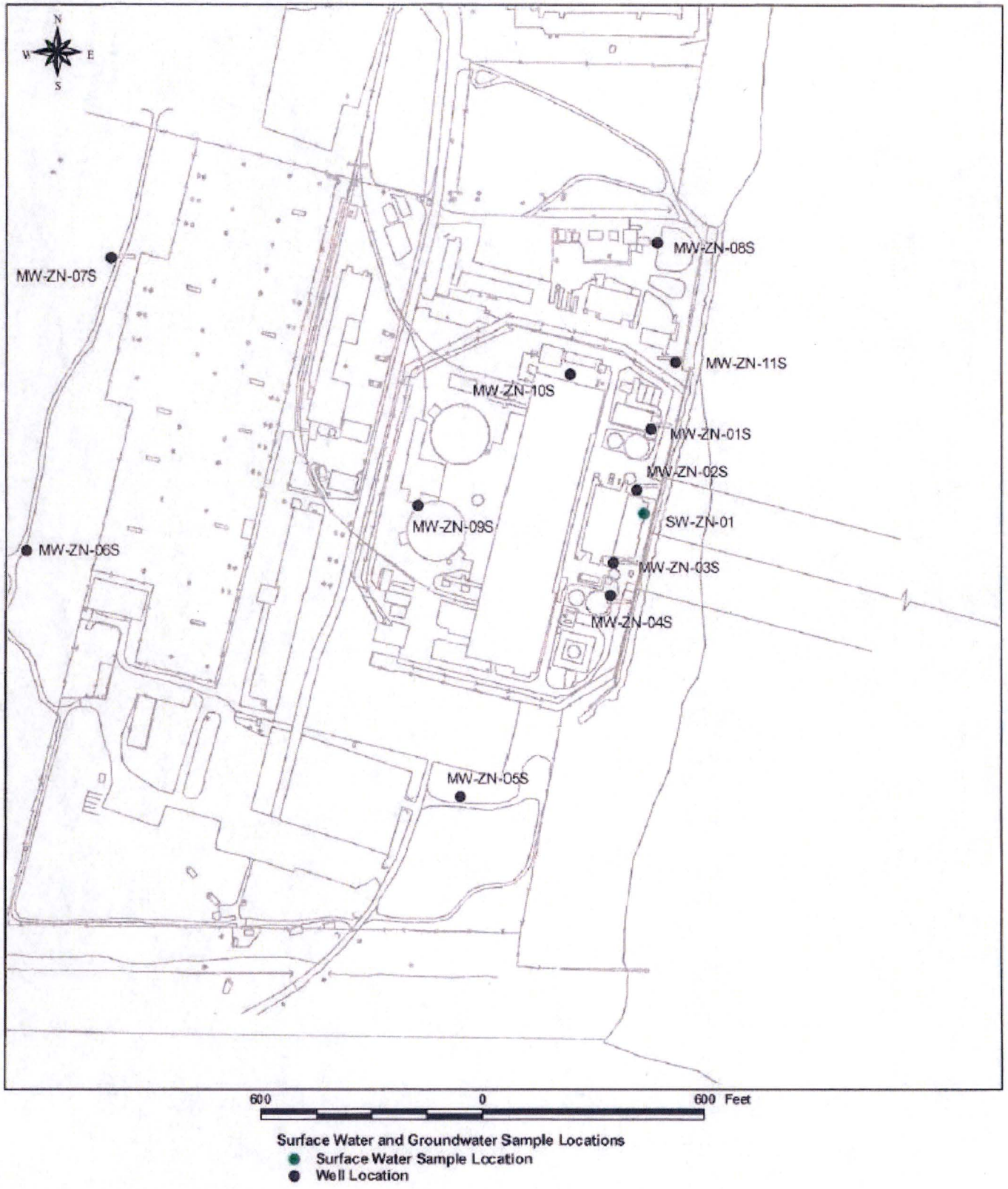

Figure A-1

Radiological Ground Water Protection Program
Groundwater and Surface Water Locations of the Zion Station, 2016

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APPENDIX B

DATA TABLES

TABLE B-I.1

CONCENTRATIONS OF TRITIUM, STRONTIUM, GROSS ALPHA AND GROSS BETA IN GROUNDWATER SAMPLES COLLECTED IN THE VICINITY OF ZION NUCLEAR POWER STATION, 2016

RESULTS IN UNITS OF PCI/LITER ± 2 SIGMA

SITE	COLLECTION DATE	H-3	Sr-90	Gr-A (Dis)	Gr-A (Sus)	Gr-B (Dis)	Gr-B (Sus)
MW-ZN-01S	03/09/16	< 185	< 0.4	< 2.2	< 0.5	8.8 ± 1.4	< 1.6
MW-ZN-01S	05/03/16	< 184	< 1.0	< 2.5	< 0.5	10.8 ± 1.5	< 1.6
MW-ZN-01S	08/02/16	< 182	< 0.6	< 1.7	< 0.5	6.9 ± 1.2	< 1.5
MW-ZN-01S	11/13/16	< 194	< 0.9	< 1.6	< 0.6	8.6 ± 1.2	< 1.6
MW-ZN-02S	03/09/16	< 184	< 0.4	< 1.6	< 0.5	6.3 ± 1.1	< 1.6
MW-ZN-02S	05/03/16	< 177	< 0.6	< 2.1	< 0.5	9.6 ± 1.4	< 1.6
MW-ZN-02S	08/02/16	< 180	< 0.8	< 1.5	< 0.5	8.6 ± 1.2	< 1.5
MW-ZN-02S	11/13/16	< 196	< 0.6	< 1.4	< 0.6	7.4 ± 1.1	< 1.6
MW-ZN-03S	03/08/16	< 183	< 0.8	< 1.6	< 0.5	4.8 ± 1.0	< 1.6
MW-ZN-03S	05/03/16	< 176	< 0.8	< 4.6	< 0.5	11.8 ± 1.7	< 1.6
MW-ZN-03S	08/03/16	< 177	< 0.7	< 2.3	< 0.5	9.1 ± 1.5	< 1.5
MW-ZN-03S	11/13/16	< 197	< 0.8	< 4.5	< 0.6	10.5 ± 1.6	< 1.6
MW-ZN-04S	03/08/16	< 181	< 0.8	< 3.7	< 0.5	15.7 ± 1.8	< 1.6
MW-ZN-04S	05/03/16	< 178	< 0.9	< 2.8	< 0.5	12.9 ± 1.6	< 1.6
MW-ZN-04S	08/03/16	< 180	< 0.6	< 2.4	< 0.5	11.3 ± 1.5	< 1.5
MW-ZN-04S	11/12/16	< 200	< 0.6	< 2.0	< 0.6	14.7 ± 1.7	< 1.6
MW-ZN-05S	03/08/16	< 185	< 0.7	< 1.4	< 0.5	5.2 ± 1.4	< 1.6
MW-ZN-05S	05/02/16	< 177	< 0.6	< 1.4	< 0.5	5.0 ± 1.3	< 1.6
MW-ZN-05S	08/01/16	< 177	< 0.6	< 1.3	< 0.5	4.1 ± 1.2	< 1.5
MW-ZN-05S	11/11/16	< 198	< 0.6	< 1.5	< 0.6	4.1 ± 1.1	< 1.6
MW-ZN-06S	03/07/16	< 183	< 0.5	< 1.7	< 0.5	6.1 ± 1.5	< 1.6
MW-ZN-06S	05/04/16	< 178	< 0.7	< 1.4	< 0.5	6.3 ± 1.4	< 1.6
MW-ZN-06S	08/08/16	< 179	< 0.7	< 1.6	< 0.5	5.4 ± 1.4	< 1.5
MW-ZN-06S	11/12/16	< 196	< 0.6	< 1.6	< 0.6	5.3 ± 1.3	< 1.6
MW-ZN-07S	03/09/16	< 183	< 0.8	< 1.9	< 0.5	6.7 ± 1.6	< 1.6
MW-ZN-07S	05/04/16	< 178	< 0.7	< 1.8	< 0.8	5.4 ± 1.5	< 1.7
MW-ZN-07S	08/08/16	< 185	< 0.6	< 1.8	< 0.7	3.5 ± 1.4	< 1.7
MW-ZN-07S	11/13/16	< 194	< 0.6	< 1.7	< 0.4	4.6 ± 1.3	< 1.6
MW-ZN-08S	03/07/16	< 182	< 0.4	< 2.3	< 0.5	6.3 ± 1.6	< 1.6
MW-ZN-08S	05/02/16	< 175	< 0.9	< 1.6	< 0.8	7.6 ± 1.5	< 1.6
MW-ZN-08S	08/02/16	< 180	< 0.6	< 1.4	< 0.6	4.8 ± 1.3	< 1.6
MW-ZN-08S	11/11/16	< 200	< 0.7	< 1.4	< 0.3	5.0 ± 1.2	< 1.6
MW-ZN-09S	03/07/16	< 187	< 0.4	< 1.3	< 0.5	8.2 ± 1.3	< 1.6
MW-ZN-09S	05/03/16	< 177	< 0.6	< 1.3	< 0.8	4.9 ± 0.9	< 1.6
MW-ZN-09S	08/08/16	< 178	< 0.5	< 1.8	< 0.6	11.2 ± 1.5	< 1.6
MW-ZN-09S	11/11/16	< 200	< 0.5	< 0.9	< 0.3	3.7 ± 0.8	< 1.6
MW-ZN-10S	03/08/16	< 184	< 0.4	< 1.8	< 0.5	15.2 ± 1.7	< 1.6
MW-ZN-10S	05/03/16	< 179	< 0.6	< 1.7	< 0.8	7.6 ± 1.3	< 1.6
MW-ZN-10S	08/01/16	< 181	< 0.6	< 1.9	< 0.6	10.4 ± 1.5	< 1.6
MW-ZN-10S	11/12/16	< 197	< 0.8	< 1.5	< 0.3	7.8 ± 1.2	< 1.6
MW-ZN-11S	03/07/16	< 178	< 0.5	< 1.7	< 0.5	7.8 ± 1.5	< 1.6
MW-ZN-11S	5/2/2016	< 179	< 0.7	< 1.8	< 0.8	8.7 ± 1.4	< 1.6
MW-ZN-11S	8/1/2016	< 180	< 0.5	< 1.8	< 0.6	8.1 ± 1.4	< 1.6
MW-ZN-11S	11/11/16	< 198	< 0.7	< 1.5	< 0.3	7.3 ± 1.2	< 1.6

TABLE B-I.1

CONCENTRATIONS OF GAMMA EMITTERS IN GROUNDWATER SAMPLES COLLECTED IN THE VICINITY OF ZION NUCLEAR STATION, 2016

RESULTS IN UNITS OF PCI/LITER ± 2 SIGMA

SITE	COLLECTION DATE	Be-7	K-40	Mn-54	Co-58	Fe-59	Co-60	Zn-65	Nb-95	Zr-95	Cs-134	Cs-137	Ba-140	La-140
MW-ZN-01S	03/09/16	< 85	< 108	< 6	< 7	< 17	< 8	< 20	< 9	< 11	< 7	< 4	< 96	< 36
MW-ZN-01S	05/03/16	< 16	< 30	< 2	< 2	< 3	< 2	< 3	< 2	< 3	< 2	< 2	< 12	< 4
MW-ZN-01S	08/02/16	< 79	< 42	< 7	< 6	< 19	< 7	< 12	< 7	< 16	< 5	< 5	< 179	< 59
MW-ZN-01S	11/13/16	< 56	< 40	< 5	< 7	< 17	< 6	< 12	< 7	< 11	< 5	< 6	< 67	< 23
MW-ZN-02S	03/09/16	< 46	< 38	< 4	< 5	< 12	< 4	< 9	< 5	< 10	< 3	< 4	< 56	< 16
MW-ZN-02S	05/03/16	< 34	< 34	< 4	< 4	< 8	< 4	< 8	< 4	< 7	< 4	< 4	< 24	< 9
MW-ZN-02S	08/02/16	< 68	< 75	< 6	< 7	< 19	< 6	< 11	< 7	< 12	< 5	< 5	< 158	< 52
MW-ZN-02S	11/13/16	< 49	162 ± 73	< 5	< 5	< 11	< 5	< 9	< 6	< 10	< 5	< 5	< 56	< 17
MW-ZN-03S	03/08/16	< 51	< 45	< 5	< 6	< 12	< 5	< 10	< 6	< 10	< 5	< 5	< 69	< 24
MW-ZN-03S	05/03/16	< 26	< 23	< 3	< 3	< 6	< 3	< 5	< 3	< 5	< 3	< 3	< 18	< 6
MW-ZN-03S	08/03/16	< 70	< 44	< 4	< 6	< 19	< 5	< 12	< 8	< 12	< 5	< 5	< 157	< 50
MW-ZN-03S	11/13/16	< 46	< 41	< 4	< 5	< 11	< 4	< 11	< 5	< 8	< 4	< 4	< 53	< 17
MW-ZN-04S	03/08/16	< 50	< 38	< 4	< 5	< 12	< 5	< 7	< 5	< 9	< 4	< 5	< 59	< 18
MW-ZN-04S	05/03/16	< 17	< 17	< 2	< 2	< 4	< 2	< 4	< 2	< 4	< 2	< 2	< 13	< 5
MW-ZN-04S	08/03/16	< 72	< 58	< 6	< 8	< 20	< 5	< 11	< 8	< 13	< 5	< 6	< 160	< 57
MW-ZN-04S	11/12/16	< 57	< 102	< 5	< 6	< 15	< 5	< 11	< 7	< 10	< 4	< 5	< 61	< 20
MW-ZN-05S	03/08/16	< 51	< 53	< 6	< 6	< 15	< 5	< 8	< 6	< 8	< 5	< 5	< 71	< 18
MW-ZN-05S	05/02/16	< 27	< 26	< 3	< 3	< 7	< 3	< 6	< 3	< 5	< 3	< 3	< 21	< 6
MW-ZN-05S	08/01/16	< 67	< 36	< 4	< 7	< 17	< 5	< 10	< 7	< 11	< 4	< 5	< 203	< 45
MW-ZN-05S	11/11/16	< 55	< 88	< 6	< 7	< 8	< 6	< 9	< 6	< 11	< 5	< 5	< 75	< 21
MW-ZN-06S	03/07/16	< 44	< 133	< 3	< 4	< 6	< 3	< 10	< 6	< 7	< 4	< 3	< 65	< 16
MW-ZN-06S	05/04/16	< 15	< 28	< 2	< 2	< 4	< 2	< 3	< 2	< 3	< 1	< 2	< 11	< 4
MW-ZN-06S	08/08/16	< 64	< 110	< 5	< 6	< 16	< 4	< 9	< 6	< 12	< 5	< 4	< 107	< 33
MW-ZN-06S	11/12/16	< 46	< 75	< 4	< 5	< 12	< 4	< 8	< 6	< 9	< 4	< 4	< 50	< 10
MW-ZN-07S	03/09/16	< 51	< 46	< 5	< 6	< 13	< 5	< 9	< 6	< 11	< 5	< 5	< 74	< 22
MW-ZN-07S	05/04/16	< 24	< 22	< 2	< 3	< 5	< 3	< 5	< 3	< 5	< 2	< 3	< 18	< 6
MW-ZN-07S	08/08/16	< 69	< 47	< 6	< 7	< 15	< 4	< 12	< 7	< 10	< 5	< 6	< 118	< 33
MW-ZN-07S	11/13/16	< 54	< 40	< 5	< 4	< 10	< 4	< 10	< 5	< 9	< 4	< 5	< 55	< 16
MW-ZN-08S	03/07/16	< 26	< 47	< 2	< 2	< 6	< 2	< 4	< 3	< 5	< 2	< 2	< 37	< 11
MW-ZN-08S	05/02/16	< 21	< 20	< 2	< 2	< 5	< 2	< 5	< 2	< 4	< 2	< 2	< 16	< 5.9
MW-ZN-08S	08/02/16	< 63	< 43	< 5	< 8	< 18	< 4	< 12	< 7	< 12	< 5	< 6	< 166	< 69
MW-ZN-08S	11/11/16	< 56	< 53	< 6	< 6	< 15	< 5	< 13	< 7	< 11	< 5	< 5	< 70	< 24
MW-ZN-09S	03/07/16	< 20	< 17	< 2	< 2	< 5	< 2	< 4	< 2	< 4	< 2	< 2	< 32	< 9.9
MW-ZN-09S	05/03/16	< 17	44 ± 25	< 2	< 2	< 4	< 2	< 3	< 2	< 3	< 2	< 2	< 11	< 4
MW-ZN-09S	08/08/16	< 58	< 118	< 6	< 7	< 20	< 7	< 11	< 8	< 14	< 6	< 6	< 138	< 46
MW-ZN-09S	11/11/16	< 52	< 88	< 5	< 6	< 13	< 5	< 10	< 7	< 9	< 4	< 4	< 59	< 19
MW-ZN-10S	03/08/16	< 25	62 ± 31	< 2	< 2	< 6	< 2	< 5	< 3	< 4	< 2	< 2	< 38	< 13
MW-ZN-10S	05/03/16	< 23	< 21	< 2	< 2	< 5	< 2	< 5	< 3	< 5	< 3	< 2	< 17	< 5
MW-ZN-10S	08/01/16	< 72	< 39	< 5	< 6	< 16	< 4	< 10	< 8	< 13	< 6	< 5	< 195	< 48
MW-ZN-10S	11/12/16	< 52	107 ± 59	< 5	< 5	< 11	< 5	< 10	< 5	< 10	< 5	< 5	< 67	< 17
MW-ZN-11S	03/07/16	< 19	38 ± 22	< 2	< 2	< 5	< 1	< 3	< 2	< 4	< 2	< 2	< 28	< 9
MW-ZN-11S	05/02/16	< 20	< 14	< 2	< 2	< 5	< 2	< 3	< 2	< 4	< 2	< 2	< 31	< 9
MW-ZN-11S	08/01/16	< 63	< 101	< 6	< 7	< 16	< 4	< 11	< 7	< 11	< 4	< 5	< 155	< 52
MW-ZN-11S	11/11/16	< 50	< 46	< 5	< 5	< 12	< 4	< 10	< 6	< 9	< 4	< 5	< 61	< 20

TABLE B-I.3 CONCENTRATIONS OF IRON-55 AND NICKEL-63 IN GROUNDWATER SAMPLES COLLECTED IN THE VICINITY OF ZION NUCLEAR STATION, 2015

RESULTS IN UNITS OF PCI/LITER ± 2 SIGMA

SITE	COLLECTION DATE	Fe-55	Ni-59	Ni-63
MW-ZN-01S	03/09/16	< 151	< 79	< 4.9
MW-ZN-01S	05/03/16	< 96	< 97	< 3.7
MW-ZN-01S	08/02/16	< 164	< 52	< 3.4
MW-ZN-01S	11/13/16	< 147	< 39	< 3.2
MW-ZN-02S	03/09/16	< 168	< 46	< 4.7
MW-ZN-02S	05/03/16	< 95	< 101	< 3.7
MW-ZN-02S	08/02/16	< 122	< 33	< 3.4
MW-ZN-02S	11/13/16	< 101	< 45	< 3.1
MW-ZN-03S	03/08/16	< 185	< 97	< 4.3
MW-ZN-03S	05/03/16	< 177	< 34	< 3.8
MW-ZN-03S	08/03/16	< 178	< 34	< 3.2
MW-ZN-03S	11/13/16	< 123	< 42	< 3.2
MW-ZN-04S	03/08/16	< 153	< 88	< 4.8
MW-ZN-04S	05/03/16	< 162	< 48	< 3.7
MW-ZN-04S	08/03/16	< 156	< 39	< 3.3
MW-ZN-04S	11/12/16	< 162	< 96	< 3.1
MW-ZN-05S	03/08/16	< 190	< 69	< 4.8
MW-ZN-05S	05/02/16	< 156	< 69	< 3.8
MW-ZN-05S	08/01/16	< 135	< 30	< 3.3
MW-ZN-05S	11/11/16	< 125	< 68	< 3.1
MW-ZN-06S	03/07/16	< 143	< 92	< 4.2
MW-ZN-06S	05/04/16	< 188	< 63	< 3.9
MW-ZN-06S	08/08/16	< 61	< 25	< 3.3
MW-ZN-06S	11/12/16	< 180	< 83	< 3.2
MW-ZN-07S	03/09/16	< 161	< 88	< 4.0
MW-ZN-07S	05/04/16	< 139	< 64	< 3.9
MW-ZN-07S	08/08/16	< 152	< 40	< 3.3
MW-ZN-07S	11/13/16	< 190	< 42	< 3.2
MW-ZN-08S	03/07/16	< 152	< 61	< 4.0
MW-ZN-08S	05/02/16	< 147	< 54	< 3.7
MW-ZN-08S	08/02/16	< 160	< 27	< 3.4
MW-ZN-08S	11/11/16	< 181	< 63	< 3.6
MW-ZN-09S	03/07/16	< 153	< 70	< 3.9
MW-ZN-09S	05/03/16	< 164	< 67	< 3.6
MW-ZN-09S	08/08/16	< 142	< 49	< 3.3
MW-ZN-09S	11/11/16	< 69	< 108	< 3.6
MW-ZN-10S	03/08/16	< 177	< 69	< 3.8
MW-ZN-10S	05/03/16	< 162	< 95	< 3.7
MW-ZN-10S	08/01/16	< 169	< 34	< 3.4
MW-ZN-10S	11/12/16	< 181	< 96	< 3.2
MW-ZN-11S	03/07/16	< 157	< 58	< 3.8
MW-ZN-11S	05/02/16	< 141	< 86	< 3.8
MW-ZN-11S	08/01/16	< 115	< 40	< 3.3
MW-ZN-11S	11/11/16	< 194	< 42	< 3.2

TABLE B-II.1 **CONCENTRATIONS OF TRITIUM, STRONTIUM, GROSS ALPHA AND GROSS BETA IN SURFACE WATER SAMPLES COLLECTED IN THE VICINITY OF ZION NUCLEAR POWER STATION, 2015**

RESULTS IN UNITS OF PCI/LITER ± 2 SIGMA

SITE	COLLECTION DATE	H-3	Sr-90	Gr-A (Dis)	Gr-A (Sus)	Gr-B (Dis)	Gr-B (Sus)
SW-ZN-01	03/08/16	< 181	< 0.4	< 0.9	< 0.5	3.5 ± 0.8	< 1.6
SW-ZN-01	05/03/16	< 178	< 0.7	< 1.0	< 0.8	11.4 ± 1.1	< 1.6
SW-ZN-01	08/02/16	< 181	< 0.5	< 0.9	< 0.6	1.6 ± 0.7	< 1.6
SW-ZN-01	11/13/16	< 197	< 0.6	< 0.9	< 0.3	2.2 ± 0.7	< 1.6

TABLE B-II.2

CONCENTRATIONS OF GAMMA EMITTERS IN SURFACE WATER SAMPLES COLLECTED IN THE VICINITY OF ZION NUCLEAR STATION, 2016

RESULTS IN UNITS OF PCI/LITER ± 2 SIGMA

SITE	COLLECTION DATE	Be-7	K-40	Mn-54	Co-58	Fe-59	Co-60	Zn-65	Nb-95	Zr-95	Cs-134	Cs-137	Ba-140	La-140
SW-ZN-01	03/08/16	< 19	< 15	< 2	< 2	< 5	< 2	< 3	< 2	< 4	< 2	< 2	< 28	< 9
SW-ZN-01	05/03/16	< 15	54 ± 23	< 1	< 2	< 3	< 1	< 3	< 2	< 3	< 1	< 2	< 11	< 3
SW-ZN-01	08/02/16	< 79	< 52	< 6	< 6	< 19	< 5	< 13	< 7	< 13	< 5	< 5	< 177	< 53
SW-ZN-01	11/13/16	< 55	< 44	< 5	< 6	< 12	< 5	< 9	< 6	< 11	< 4	< 5	< 64	< 15

TABLE B-II.3 CONCENTRATIONS OF IRON-55 AND NICKEL-63 IN SURFACE WATER SAMPLES COLLECTED IN THE VICINITY OF ZION NUCLEAR STATION, 2016

RESULTS IN UNITS OF PCI/LITER ± 2 SIGMA

SITE	COLLECTION DATE	Fe-55	Ni-59	Ni-63
SW-ZN-01	03/08/16	< 137	< 94	< 3.7
SW-ZN-01	05/03/16	< 133	< 88	< 3.6
SW-ZN-01	08/02/16	< 123	< 45	< 3.2
SW-ZN-01	11/13/16	< 124	< 107	< 3.5