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ZION NUCLEAR POWER STATION
UNITS 1 and 2

Annual Radiological Groundwater Protection Program Report

1 January through 31 December 2016

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Table Of Contents

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 groundwater 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 in all 44 samples.

The concentrations ranged from 3.5 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 all four surface water samples at one location. The concentrations ranged from 1.6 to 11.4 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), Nickel-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. <u>Lower Limit of Detection and Minimum Detectable Concentration</u>

   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. <u>Laboratory Measurements Uncertainty</u>

   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.

<u>Tritium</u>

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.

<u>Strontium</u>

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

<u>Iron</u>

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

<u>Nickel</u>

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

<u>Gross Alpha and Gross Beta (Dissolved and Suspended)</u>

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 3.5 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 Appendix B, Table B–I.1 and Table B–II.1.

<u>Gamma Emitters</u>

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).

<u>Other Naturally-occurring Isotopes</u>

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.

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

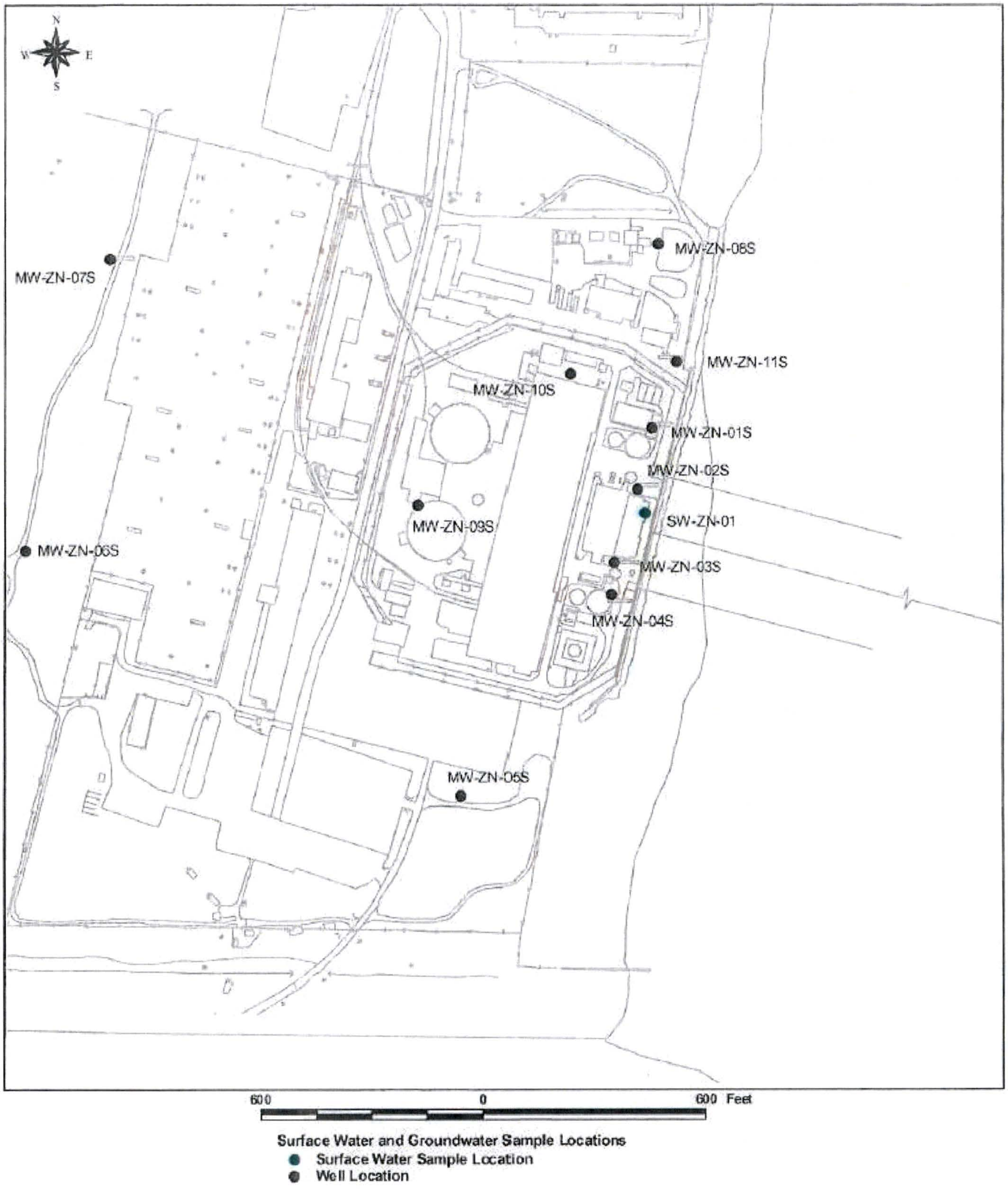

Figure A-1

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.2

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