ZIONSOLUTIONS LLC
An EnergySolutions Company

March 28, 2022

ZS-2022-010

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

Zion Nuclear Power Station, Units 1 and 2
Facility Operating License Nos. DPR-39 and DPR-48
NRC Docket Nos. 50-295 and 50-304

Subject: Revised Response to Request for Additional Information Related to Partial Site Release and Recent Site Survey Activities

References:

1) Marlayna V. Doell, U.S. Nuclear Regulatory Commission, Letter to John Sauger, Zion*Solutions,* "Zion Nuclear Power Station Units 1 and 2 - Request for Additional Information Related to Partial Site Release and Recent Site Survey Activities," dated August 19, 2021

2) Kim A. Conway, U.S. Nuclear Regulatory Commission, Letter to John Sauger, Zion*Solutions,* "Zion Nuclear Power Station Units 1 and 2 - Request for Additional Information Related to Partial Site Release and Recent Site Survey Activities," dated October 14, 2021

3) Gerard van Noordennen, Zion*Solutions*, Letter to U.S. Nuclear Regulatory Commission, "Response to Request for Additional Information Related to Partial Site Release and Recent Site Survey Activities, and Notification of Foundation Pad Discovery," dated March 8, 2022

Zion*Solutions* received Requests for Additional Information (RAIs), related to the partial site release request and site survey activities, on August 19, 2021 (Reference 1) and October 14, 2021 (Reference 2). On March 8, 2022, Zion*Solutions* provided responses to the RAIs (References 1 and 2) as documented in Reference 3.

In reviewing post-processing survey data, Zion*Solutions* identified that a conservative calculation of the minimum detectable activity for the investigation areas was made. Therefore, the responses to the RAIs provided in Reference 3 have been revised to reflect the net count rate of the towed-array versus the gross count rate. This revision reflects a more realistic and lower discrete radioactivity particle activity sensitivity for identifying an area for investigation using post-processing methods for the towed-array surveys.

The purpose of this letter is to provide the revised responses to the RAIs related to the partial site release request and site survey activities; the revised responses replace the previous responses, provided in Reference 3, in their entirety. The revised responses to the RAIs are provided in the attachment to this letter. A revision bar is used to show where RAI responses were revised.

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If you should have any questions regarding this submittal, please contact me at (860) 462-9707.

Respectfully,

Gerard van Noordennen

Digitally signed by Gerard van Noordennen
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Gerard van Noordennen
Senior Vice President Regulatory Affairs

Attachment: Revised Response to Request for Additional Information Related to Partial Site Release and Recent Site Survey Activities

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Zion Nuclear Power Station, Units 1 and 2 Service List

Zion Nuclear Power Station, Units 1 and 2 Service List

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Zion*Solutions*

ZS-2022-010
Attachment

Zion Nuclear Power Station, Units 1 and 2

Revised Response to Request for Additional Information Related to Partial Site Release and Recent Site Survey Activities

Zion Nuclear Power Station, Units 1 and 2 – Request for Additional Information Related to Partial Site Release and Recent Site Survey Activities, dated August 19, 2021, and October 14, 2021

REQUEST FOR ADDITIONAL INFORMATION:

The NRC staff is reviewing the Zion FSSR and the associated partial site release request to ensure that the proposed removal of 128 survey units from the ZNPS 10 CFR Part 50 licenses demonstrates the ability of the site to meet the criteria for unrestricted release contained in Subpart E of 10 CFR Part 20. The NRC staff has reviewed the FSSR submittals and supplements provided to date, as well as the results from the April 2021 inspection survey, and determined that additional information related to current radiological conditions at the site is needed to complete its review, as described in the following RAIs. The information gathered in response to these RAIs will be used, in part, by the NRC staff to perform additional risk assessments and/or dose calculations to obtain reasonable assurance that the Zion site meets the assumptions outlined in the Zion LTP and may be released from the ZNPS 10 CFR Part 50 licenses without undue risk to public health and safety, or impact on the environment.

ZION*SOLUTIONS* OVERVIEW

Zion*Solutions* understands that the NRC staff is seeking additional information regarding the origin, release, and transport of discrete radioactive particles (DRPs) that have been discovered at the Zion site. We further understand that NRC is seeking confirmation that work at the site was performed in accordance with the Zion License Termination Plan (LTP). This information is important in order for the staff to have confidence that the site may be released from the Zion Nuclear Power Station (ZNPS) 10 CFR Part 50 licenses without undue risk to public health and safety, or impact on the environment.

Zion*Solutions* believes that the issues raised in the RAIs can be summarized as follows:

- What is the origin of the DRPs at the Zion site and how did they get where they are?
- Why were the DRPs not detected during the FSS?
- Was the work at the site conducted in accordance with the LTP?
- How can Zion*Solutions* and the NRC be confident that there are not DRPs remaining at the site that pose an unacceptably high risk to a future occupant?

In the following pages, Zion*Solutions* provides answers to each of the RAIs that address these questions. We believe that the totality of this information is adequate to justify unrestricted release of the site. In this overview, we have summarized the key issues and the justification for our conclusions.

Origin and Transport of DRPs. The DRPs that were detected and remediated during FSS and ORISE independent verification surveys come from a variety of sources. While we cannot precisely identify their source or the pathway to the location at which they were discovered, we can infer both from the radioisotopic content, type of particle, and our understanding of activities at the site. This information is useful in order to bound the scope of the problem; however, it is important to recognize that these details are not adequate to absolutely confirm that no DRPs will remain on-site. As explained below, with the additional survey and sampling measures that have been implemented by Zion*Solutions*, we believe there is reasonable assurance that there will be no DRPs posing an unacceptably high risk remaining on-site.

Adequacy of FSS and DRPs. The FSS methodology is designed consistent with NRC guidance and industry best practice to detect distributed activity that exceeds the derived concentration guideline levels (DCGLs) so that these areas may be remediated. It is not designed specifically to be sensitive for the detection of DRPs. This notwithstanding, 19 DRPs were detected during FSS. That all DRPs were not detected is not an indication that the FSS was not adequate to perform its intended function. Neither is it an indication that FSS was not executed properly. Zion*Solutions* has designed and implemented an additional survey plan to detect and remediate DRPs. The data quality objectives (DQOs) of this survey and the equipment used supplement the FSS and provide confidence that any remaining DRPs that would pose an unacceptably high risk have been identified and remediated.

Work in accordance with the LTP. Zion*Solutions* has conducted the decommissioning of the ZNPS in accordance with the requirements and commitments contained in the LTP. The execution of certain portions of this work (e.g., timing, source and depth of fill, classification of survey units, identification of radionuclides of concern (ROC), and dose calculations) has come into question due to the identification of DRPs. As described below, we are confident and have provided evidence that the work was done in accordance with the LTP. Zion*Solutions* has considered if the LTP should have been modified in response to the detection of and calculation of dose from DRPs, and if so, whether the advance approval of the NRC is required. We have concluded that revisions to Chapters 5 and 6 are necessary, and we are preparing and will submit a license amendment request (LAR) for NRC approval.

The DRP Survey Plan. Zion*Solutions* has designed and implemented a survey plan, "Survey Plan for Discrete Radioactive Particle Identification and Remediation," ZS-LT-07, Revision 1 (the "DRP Survey Plan"),[1] specifically for the purpose of detecting and removing DRPs. The

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[1] Zion*Solutions* ZS-LT-07, "Survey Plan for Discrete Radioactive Particle Identification and Remediation" Revision 1, December 2021.

DRP Survey Plan is included as part of the Zion*Solutions* response to RAI-10. Following the execution of the DRP Survey Plan, there will be no known DRPs remaining on the Zion site. Based on the completion of the survey and investigations, an estimate of the number and activity of DRPs that may hypothetically remain has been made and the dose and risk from the hypothetical DRPs have been estimated. Any DRPs that do remain will not contain sufficient activity to pose an unacceptable risk to a future occupant of the site.

Presence of DRPs at the Zion Site. Despite the extensive work to detect and remediate DRPs, the prospect of DRPs hypothetically remaining on the Zion site cannot be dismissed. Consistent with NRC guidance in NUREG-1757, Zion*Solutions* has used a risk-based approach as described below to assess the risk of dose from a DRP that may hypothetically be left on the site. The proposed change will be incorporated into the LTP by license amendment and will supplement how Zion*Solutions* demonstrates compliance with the dose criteria for unrestricted release in Subpart E of 10 CFR Part 20. Based on our probability analysis, it is our estimation that as many as 31 DRPs could hypothetically remain on the site. We are confident based upon our implementation of additional survey and sampling measures that no DRPs that could deliver a significant dose to a member of the public, including a future occupant, remain at the site. The analyses to document and justify this conclusion are described in detail in our response to RAI-10.

Our detailed responses to each of the NRC questions enumerated in the RAIs dated August 19, 2021, and October 14, 2021, are given below. These responses justify our conclusion that the ZNPS 10 CFR Part 50 licenses can be terminated without undue risk to public health and safety, or impact on the environment.

NRC RAI-1a:

For each particle or sample identified during the April 2021 inspection survey and described above, please explain to the extent possible: The likely origin of the particle or material identified in the sample (e.g., activated metal, bioshield concrete, irradiated fuel fragments, etc.) from decommissioning operations, including the hypothetical radionuclide mix for each type of particle based on the reactor operational history of both (e.g., fuel burnup and activation).

ZION*SOLUTIONS* RESPONSE:

While the specific origin for each particle is unknown, Zion*Solutions* has postulated the most likely origin for each particle based primarily upon the radionuclide profile of each. As discussed in the February 10, 2021, response to RAI-11b, the likely origin of the majority of particles found in site soil are from reactor vessel internals (RVI) segmentation. Based upon the radionuclide profile of particles discovered by the Oak Ridge Institute for Science and Education

(ORISE) during the April 2021 inspection survey (as documented in final report 5271-SR-09-0[2]), Zion*Solutions* believes that the additional particles originated from fuel fragments, internal containment concrete (originating from under vessel or the bioshield), or welding rod residue. The internal containment concrete was likely introduced into the soil during waste handling operations. The postulated origin and hypothetical radionuclide mix for each particle is shown below in Table 1.

Table 1 – Particle Origins and Hypothetical Radionuclides

Sample	Likely Origin	Hypothetical Radionuclides
S0112A	RVI segmentation	Co-60
S0116	RVI segmentation	Co-60
S0120	Internal containment concrete	Co-60, Ba-133, Eu-152, Eu-154, Pu-238, Pu-239/240
S0124	RVI segmentation	Co-60
S0126	Fuel fragment	Co-60, Cs-137, Eu-154, Eu-155, Am-241, Cm-244, Pu-238, Pu-239/240
S204AEu	Internal containment concrete	Co-60, Ba-133, Eu-152, Eu-154, Pu-238, Pu-239/240
S203B	Welding rod residue	Ra-228, Th-228, Th-230, Th-232, U-234, U-238
5271-S-203ATh	Welding rod residue	Ra-228, Th-228, Th-230, Th-232, U-234, U-238

NRC RAI-1b:

For each particle or sample identified during the April 2021 inspection survey and described above, please explain to the extent possible: The size range of particles expected to be produced by decommissioning operations for the three types of particles identified (i.e., Co-60 metal, possible activated bioshield concrete, possible activated fuel fragment). Specifically, for the types of cutting operations above and below water and demolition activities that were performed at Zion, the range of expected particle sizes should be identified, along with technical references for the expected size range where available.

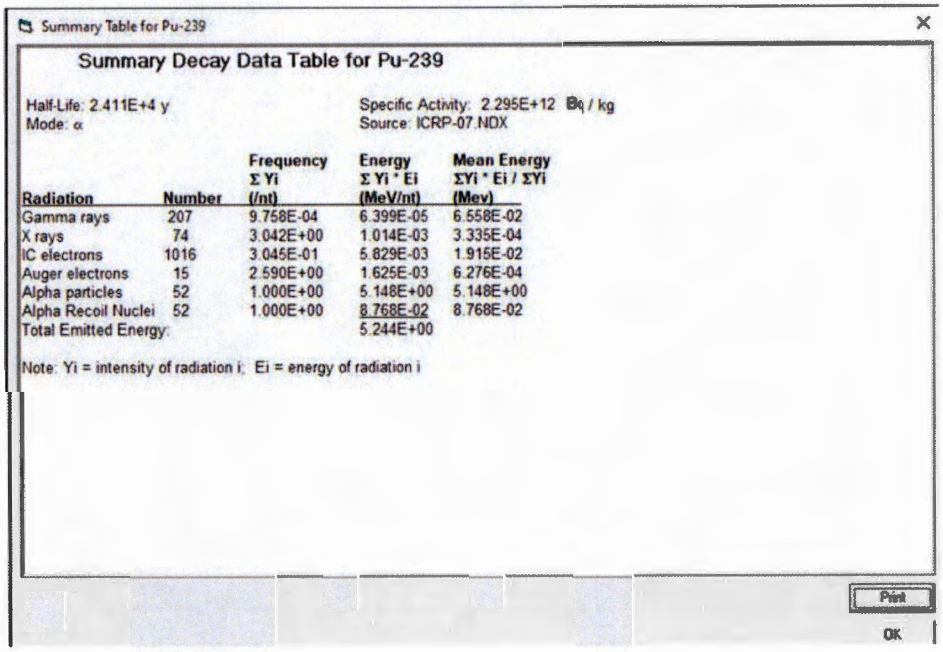
[2] "Independent Confirmatory Survey Summary and Results Assessing the Presence of Residual Radioactivity and Radioactive Particles within Select Land Area at the Zion Nuclear Power Station, Zion, Illinois," Oak Ridge Institute for Science and Education, Report No. 5271-SR-09-0, September 3, 2021.

ZION*SOLUTIONS* RESPONSE:

Co-60 Metal Particle Size. For the decommissioning of Zion, a mechanical complex tool system for underwater RVI segmentation was used. During the mockup testing of this system for Zion, particles produced were approximately 1 mm in diameter and less than 1 mm thick, as discussed in the February 10, 2021, response to RAI-11b. According to the EPRI Report, "Characterization and Management of Cutting Debris During Plant Dismantlement," mechanical techniques for RVI segmentation produce debris in the 2 mm to 6 mm range, with no airborne debris.[3]

Fuel Particle Size. The fuel particle mass was estimated using the activity and the specific activity (Bq/kg) of Pu-239 in sample S0126 (shown in Figure 1), as documented in the ORISE report 5271-SR-09-0.

Figure 1 - NRC Radiological Toolbox Specific Activity for Pu-239


Summary Table for Pu-239

Summary Decay Data Table for Pu-239

Half-Life: 2.411E+4 y
Mode: α

Specific Activity: 2.295E+12 Bq / kg
Source: ICRP-07.NDX

Radiation	Number	Frequency Σ Yi (/nt)	Energy Σ Yi * Ei (MeV/nt)	Mean Energy ΣYi * Ei / ΣYi (Mev)
Gamma rays	207	9.758E-04	6.399E-05	6.558E-02
X rays	74	3.042E+00	1.014E-03	3.335E-04
IC electrons	1016	3.045E-01	5.829E-03	1.915E-02
Auger electrons	15	2.590E+00	1.625E-03	6.276E-04
Alpha particles	52	1.000E+00	5.148E+00	5.148E+00
Alpha Recoil Nuclei	52	1.000E+00	8.768E-02	8.768E-02
Total Emitted Energy:			5.244E+00	

Note: Yi = intensity of radiation i; Ei = energy of radiation i

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The Pu-239 specific activities in GBq/g, Bq/g, and pCi/g are shown in Table 2.

[3] "Characterization and Management of Cutting Debris During Plant Dismantlement," The Electric Power Research Institute, July 28, 2015.

Table 2 - Pu-239 Specific Activity in various Units

Specific Activity	Unit
2.30E+00	GBq/g
2.30E+09	Bq/g
6.20E+10	pCi/g

The mass of the Pu-239 in the particle can be estimated from the reported activities in 5271-SR-09-0 by dividing the activity in GBq/g by the specific activity in GBq/g in Table 2. The estimated Pu-239 mass of the particle is shown in Table 3.

Equation 1 - Calculation of Particle S0126 Pu-239 Mass

$$M_{Pu-239} = \frac{A_{Pu-239} \times 3.70E\text{-}11\ GBq/pCi}{SA_{Pu-239} \times 1000\ g/kg}$$

where $M_{Pu\text{-}239}$ = the mass Pu-239 in the S0126 particle

$A_{Pu\text{-}239}$ = the activity of Pu-239 in pCi

$SA_{Pu\text{-}239}$ = the specific activity of Pu-239 from Figure 1 in Bq/kg

3.70E-11 = the conversion factor for pCi to giga Becquerel where 1 pCi = 1.00E-12 Ci and 3.70E+10 Bq = 1 Ci and 1 GBq = 1.00E+09 Bq.

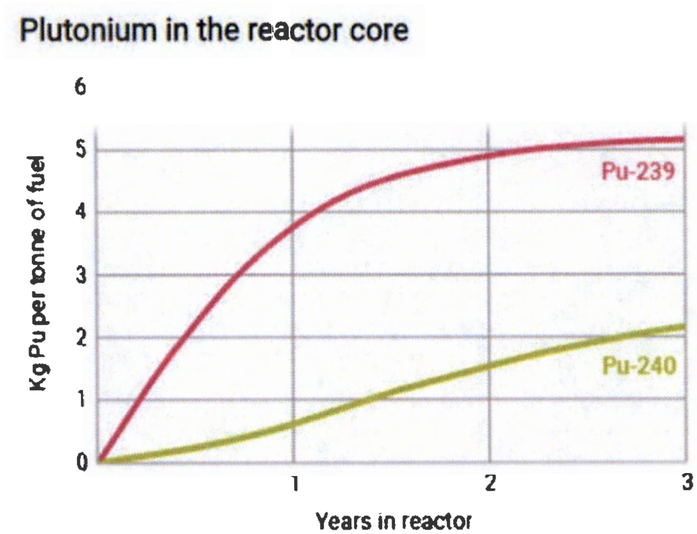
Table 3 - Estimated Pu-239 Particle Mass of Particle S0126

Radionuclide	Activity (pCi)	Activity (GBq)	Mass (g)
Pu-239	7.74E+03	2.7898E-07	1.22E-07

According to the World Nuclear Organization[4], as seen in Figure 2 below, approximately 5 kg of Pu-239 are contained in one tonne (1,000 kg) of spent fuel in a power reactor at discharge (approximately 2 years).

[4] Plutonium in the Reactor Core, World Nuclear Organization Plutonium Webpage.

Figure 2 - Plutonium in the Reactor Core, World Nuclear Organization Plutonium Webpage



Equation 2 - Fractional Mass Pu-239 per Mass of Spent Fuel

$$F_{Pu\text{-}239} = \frac{5\ kg\ x\ 1000\ g/kg}{1000\ kg\ x\ 1000\ g/kg} = 0.005\ g\ Pu\text{-}239\ per\ g\ spent\ fuel$$

where $F_{Pu\text{-}239}$ = Fractional mass of Pu-239 per mass of spent fuel

Therefore, the mass of Pu-239 in particle S0126 (1.22E-07 g) is equivalent to 2.43E-05 g of spent fuel as follows.

Equation 3 - Mass of Spent Fuel Based on Mass of Pu-239

$$M_{SF} = \frac{1.22E\text{-}07\ g\ Pu\text{-}239}{0.005\ Pu\text{-}239 \frac{g}{SF\ g}} = 2.43E\text{-}05\ g\ SF$$

Spent fuel contains 941 kg/tonne of U-238 or 0.941 gram U-238 per gram of spent fuel.[5] Based on this, the U-238 or uranium oxide mass is shown in Equation 4 as 2.29E-05 gram.

Equation 4 - Mass of Uranium Dioxide based on U-238 Mass and Fraction of U-238 per gram of Spent Fuel

$$M_U = 0.941\ \frac{U\text{-}238\ g}{SFg}\ x\ 2.43E\text{-}05\ g\ SF = 2.29E\text{-}05\ g$$

Converting the U-238 mass to volume using a uranium dioxide density of 10.97 g/cm^3 estimates a particle volume of 2.09E-06 cm^3 using Equation 5.

[5] From Radioactivity.EU.com

Equation 5 - Volume of Uranium Oxide in Particle S0126 Based on Mass of U-238 and Density of Uranium Dioxide

$$V_{UO_2} = \frac{2.29E-05g}{10.97\frac{g}{cm^3}} = 2.09E-06\ cm^3$$

Using Equation 6, the diameter of a spherical particle of that volume is 159 µm.

Equation 6 - Particle Diameter Based on Spherical Volume

$$V = \frac{4}{3}\pi r^3$$

$$D = 2 \times \left(\frac{V}{{}^{3}/_{4}\ \pi}\right)^{1/3} = 1.59E\text{-}02\ cm \times 10{,}000\ \frac{\mu m}{cm} = 159\ \mu m$$

where *D* = diameter of the uranium oxide particle in cm

2 = double the radius length to that of the diameter

V = 2.09E-06 cm^3 volume of the uranium oxide sphere

Activated Concrete Size. Zion*Solutions* is unable to estimate a size for a DRP consisting of activated concrete. DRPs of this nature were first identified by ORISE in the April 2021 inspection survey, and particle sizes were not presented in their final report, 5271-SR-09-0. Concrete demolition debris on-site was required to be reduced to a size smaller than 10 inches in diameter before it was packaged and shipped off-site or reused as backfill. As such, residual activated concrete discovered on-site would be expected to be smaller than 10 inches in diameter. A particle would clearly be much smaller, but we have no data to postulate a specific size range.

DRP Size Change over Time. It is important to recognize that these projected particle sizes may change due to weathering and other environmental influences over the 1,000-year compliance period. These particle size changes will affect the potential dose to a future occupant. Zion*Solutions* accounted for particle size changes in order to develop dose estimates in response to RAI-10. Our analysis of how particles may change in size and the resulting dose estimates is described in the response to RAI-10, Specific Consideration 3b.

NRC RAI-1c:

For each particle or sample identified during the April 2021 inspection survey and described above, please explain to the extent possible: A description of how the particle or material transported from the contamination source to where it was found during the April 2021 inspection survey, as well as the potential timing or time range of when the particle was transported to that location.

From p. 12 of the RAI letter: "The licensee should attempt to determine the origin of this contamination, or provide reasonable assumptions regarding the potential origin of this [enhanced thorium] material." And "…the licensee should state whether the thorium material is likely a result of decommissioning operations, such as cutting or welding metal components; whether it was inadvertently imported…"

ZION*SOLUTIONS* RESPONSE:

Zion*Solutions* believes that particles were introduced to the environment via the following events:

1. Particles in the form of shavings from RVI segmentation were likely introduced into the soil via the transportation of the 8-120 liners loaded with RVI segments. The original incident in 2014 started when an 8-120 liner was transported from the south array storage area to the parking area to the north of the old NGET building. It is believed that the contents of the liner dried out. When Radiation Protection was surveying the vehicle for exit of the site, elevated readings were encountered and a DRP was captured. At this time, the exit to the site was closed for all vehicles and personnel, and FSS personnel were brought in, along with 2" x 2" sodium iodide (NaI) detectors, to help locate and capture other potential DRPs from this event. These scan surveys covered the south-north travel route and extended east-west as necessary to ensure that all particles were captured. Personnel exiting the site had to perform a hand and foot frisk prior to entering the portal monitors. These mitigating measures that were immediately implemented after the event limited the spread of contamination to other areas of the site. While Zion*Solutions* believes that these measures were useful in limiting contamination, this event likely is responsible for the majority of the DRPs identified on-site.

2. Particles in the form of fuel fragments or metal, entered the soil via a lack of negative pressure and the movement of potentially contaminated equipment and large components through the equipment hatches of each Containment Building prior to the erection of the waste loadout tents. This source term origin was mitigated once the waste loadout tents were erected in early 2017.

3. Particles in the form of concrete material associated with internal containment generated during demolition were likely introduced into the soil during waste handling operations. Zion*Solutions* believes waste handling operations to be the source of contamination based on the location and radionuclide contents of the particles identified by ORISE during the April 2021 inspection survey.

4. Particles containing thorium were likely introduced into the soil during welding activities, which frequently occurred throughout decommissioning both inside buildings and in outdoor areas. It was not uncommon to identify elevated areas of radioactivity during

scan surveys of buildings and soil and identify welding rods to be the source of the elevated activity. While this activity was remediated when discovered, it is possible that an individual DRP escaped detection and remediation.

Zion*Solutions* performed a review described in the response to RAI-1n to determine if other events could have introduced DRPs into the environment. Based upon this review, Zion*Solutions* does not believe that any events other than those described above contributed to the presence of particles or contaminated debris at the site.

The following timeline summarizes the timing of potential releases from these events, as well as actions taken to remediate the releases.

- 2012 through 2014: Segmentation of reactor vessel and reactor vessel internals.
- 2012 through 2017: Containment equipment hatches expanded and open until the waste tent structures were constructed in January and February 2017.
- September 2014: Storage outside of 8-120 liners containing reactor internals segments, loading of the 8-120 liner in an overpack, and transportation across the site.
- September 24 and September 25, 2014: Survey, detection of particles, and remediation of the contaminated areas (survey units 10221A, 10221B, 10221C, 10202, 10208, 10206, 10204, and 10203).
- June 3, 2015: The area north of Unit 2 Containment was established as a temporary radioactive materials area for the purpose of containing several pieces of segmented steam generator components awaiting loadout into railcars. Particles were detected in the soil north of Unit 2 containment during the down-posting survey.
- June 3 through June 11, 2015: Survey, detection of particles, and remediation of the contaminated areas (survey units 12201A, 12201B, 12201C, 12202A, 12202B, 12202C, 12202D, 12202F, 12109, and 12111).
- January and February 2017: The containment waste tent structures were erected and interior demolition of Unit 1 and Unit 2 Containment Buildings commenced.
- January 29, 2018, through March 1, 2018: Removed debris from Unit 1 under vessel.
- February 2, 2018, through April 5, 2018: Removed debris from Unit 2 under vessel.

Once introduced into the environment, the likely transportation pathways for particles are surface water flow (runoff during heavy rains) and/or heavy equipment and vehicle movement.

In immediate response to the events described above, and in response to the detection of DRPs at any time during decommissioning, biased surveys were conducted and the DRPs were successfully remediated. While this was the case, DRPs were still intermittently detected throughout decommissioning at different stages, during radiological assessments (RA), FSS, or even after FSS. The most recent example of the detection of DRPs after FSS completion is the April 2021 inspection survey conducted by ORISE, in which eight DRPs were identified.

Because the DRPs were identified post-FSS and, in some cases, their radiological characteristics differed from the historical DRPs discovered at the site, ZionSolutions designed and implemented the DRP Survey Plan to address the presence of DRPs on-site. The survey design included a 100% gamma scan of the survey units of interest using a 6-detector (2" x 2" NaI) towed array and systematic sampling using a presence/absence design. The DRP Survey Plan is described in detail in the response to RAI-10.

NRC RAI-1d:

The most likely cause for why the particle or material was not found in licensee surveys.

ZION*SOLUTIONS* RESPONSE:

The most likely cause for why particles or other materials were not identified during licensee surveys is that the DQO development process for the surveys was not designed to detect particles. Had that been the intent, different DQOs (e.g., use of slower scan speeds) would have been implemented.

It is important to note that during active decommissioning, 255 particles were identified and remediated and another 25 particles were identified and remediated during FSS or RAs, for a total of 280 particles discovered by Zion*Solutions* using the standard instrumentation and survey methodologies in use at the time. So as designed, the surveys were adequate to detect the majority of particles on-site.

Zion*Solutions* implemented the DRP Survey Plan to provide high confidence that no particles remain on-site that could deliver a significant dose to a member of the public. The survey plan included DQOs and survey methodologies that focus on DRP detection and remediation.

NRC RAI-1e:

Whether these areas received an ORISE confirmatory survey in their final condition.

ZION*SOLUTIONS* RESPONSE:

Survey unit 12201B did not receive a confirmatory survey during the FSS confirmatory surveys performed by ORISE in January 2020, when the survey unit was in its final condition. However, survey unit 12201B was included in the scope of the April 2021 ORISE inspection survey, but the survey was limited to a small portion of the survey unit and the intent of the survey was to identify particles, not to confirm FSS findings. Survey unit 12201B was not impacted by final site grading.

Survey unit 12203D did receive an ORISE confirmatory survey during the January 2020 site visit, as documented in the ORISE Final Report 5271-SR-08-0.[6] Survey unit 12203D was not impacted by final site grading. Since the ORISE confirmatory survey in January 2020, a portion of the survey unit was subject to investigation during the April 2021 inspection survey. FSS has since been reperformed in survey unit 12203D, and the survey unit was also within the scope of the DRP Survey Plan.

The table below lists the survey units where particles were identified (during the entire project) and whether or not they received an FSS confirmatory survey by ORISE.

Table 4 – Survey Units with Particles Identified that Received ORISE FSS Confirmatory Survey

Survey Unit	FSS Confirmatory	Survey Unit	FSS Confirmatory
10202B	Yes	12104	No
10202D	Yes	12106	No
10203A	Yes	12109	No
10203F	No	12111	No
10204B	No	12112	Yes
10204D	No	12113	Yes
10206D	Yes	12201A	No
10207A	Yes	12201B	No
10207B	No	12201C	No
10207C	No	12201D	Yes
10209A	Yes	12201E	No
10209C	Yes	12202A	No
10209E	Yes	12202B	No
10214E	Yes	12202C	No
10214F	Yes	12202D	No
10220A	Yes	12202F	No
10220G	Yes	12203A	Yes
10220I	Yes	12203C	Yes
10221C	Yes	12203D	Yes
10221D	Yes	12204A	Yes

[6] "Independent Confirmatory Survey Summary and Results of the Remaining Land Areas at the Zion Nuclear Power Station, Zion, Illinois," Oak Ridge Institute for Science and Education, Report No. 5271-SR-08-0, April 24, 2020.

NRC RAI-1f:

If the area received a confirmatory survey in its final condition, provide an estimate of whether the particles were present and missed during the confirmatory survey or were transported to the area after the confirmatory survey due to other site activities.

ZION*SOLUTIONS* RESPONSE:

Zion*Solutions* is unable to estimate whether the particles were present and missed during the confirmatory survey or were transported to the area after the confirmatory survey due to other site activities (e.g., personnel and vehicle traffic). Zion*Solutions* believes both scenarios to be equally likely.

As discussed in the response to RAI-1d, the most likely cause for why DRPs were not identified during licensee surveys is that the DQO development process for the survey was not designed to focus on the detection of DRPs.

NRC RAI-1g:

Given the observations in the survey units listed above, as well as any additional observations resulting from ongoing licensee activities under the Final Status Survey Due Diligence Plan, provide an explanation for why the licensee surveys are adequate.

ZION*SOLUTIONS* RESPONSE:

The licensee surveys were conducted following the process for performing FSS in accordance with the LTP, MARSSIM[7], and other regulatory guidance documents. As such, Zion*Solutions* believes that the surveys were conducted in accordance with best industry practice. The licensee surveys were designed to find uniformly distributed contamination and were adequate and successful for that purpose.

Particles are a source term, and it is Zion*Solutions*' intention to not leave any particles in site soil that present an unacceptably high risk. Zion*Solutions* accomplished this by performing a 100% surface area scan in survey units 12201B, 12203D, and 34 additional survey units within the scope of the DRP Survey Plan using appropriate DQOs and survey methods with sensitivity sufficient for the detection of particles.[8]

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[7] "Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)," NUREG-1575, Revision 1, U.S. Nuclear Regulatory Commission, August 2000.

[8] *See Connecticut Yankee Atomic Power Co.*, 58 N.R.C. 262, 297-299 (2003) (finding that Connecticut Yankee's compliance with MARSSIM provides a sufficient plan for detecting hot particles in its LTP, with a separate opinion noting that a licensee cannot implement a detection plan until the final site survey results are available).

Within the DRP Survey Plan, Zion*Solutions* targeted survey units that had the potential to contain DRPs. In determining what survey units to target, Zion*Solutions* selected survey units:

- where clean concrete demolition debris (CCDD) was temporarily staged or transported through after completion of FSS
- where waste loadout areas resided
- with areas of elevated activity identified by ORISE during the April 2021 inspection survey
- that were adjacent to Class 1 survey units (e.g., survey units 10214, 10213, 10212) where particles or elevated areas had been previously identified

The rationale for survey units *not* included in the DRP Survey Plan includes a combination of the following:

- Zion*Solutions* assessment of the source and transport of the DRPs that have been identified did not give any indication that the survey unit would contain DRPs.
- DRPs were not detected in prior surveys.
- FSS was performed in the survey unit with no identification of DRPs.
- ORISE performed an FSS confirmatory survey or other independent verification survey in the survey unit with no identification of DRPs.
- Surveys performed during final site grading did not identify DRPs.

NRC RAI-1h:

Given that the licensee's FSS and other survey activities did not identify these particles or other radiological material, provide a discussion to support reasonable assurance that there are not similar particles in other areas at a concentration level or to an extent that might challenge the unrestricted release criterion of 10 CFR Part 20.

ZION*SOLUTIONS* RESPONSE:

Zion*Solutions* has evaluated the likely sources and transportation pathways of particles on-site. Based on this evaluation, survey units of medium to high risk were included in the DRP Survey Plan to undergo a 100% scan survey with instrumentation of the appropriate sensitivity and particle-specific DQOs. Because the DRP Survey Plan was designed to identify and remediate any remaining particles on-site, it provides reasonable assurance that DRPs that may have been missed during previous surveys were detected and remediated and there are no particles remaining on-site to challenge the unrestricted release criterion of 10 CFR 20. The focus of the surveys on survey units that were most likely to contain DRPs provides reasonable assurance that there are no DRPs in other areas of the site. If warranted, the scope of the DRP Survey Plan was expanded as required by bounding investigations or remediation.

NRC RAI-1i:

When clean fill was placed over and surrounding the basement substructures in the Zion Power Block area.

ZION*SOLUTIONS* RESPONSE:

Table 5 gives the dates when clean fill was placed over and surrounding the basement structures. A review was performed of the daily work reports for 2018 and 2019 to determine the dates for the performance of fill work. Off-site material may have come from one of two sources (listed in the notes) and may be different types of material, but it is all clean fill.

Table 5 – Backfill Timeline

Date	Activity
02/21/18	Began moving AB rubble pile from rail spur loading areas to south loading area (10221).
03/28/18	Began receiving and stockpiling backfill for AB using clean, off-site material from Zion landfill. Placed on TB footprint (12205) for interim storage. TB footprint was under I&C prior to and during interim storage.
06/15/18	Began AB backfill.
07/20/18	Began backfill of Forebay using Turbine Building CCDD material.
07/23/18	Began U2 Containment interior backfill (dome in place) using clean, off-site material from Zion landfill.
08/02/18	Installed U2 Containment sacrificial backfill around perimeter.
08/10/18	Began backfill of FHB using clean, off-site material from Zion landfill.
08/10/18	Began Unit 1 Containment interior backfill (dome in place) using clean, off-site material from Zion landfill.
08/27/18	Installed U1 Containment sacrificial backfill around perimeter.
08/28/18	Began Unit 2 Containment demolition.
09/26/18	Began Unit 1 Containment demolition.
12/10/18	Began backfill of Wastewater Treatment Facility.
01/24/19	Began moving CCDD from 12202 to 12205, 12112, 12113
02/27/19	Began removing sacrificial soil working from south to north. Placed in 10207.
03/20/19	Began moving CCDD material to NW parking area.
04/17/19	Move of CCDD to NW parking area suspended.
06/24/19	Began moving CCDD from 12205, 12112, 12113 to west loading area (10206).

Date	Activity
07/11/19	Completed moves of CCDD to 10206.
08/05/19	Began back fill of power block area (where the sacrificial soil was removed) to bring to final elevation. Used clean, off-site fill from Antioch quarry (Sand)
Notes:	• CCDD was used to fill basements up to 3 feet below grade • Clean fill from the Zion Landfill was used as the top 3 feet layer in a basement • Clean fill from the Antioch quarry (sand) was used to bring the power block area back to grade after the sacrificial soil was removed • Sandstone gravel from off-site was used for roadways

As noted in the last item of the timeline, the final cover soil (clean fill) was applied in August 2019 when basement backfills were complete. The DRPs that have been detected on the surface of the final clean fill applied to grade were likely attached to the equipment used to apply and grade the Antioch quarry sand. This equipment may have traversed the locations described in the response to RAI-1c and picked up DRPs.

NRC RAI-1j:

When final grading of the site commenced and was completed.

ZION*SOLUTIONS* RESPONSE:

Final site grading of the site commenced on August 31, 2020, and was completed on September 23, 2020. A detailed timeline of final site grading and supporting maps are included in the enclosure to this response ("Final Site Grading and Seeding Timeline with Maps").

Gamma scan surveys were performed prior to and after grading in all areas that were impacted by final site grading. This includes areas where soil was scraped, dispositioned, and where swales were created. No areas of elevated activity were identified during these surveys. Based on these surveys, the potential for final site grading to spread DRPs is low. Because DRPs were not identified during final site grading, the impacted survey units were not included in the scope of the DRP Survey Plan.

NRC RAI-1k:

When final grading occurred for the area where concrete debris was stored.

ZION*SOLUTIONS* RESPONSE:

As detailed in "Final Site Grading and Seeding Timeline with Maps" (provided in the enclosure to this response), grading occurred in survey units where concrete debris was stored on September 7, 9, 11, 14, 15, 16, 17, 18, 21, and 22 of 2020.

NRC RAI-1l:

When the final cover of seed bed (i.e., grass) on the final site grade was placed.

ZION*SOLUTIONS* RESPONSE:

Seeding began on September 11, 2020, and was completed on October 2, 2020.

NRC RAI-1m:

When ZNPS waste handling activities occurred in each of the locations where the particles and radiological material "chunks" were found (south of the railroad track, south of the Auxiliary Building, southeastern portion of the site near the beach, etc.).

ZION*SOLUTIONS* RESPONSE:

For each of the locations where particles and radiological materials were found, waste handling activities occurred throughout most of the decommissioning, with the first waste handling activities beginning in 2014, as described in the response to RAI-1c. However, interior containment concrete was not potentially introduced into the environment until January and February 2017, when the Unit 1 and Unit 2 tent structures were completed and interior demolition of the buildings commenced.

NRC RAI-1n:

Timing of any other operational events that could explain the origin or presence of the particles and radiological material "chunks" of contaminated debris at the site.

ZION*SOLUTIONS* RESPONSE:

Zion*Solutions* has the reviewed the operational and decommissioning history of Zion to determine if any other events (other than the events described in the responses to RAI-1a and RAI-1c) could explain the origin or presence of particles or radiological material at the site. Zion*Solutions* reviewed condition reports that were written to assess the prospect that the events could have been a source of particles or contaminated debris. Based upon this review, Zion*Solutions* does not believe that any events other than those described in the responses to RAI-1a and RAI-1c contributed to the presence of particles or contaminated debris at the site.

For example, on March 8, 2017, the Unit 2 Containment waste loadout tent sustained rips due to high winds. According to the condition report (ES-ZION-CR-2017-0038, included in the enclosure to this response), little, if any, radioactive material was within the tent at the time of the breach. For this reason, Zion*Solutions* does not consider this event as a contributor to the release of particles or material chunks to the environment. Prior to this, all handling of interior containment concrete occurred within the Unit 1 and Unit 2 tents under controlled conditions.

NRC RAI-2a:

Please explain the process the licensee underwent to determine whether or not the information available since approval of the Zion LTP has triggered an evaluation of the LTP change criteria. Information potentially impacting the Zion LTP licensing basis is included in: an RAI response submitted in February 2021 (draft form in November 2020) related to dose from potential radioactive particles left on the Zion site, the April 2021 inspection survey results, and the Zion Final Status Survey Due Diligence Plan.

ZION*SOLUTIONS* RESPONSE:

During the performance of decommissioning activities, all employees have been trained and are responsible for executing work in conformance with the LTP. It is the responsibility of the C/LT Manager to ensure that work is conducted in compliance with the LTP. If any activity is identified as potentially inconsistent with the LTP, it is the responsibility of the C/LT Manager to conduct a review and determine if a change to the LTP is or is not required.

Once it has been determined that a ZNPS activity requires a change to the LTP, AD-11, "Regulatory Reviews," is used to perform an LTP evaluation. The LTP evaluation is required, for all LTP revisions, to address the license criteria in License Condition 2.C.(17). In addition to the LTP evaluation, the activity is required to be reviewed under 10 CFR 50.59. AD-11 provides guidance for the 50.59 review as well.

There are 13 license change criteria in Attachment E-1 of AD-11 (the same conditions that are listed in ZNPS License Condition 2.C.(17)). These criteria apply once it has been determined that a change to the LTP is necessary. As such, they are not considered in the assessment of whether or not to make a change to the LTP. Zion*Solutions* does not believe that there has been any information generated that would necessitate a change to the LTP change criteria.

In response to this RAI, Zion*Solutions* has performed a review of the response to Supplemental NRC RAI Question No. 11, submitted in February 2021, the April 2021 inspection survey results, and the results of subsequent site surveys performed by Zion*Solutions* since the April 2021 inspection survey in order to identify activities that may have triggered a change to the LTP. In preparing this response, Zion*Solutions* examined the following activities:

1. Detection of radionuclides defined as "insignificant"
2. Revised survey unit classification due to DRP detection
3. Detection of DRPs and the potential dose consequences

In so doing, Zion*Solutions* reviewed the initial determinations that none of these activities required a change to the LTP. Upon further review, Zion*Solutions* has reaffirmed that the first two activities listed above did not require a change to the LTP; however, the third activity, the detection of DRPs, was found to require a change to the LTP. Detailed findings and the proposed changes to the LTP are described below.

Results of the Activity Review

1. **Activities that do not require a change to the LTP**

   The first two activities identified above do not require changes to the LTP as described below. As those activities did not result in a change to the LTP, an LTP evaluation, to address the 13 criteria in ZNPS License Condition 2.C.(17), was not required. Those criteria apply when a ZNPS activity results in a change to the LTP. The criteria are used to determine if the changes to the LTP require prior NRC approval.

   A. Detection of Radionuclides Defined as Insignificant
   Zion*Solutions* performed a review of the preliminary results of the April 2021 inspection survey to determine if a revision to LTP Table 5-2 was necessary. Specifically, Zion*Solutions* evaluated the need to include radionuclides that previously had been defined as "insignificant" in the table. Section 5.1 of the LTP states that for all samples analyzed for the full suite of radionuclides (LTP Table 5-1), the actual insignificant contributor (IC) dose will be calculated for each individual sample result. If the IC dose calculated is less than the IC dose assigned for DCGL adjustment (2.5 mrem/yr for soils), then no further action will be taken. If the IC dose exceeds 10 percent, then the additional radionuclides that were the cause of the IC dose exceeding 10 percent will be added as additional ROC for that survey unit.
   For all soil samples analyzed for the full suite of radionuclides, the IC dose was less than 10 percent; therefore, the positive identifications of Am-241, Pu-238/239, or Np-237 remained insignificant to the dose contribution. As described in the response to RAI-6a, the hard-to-detect (HTD) radionuclides identified in the samples do not change the ROC list for distributed radioactivity. However, a LAR will be submitted for NRC review and approval to revise Chapter 6 of the LTP to include DRP ROCs. The original ROC list (for distributed radioactivity) for the Zion site does not need to be changed.

   B. Revised Survey Unit Classification due to DRP Detection

   If a DRP was identified in a survey unit, the survey unit classification was changed, as necessary. A revision to a survey unit classification would not require a change to the LTP unless the survey unit was reclassified to a *less* restrictive classification. During decommissioning, most DRPs were found in Class 1 survey units and therefore, no changes to the classifications were necessary. In some cases, DRPs were identified in Class 3 survey units (e.g., survey unit 10214); portions of those survey units were reclassified as Class 1. As Zion*Solutions* has not revised a classification to a less restrictive designation, no changes to the LTP are necessary.

2. **Activity that requires a change to the LTP**

Zion*Solutions* originally concluded that the detection of DRPs did not require a revision to the LTP. However, upon further consideration, Zion*Solutions* has concluded that a change to the LTP is necessary to describe the process for detecting and calculating the dose from DRPs. The process for calculating the dose from DRPs is fundamentally different from calculating the dose using DCGLs to demonstrate compliance.

Detection of DRPs and the Potential Dose Consequences

Zion*Solutions* initially determined that a change to the LTP due to the identification of DRPs and the potential dose consequences of the DRPs was not required because DRPs are a separate source term that is removed from the site upon detection. As such, there would be no residual DRP radioactivity to be evaluated in the LTP (i.e., no pathway for dose needed to be modeled and there was no need to revise DCGLs). In that regard, finding a DRP is no different than finding a soil sample with concentrations in excess of the Base Case DCGL. In both instances, Section 5.2.14 of the LTP requires the material to be remediated. Each time a DRP was discovered, the DRP was removed from the survey unit. Therefore, no change to the DCGLs was required and no change to the methodology for calculating dose was required.

<u>LTP, Chapter 5</u>

Upon further consideration, Zion*Solutions* has concluded that because the survey methodology of the DRP Survey Plan to detect DRPs is different from the survey techniques described in the LTP, a revision to the LTP is necessary. Zion*Solutions* proposes to revise the LTP by incorporating a new section into Chapter 5 entitled, "Survey Considerations for Suspected Discrete Radioactive Particle Areas." The new section will discuss the definition of a DRP and the need for special survey techniques and actions to be used specifically for the detection of DRPs.

Zion*Solutions* will submit the revised LTP Chapter 5 with a LAR to the NRC.

<u>LTP, Chapter 6</u>

Because it is hypothetically possible that DRPs could be left at the site, and because the dose for DRPs is calculated differently than the dose calculated to demonstrate compliance using DCGLs, a change to Chapter 6 is necessary.

Zion*Solutions* will demonstrate compliance with the dose criteria in Part 20 Appendix E. The proposed change will supplement how Zion*Solutions* demonstrates compliance with the dose criteria by also considering the risk of dose from a DRP that may hypothetically be left on the site. This risk-based approach is in accordance with the guidance contained in NUREG-1757.

The DRP exposure scenario will be evaluated as a less likely but plausible (LLBP) scenario due to the low probability of DRP exposure occurring. In accordance with Section 5.5.2 of NUREG-1757,[9] an LLBP is used to "...better risk inform the decision" and to ensure that "...unacceptably high risks would not result." This is consistent with the approach approved in the Zion LTP for assessing the low-probability scenario of the well driller contacting the Auxiliary Building drains, which was also designated as an LLBP scenario. Zion*Solutions*' approach is to demonstrate that the risk from the hypothetically remaining DRPs is not unacceptably high. Consistent with the designation as an LLBP exposure scenario, the dose from hypothetical DRPs will not be added to the Zion site boundary dose for demonstrating compliance with 10 CFR 20 Subpart E.

Zion*Solutions* proposes to revise the LTP by incorporating a new attachment into Chapter 6 entitled, "Less Likely but Plausible Scenario for Exposure to Hypothetical Discrete Radioactive Particles." The new attachment will discuss the assessment of DRP dose and risk as an LLBP scenario, DRP exposure probability, and the methodology used to calculate ingestion, inhalation, and skin exposure dose from DRPs in order to demonstrate that the risk from encountering a DRP is not unacceptably high. Additionally, the criteria for determining that "unacceptably high risks would not result" from the LLBP DRP exposure scenario will be provided.

The LTP Chapter 6 revision will also address radionuclides of concern and mixes specific to DRPs.

Zion*Solutions* will submit the revised LTP Chapter 6 with a LAR to the NRC.

LTP Change Criteria (AD-11)

Zion*Solutions* has evaluated this activity against the change conditions in Attachment E-1 of procedure AD-11 and concluded that it requires prior NRC approval. As such, the proposed changes to LTP, Chapters 5 and 6, will be the basis of a LAR. Our conclusion is based on our reading of change criterion 9:

> Change the approach used to demonstrate compliance with the dose criteria (e.g., change from demonstrating compliance using derived concentration levels to demonstrating compliance using a dose assessment that is based on final concentration data)?

The technical basis for the proposed changes to Chapters 5 and 6 of the LTP are described in detail in our response to RAI-10.

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[9] NUREG-1757, Vol. 2, Rev. 2, Draft, "Consolidated Decommissioning Guidance – Characterization, Survey, and Determination of Radiological Criteria," Section 5.5.2, Evaluation Criteria for Decommissioning Groups 4 – 5 (Unrestricted Release Using Site-Specific Information), p. 5-20, September 2020.

NRC RAI-2b:

Please discuss the results of the evaluation as they impact the ZNPS licensing basis. If an outcome of the process was that the licensing basis is not impacted, please justify why this is the case when considering the information available.

ZION*SOLUTIONS* RESPONSE:

As described in the response to RAI-2a, Zion*Solutions* has concluded that the methodologies to detect DRPs and to calculate the potential dose from DRPs hypothetically remaining at the site constitute a change to the ZNPS licensing basis. Specifically, proposed changes to the ZNPS LTP, Chapters 5 and 6, are being submitted to the NRC in a LAR for approval.

NRC Additional NRC Comment, p. 12:

"Given the current information on final site radiological status, more information is necessary in order for the NRC staff to reach a determination that the Zion site meets the LTP bounding assumptions."

ZION*SOLUTIONS* RESPONSE:

Zion*Solutions* believes the term "bounding assumptions" to be equivalent to "license conditions" within the context of this RAI. In this sense, Zion*Solutions* believes that the responses to RAI-2a and RAI-2b have adequately provided the additional information necessary for NRC to reach a determination that the Zion site will meet the LTP bounding assumptions following revisions as proposed in the LAR.

NRC RAI-3a:

Please explain whether the Zion LTP considered or addressed these radionuclides.

ZION*SOLUTIONS* RESPONSE:

Transuranics, including Am-241 and Pu-239, were evaluated as part of the LTP development and were identified in the initial radionuclide list as stated in Section 2.3.2 of the LTP. During the final development of the ROC list and the IC radionuclide list, several radionuclides were evaluated to be in the IC list including the transuranic radionuclides. The development of the ROC and IC lists is detailed within TSD 11-001, "Potential Radionuclides of Concern During the

Decommissioning of the Zion Station,"[10] TSD 14-019, "Radionuclides of Concern for Soil and Basement Fill Model Source Terms,"[11] and captured in the LTP.

However, the site's ROC and IC lists are based on characterization data for distributed contamination in soil, radioactive waste, systems, structures, and components, and not DRPs. A LAR will be submitted to the NRC staff for review and approval that will include separate criteria for DRPs and the specific radionuclides.

NRC RAI-3b:

Please provide additional information on the background levels of Am-241 and Pu-239 that might be attributable to fallout in the local area surrounding the Zion site. Alternatively, please provide an explanation for the presence of Am-241 and Pu-239 in the soils if these radionuclides are not attributable to fallout in the local area.

ZION*SOLUTIONS* RESPONSE:

Background radionuclides at Zion were evaluated as documented in TSD 13-004, "Examination of Cs-137 Global Fallout in Soils at Zion Station."[12] This TSD contains information on the production of Cs-137 and Pu-239/240 in weapons testing and notes that the activity ratio of Pu-239 to Cs-137 in weapons testing is 1/86.

The TSD also contains information on Cs-137 (Figure 3) and Pu-239/240 (Figure 4) depositions by county in the United States. From this, the TSD concludes that the Cs-137 from fallout is 50 times higher than the Pu-239/240 depositions from fallout in the Zion area.

As part of the background assessment, a total of 64 samples were submitted to an off-site laboratory for analysis. Each soil sample was analyzed for gamma-emitting nuclides by gamma spectroscopy. The off-site laboratory analysis included Co-60, Cs-137, Sr-90, thorium isotopic (Th228, Th-230, and Th-232), and uranium isotopic (U-234, U-23S, and U-238).

From the soil sample analysis, the highest Cs-137 result reported in TSD 13-004 was 1.14 pCi/g. Using the expected activity ratio of Cs-137 to Pu-239 of 50, the estimated expected concentration of Pu-239 would be 2.82E-02 pCi/g. This is well below the nominal detection sensitivities for Pu-239 of approximately 0.1 to 1 pCi/g. Therefore, any positive detections of transuranic radionuclides in soil would be considered plant-related rather than from fallout contributions.

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[10] Zion*Solutions* TSD 11-001, "Potential Radionuclides of Concern During the Decommissioning of the Zion Station," Revision 1, October 2012.
[11] Zion*Solutions* TSD 14-019, "Radionuclides of Concern for Soil and Basement Fill Model Source Terms," Revision 2, February 2017.
[12] TSD 13-004, "Examination of Cs-137 Global Fallout in Soils at Zion Station," Revision 0, May 2013.

The responses to RAI-1a and RAI-1c describe the likely origins of particles on-site, based primarily upon the radionuclide profile of each.

NRC RAI-3c:

Compare background radiation levels to the levels that were identified in the soil samples collected during the April 2021 inspection survey, and provide an explanation of whether the Am-241 and Pu-239 identified in these samples is the result of licensed material or background radioactivity from fallout.

ZION*SOLUTIONS* RESPONSE:

Zion*Solutions* considers the Am-241 and Pu-239 identified in these samples to be the result of licensed material. As discussed above in the response to RAI-3b, the Am-241 and Pu-239 concentrations are significantly higher than those found in background. Additionally, the responses to RAI-1a and RAI-1c describe the likely origins of particles on-site, based primarily upon the radionuclide profile of each.

NRC RAI-4a:

The ZNPS CRs indicated a "yes'" under the "50.75(g) Issue" field. Please describe the factors that go into deciding whether an event is added to the Zion 10 CFR 50.75 (g) file if it is indicated with a "yes" in an associated condition report. Please describe the factors that go into deciding whether contamination events are discussed in the site characterization portion of the LTP, and/or subsequently used to update survey plans.

ZION*SOLUTIONS* RESPONSE:

A "yes" was indicated under the "50.75(g) Issue" field for the relevant CRs to indicate that the C/LT Manager needed to evaluate the potential need for an update to the 10 CFR 50.75(g) file as a result of the contamination event. Section 7.2.1 of AD-8, "Corrective Action Program"[13] (included in the enclosure to this response) states:

> If the event involves the spill or detection of radiological contamination around the facility, equipment or site, or involves encountering unexpected buried plant systems or components, notify the FSS manager of the potential for 10 CFR 50.75(g) considerations. Code the CR as "10 CFR 50.75g" (for all areas outside the ISFSI boundary) or "10 CFR 72.30d" (for all areas inside the ISFSI boundary).

[13] Zion*Solutions* AD-8, "Corrective Action Program," Revision 12, November 2020.

According to the procedure, the positive indication of "50.75(g) Issue" acts as a trigger for C/LT management action and not as a statement of the existence of a documented update to the 10 CFR 50.75(g) file. Upon the conclusion of C/LT management's consideration, an update to the 10 CFR 50.75(g) file would be made if significant contamination remained after any cleanup procedures or there is reasonable likelihood that contaminants may have spread to inaccessible areas.

The particle release events were not included in the 10 CFR 50.75(g) file. Section 5.1.1 of ZS-RP-104-001-003, "10 CFR 50.75(G) and 10 CFR 72.30(D) Documentation Requirements"[14] (included in the enclosure to this response) states:

> Document a record of each spill or other unusual occurrence involving the spread of contamination (subject to the scope of this procedure) in and around the site, on Attachment 1, Record for 10 CFR 50.75(g) or 10 CFR 72.30(d). These records may be limited to instances when significant contamination remains after any cleanup procedures or there is reasonable likelihood that contaminants may have spread to inaccessible areas.

Because the particle contamination was thought to be successfully cleaned up and not spread to inaccessible areas, no updates to the 10 CFR 50.75(g) file were made.

Information on radioactive particles identified by the licensee throughout decommissioning as well as during the April 2021 inspection survey does not indicate a need to update or revise the process for including information in the 10 CFR 50.75(g) file. The file would be updated only when significant contamination remains after any cleanup procedures or there is reasonable likelihood that contaminants may have spread to inaccessible areas. Neither of these cases applies.

The inputs to Chapter 2 of the Zion LTP were the Historical Site Assessment (historical contamination events) and initial site characterization. Radiological characterization data collected after LTP submittal were used to verify the proper classification of survey units and to update sample plans.

NRC RAI-4b:

Considering that the majority of the site characterization activities took place prior to 2014, discuss why the site characterization discussion in the Zion LTP was not revised by the licensee to reflect the change in radiological conditions at the site that was determined in 2016, prior to the Zion LTP being approved in 2018.

[14] Zion*Solutions* ZS-RP-104-001-003, "10 CFR 50.75(G) and 10 CFR 72.30(D) Documentation Requirements," Revision 2, November 2019

ZION*SOLUTIONS* RESPONSE:

The events were not included in the characterization report or the initial LTP because a decision was made not to modify either the characterization report or the LTP with results from continuing characterization or changing radiological conditions at the site. In discussions with the NRC during the LTP submittal process, it was agreed that continuing characterization results would be presented in the relevant FSS release records. Survey unit classifications were changed from those presented during initial site characterization as warranted when particles were discovered.

As stated in the responses to RAI-2a and RAI-2b, Zion*Solutions* has concluded that the methodologies to detect DRPs and to calculate the potential dose from DRPs hypothetically remaining at the site constitute a change to the ZNPS licensing basis. These changes to the ZNPS licensing basis will be implemented via modifications to Chapters 5 and 6 of the LTP and a LAR will be submitted to the NRC.

NRC RAI-5a:

If not previously discussed in response to RAI-1, please provide information that explains the source of this particle and how it came to be present in SU 12203A.

ZION*SOLUTIONS* RESPONSE:

Likely particle origins are discussed in the responses to RAI-1a and RAI-1c. The likely source of the particle discovered by ORISE in survey unit 12203A is reactor fuel. As discussed in the response to RAI-1c, once introduced into the environment, the likely transportation pathways for particles are surface water flow (runoff during heavy rains) and/or heavy equipment and vehicle movement.

NRC RAI-5b:

Explain why the particle not being found during the licensee's FSS of SU 12203A does not indicate overall quality issues with the Zion FSS methodology, given that the particle contained gamma emitting radionuclides at levels that were within the scope and detection capabilities of the Zion FSS design.

ZION*SOLUTIONS* RESPONSE:

The designed FSS detection scan capabilities are for distributed contamination, not for particles. The failure to detect gamma-emitting radionuclides on particles at levels that were within the scope and detection capabilities of the original FSS design does not in and of itself indicate a quality issue, either with the methodology or the execution of the FSS. Although particles are within the detection capabilities of the instruments, the detection of the particles was not within the scope of the FSS design. If during the performance of the FSS a particle was detected, it was removed. Separate efficiency versus distance factors and detection capabilities would have to be calculated for particles because they represent a very different geometry, and the detector sensitivity varies with the scan rate, the probe swing rate, and the distance between a particle and the detector. The DRP Survey Plan was implemented to specifically look for and remediate particles.

Zion*Solutions* will use the DQO process to address detection of DRPs given the potential for them to be present. Thus, particle point source detection efficiencies and license termination criteria should not be conflated with $DCGL_{EMC}$s that are based on distributed contamination averaged over an area.

To address DRP detection during scanning, the Zion*Solutions* planning team used the DQO process, which is described in the DRP Survey Plan.

NRC RAI-5c:

Explain why the surrogate ratio for Sr-90/Cs-137 is different for this particle than that which was assumed for soils across the site, and as described in the Zion LTP.

ZION*SOLUTIONS* RESPONSE:

The surrogate ratio for Sr-90/Cs-137 for the particle found in survey unit 12203A applies to fuel particles, not distributed contamination. When the site characterization was performed, only Co-60 and Cs-137 were detected in soil samples. The surrogate ratio was based upon distributed contamination estimated from concentrations in Auxiliary Building concrete samples obtained during characterization. A surrogate ratio should not be based on a single sample analysis because the overall uncertainty to other samples is high.

NRC RAI-5d:

Evaluate the potential impact on the Sr-90 surrogate ratio assumed for SU 12203A due to the presence of this particle. Assess whether, in accordance with the Zion LTP, a survey unit-specific surrogate ratio should be applied to this survey unit.

ZION*SOLUTIONS* RESPONSE:

A survey unit-specific surrogate ratio does not need to be applied to this survey unit because if particle S0126 was found during the FSS, it would have been removed. The survey unit surrogate relationships apply to distributed radioactivity and require that the DCGLs be applied. If the radionuclides were detected as distributed activity and only gamma spectrometry was performed, the LTP surrogate Sr-90/Cs-137 of 0.002 would have been applied. However, only one particle containing Cs-137 and Sr-90 was identified, and this is not representative of distributed contamination. Lastly, a surrogate ratio should not be based on a single sample analysis because the overall uncertainty to other samples is high. Based on the forgoing analysis, *ZionSolutions* believes that a survey unit-specific surrogate ratio does not apply due to the presence of particles.

NRC RAI-5e:

Evaluate the potential impact on the Sr-90 surrogate ratio assumed for other Zion survey units that may contain similar particles, and explain why the surrogate ratio applied to these other survey units is still valid. Provide a discussion to support reasonable assurance that particles containing a similar ratio of Sr-90 to Cs-137 do not exist in locations outside of what the license considers to be the affected area.

ZION*SOLUTIONS* RESPONSE:

The potential impact of the Sr-90 surrogate ratios assumed for other Zion survey units that may contain similar particles has been described in the response to RAI-5d. To provide a reasonable assurance that particles containing a similar ratio of Sr-90 to Cs-137 do not exist in locations outside of the affected area, a comprehensive DRP Survey Plan (including sampling) has been implemented. There was high confidence that DRPs were not in areas not included in the scope of the DRP Survey Plan, as explained in the response to RAI-1g.

NRC RAI-5f:

Provide the potential overall or compliance dose consequences of assuming a different Sr-90 to Cs-137 surrogate ratio within what the license considers to be the affected area.

ZION*SOLUTIONS* RESPONSE:

The potential dose consequences from assuming a different Sr-90/Cs-137 (e.g., greater than 0.002) within the affected area would result in a higher dose estimate. But, as noted in the response to RAI-5c, the surrogate ratios that were previously determined from characterization data are applicable to distributed residual radioactivity and not DRPs. To determine such a relationship, DRP DCGLs and a corresponding dose model would need to be established. Therefore, using a Sr-90/Cs-137 ratio from a fuel particle for potential dose consequences for distributed contamination in soil in affected areas is not appropriate.

NRC RAI-6a:

Evaluate the potential dose contributions from the radionuclides that were defined as "insignificant" radionuclides in the Zion LTP, using the range of ratios/radionuclides observed in the samples collected during the April 2021 inspection survey.

ZION*SOLUTIONS* RESPONSE:

For the fuel DRP, the dose contributions from all radionuclides have been included. For the Co-60 particles, the dose calculations conservatively used all radionuclides estimated to be present in the reactor internals components. In these calculations, we provided the contribution from all radionuclides including those identified as insignificant in the LTP. These dose calculation results will be included in the LAR for Chapter 6 of the LTP. The details of these calculations are provided in Specific Consideration 3b of RAI-10.

NRC RAI-6b:

Evaluate the ability of the survey methods used during the Zion FSS activities to detect the potentially significant radionuclides identified during the April 2021 inspection survey that were not on the original ROC list for the Zion site.

ZION*SOLUTIONS* RESPONSE:

The scanning methods used during the Zion FSS activities are standard industry practice. If a particle is detected during scanning, that particle is removed, regardless of radioisotopic content, including isotopes considered insignificant. The ROC list for the Zion site identifies radionuclides that comprise 90% or more of the dose even though other radionuclides are present at the site. Those identified HTD radionuclides can only be detected by laboratory analyses of samples. Based upon the responses to RAI-3a and RAI-6a, the HTD radionuclides identified in the samples do not change the ROC list for distributed radioactivity. However, a LAR will be submitted for NRC review and approval to revise Chapter 6 of the LTP to include DRP ROCs. The original ROC list (for distributed radioactivity) for the Zion site does not need to be changed.

The most likely cause for why particles or other materials were not identified during licensee surveys is that the DQOs were not developed to detect particles. Nonetheless, Zion*Solutions* notes that 255 particles were identified and remediated during active decommissioning, and another 25 particles were identified and remediated during FSS or RAs, for a total of 280 particles discovered by Zion*Solutions*. The DQOs and survey methodologies were enhanced for the implementation of the DRP Survey Plan to provide a high degree of confidence that no DRPs posing an unacceptably high risk remain on-site.

NRC RAI-6c:

Evaluate whether the observed conditions are within the bounds of what was assumed in the Zion LTP (i.e., 10% of the dose is from insignificant radionuclides) and what potential actions are needed (e.g., a license amendment to change the list of ROCs) if the final site conditions do not fall within the original assumptions used in the LTP.

ZION*SOLUTIONS* RESPONSE:

As described above in the responses to RAI-6a and RAI-6b, no action is needed to change the ROC list in the LTP for distributed contamination. A LAR will be submitted to revise Chapter 6 of the LTP to separately address ROC for DRPs.

NRC RAI-7a:

Indicate how the current site conditions are consistent with the commitments in the Zion LTP given the surface materials noted during the NRC's April 2021 inspection survey.

ZION*SOLUTIONS* RESPONSE:

The surface materials noted during the NRC's April 2021 inspection survey are similar in appearance to CCDD that was previously stored and moved around the site. CCDD was surveyed in accordance with regulatory guidance and approved procedures and was found to have no detectable activity above background (see the response to RAI-1a from the February 10, 2021, submittal). The CCDD that was not placed into a basement has been removed from the site. Any residual CCDD that was inadvertently left on the surface during removal is concrete that was determined to have no activity above background. Additionally, the survey units where the residual CCDD resides was subject to a 100% gamma scan during FSS and the FSS passed in all cases. The satisfactory results of FSS do not necessitate further removal of the CCDD. In accordance with the LTP, clean fill material from an off-site source was used to fill the last 3 feet of each basement up to the 591 feet elevation (i.e., grade). As such, Zion*Solutions* believes that the current site conditions are consistent with the commitments in the Zion LTP.

Sample S204AEu in survey unit 12201B from the April 2021 inspection survey contains radionuclides consistent with neutron activation (e.g., Eu-152, Eu-154), which is indicative of activated concrete originating from the containment bioshield and not the containment exterior concrete (CCDD). A process was in place to load potentially contaminated concrete into containers in a controlled fashion to limit the spread of contamination. As discussed in the responses to RAI-1a and RAI-1c, the internal containment bioshield concrete was likely introduced into the soil during waste handling operations. This potential error in waste handling does not indicate a failure to follow commitments made in the LTP.

NRC RAI-7b:

Provide information on whether the material on the Zion site surface is demolition debris that should have been removed during decommissioning, offsite gravel that was used for grading, or some other explanation for its presence, such as basement fill that has been disturbed by action of weather (e.g., erosion, freeze-thaw cycles) or site operations.

ZION*SOLUTIONS* RESPONSE:

During decommissioning and site restoration, Zion*Solutions* attempted to ensure that demolition debris was removed. The information that Zion*Solutions* provided following the May 20, 2021, teleconference describes Zion*Solutions*' best effort to document the position that every effort was put forth towards cleaning up as much demolition and concrete debris at the site as reasonable. Upon further review, Zion*Solutions* does *not* believe that debris identified is fill material brought to the surface by freeze-thaw cycles or erosion. While conceivable, the freeze-thaw scenario is unlikely because sand was used as the majority of the surface fill material for the power block area to replace the sacrificial layer that was remediated.

While Zion*Solutions* cannot precisely explain the source of concrete debris or debris-like material, Zion*Solutions* has identified the following as the most likely sources for the material that was observed.

- **Waste Handling Operations**. It is possible that on rare occasions, minimal concrete was introduced into the environment during waste handling operations. Recent walk-downs revealed minimal instances of identified potential demolition debris. In order to ensure that any activity resulting from waste handling has been remediated, survey units where railcars were loaded and prepared for shipment were surveyed as part of the DRP Survey Plan. Additionally, when CCDD was removed from the six survey units (12203A, 12203B, 12203C, 12203D, 12112, 12113) where it was temporarily stored or transported through and the five survey units where it was stored long-term (12205A, 12205B, 12205C, 12205D, 12205E), residual CCDD may have inadvertently been left behind. In these eleven survey units, FSS has been reperformed.
- **Non-Concrete Material Was Misidentified**. Lastly, it is possible that the concrete observed by ORISE and the NRC was actually sandstone gravel, used for roadways, which can be mistaken for small concrete chunks. Additionally, clean fill soil from the Zion landfill that was used for the top 3 feet of basements and to fill excavations was clay-like. When this clay-like material is dried, hardened, and subsequently disturbed, it can resemble small concrete chunks. This material was surveyed prior to being imported on-site and was also subject to scanning during FSS.

NRC RAI-8a:

Discuss the final site configuration for the Zion site areas that received a sacrificial layer of soil that was subsequently removed and remediated, and over which clean fill material was emplaced. Specify the thickness of the clean cover material intended for the end state over these areas, and from where the clean cover material was sourced. Indicate the survey units where this final site configuration exists.

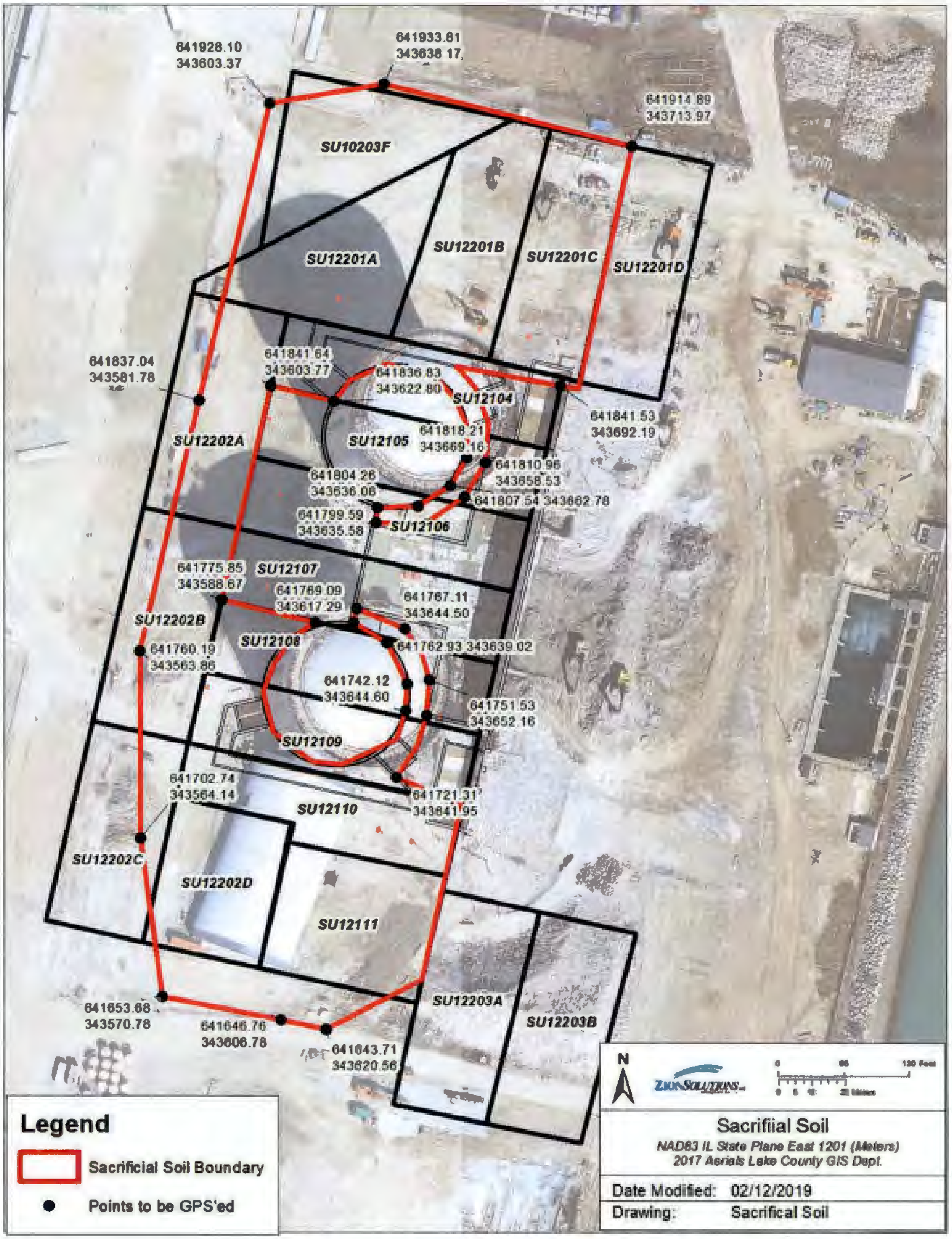
ZION*SOLUTIONS* RESPONSE:

Prior to the demolition of the Unit 1 and Unit 2 Containment Buildings, an approximate 1.5 feet layer of sacrificial soil was placed in the areas identified in Figure 3 below. The sacrificial layer was comprised of the clay-like material from the Zion landfill. After demolition of the Containment Buildings, the sacrificial layer was removed in its entirety and any soil beneath the sacrificial layer that had residual radioactivity above the OpDCGL was remediated as necessary. This remediation potentially took soil away from the minimum 3-foot thick fill layers within the footprint of previously-backfilled structures.

A large-scale RA was performed over the entire power block area, and the results were previously presented in the February 10, 2021, submittal ("Power Block RA Report Attachments"). In order to bring these areas back to grade level, in the instance that remediation necessitated the removal of soil below grade, sand was brought on-site from the Antioch quarry. The thickness of the clean cover material intended for the end state over these areas is 3 feet.

The survey units that were impacted by the sacrificial layer of soil and subsequent potential remediation are as follows: 10203F, 12201A, 12201B, 12201C, 12202A, 12202B, 12202C, 12202D, 12202E, 12202F, 12104, 12105, 12106, 12107, 12108, 12109, 12110, 12111.

Figure 3 – Sacrificial Soil Boundary



NRC RAI-8b:

For the areas of the site directly above backfilled basement structures (including the ZNPS Crib House basement in SU 12204), verify that the thickness of the clean cover material between the land surface and the upper level of the basement fill material is consistent with the Zion LTP commitments and the description of the site end state in Phase 4 of the Zion FSSR.

ZION*SOLUTIONS* RESPONSE:

The thickness of the clean cover material between the land surface and the upper level of the basement fill material for the areas of the site directly above backfilled basement structures has been reviewed and determined to be consistent with the Zion LTP commitments and the FSSR. The methodology for this assessment is described below.

All remaining structure basements were demolished to three feet below grade level (588 feet elevation). As the demolition was completed for a given structure, a third-party surveyor was brought in to perform an elevation survey. Locations for the elevation surveys were based on judgment, e.g., did the elevation appear higher than the surrounding area. Readings were collected and results were evaluated immediately. The contractor would be notified, as necessary, if any of the locations needed additional material removed to meet the 588 feet maximum elevation. The as-left elevations for the basement structures were verified by the third-party surveyor prior to backfill.

The basements were backfilled using CCDD or clean soil from the Zion landfill. The Zion landfill was tested and approved as an uncontaminated off-site soil source. The final three feet of fill from the 588 feet elevation up to grade (591 feet elevation) consisted of clean soil from the Zion landfill, or as noted in the response to RAI-8a, sand from the Antioch quarry. Final elevation measurements were performed after backfill to verify that the as-left soil elevation was at grade. Figure 4 and Figure 5 below show the as-left soil elevations for the power block area.

As detailed in the response to RAI-1j, final site grading was completed on September 23, 2020. After completion of final site grading, another elevation survey was performed, the result of which is shown in Figure 6. Zion*Solutions* commits to confirming that final soil elevations are consistent with the LTP. If future observations reveal conditions inconsistent with the assumptions made in the LTP, Zion*Solutions* commits to making any modifications necessary.

ZionSolutions, LLC
ZS-2022-010
Attachment

Figure 4 – Unit 1 Area Grade Measurement Locations

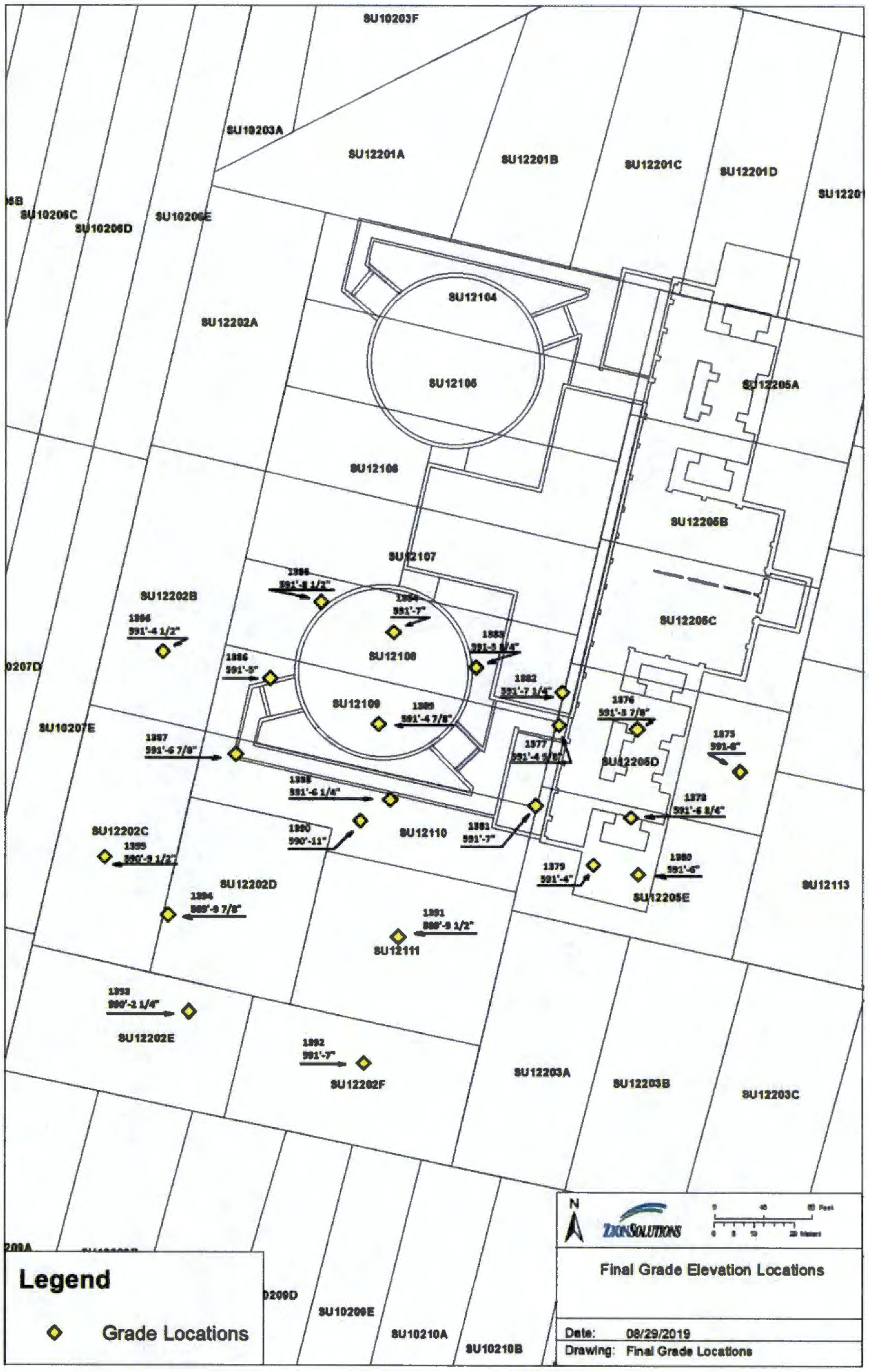


Figure 5 – Unit 2 Area Grade Measurement Locations

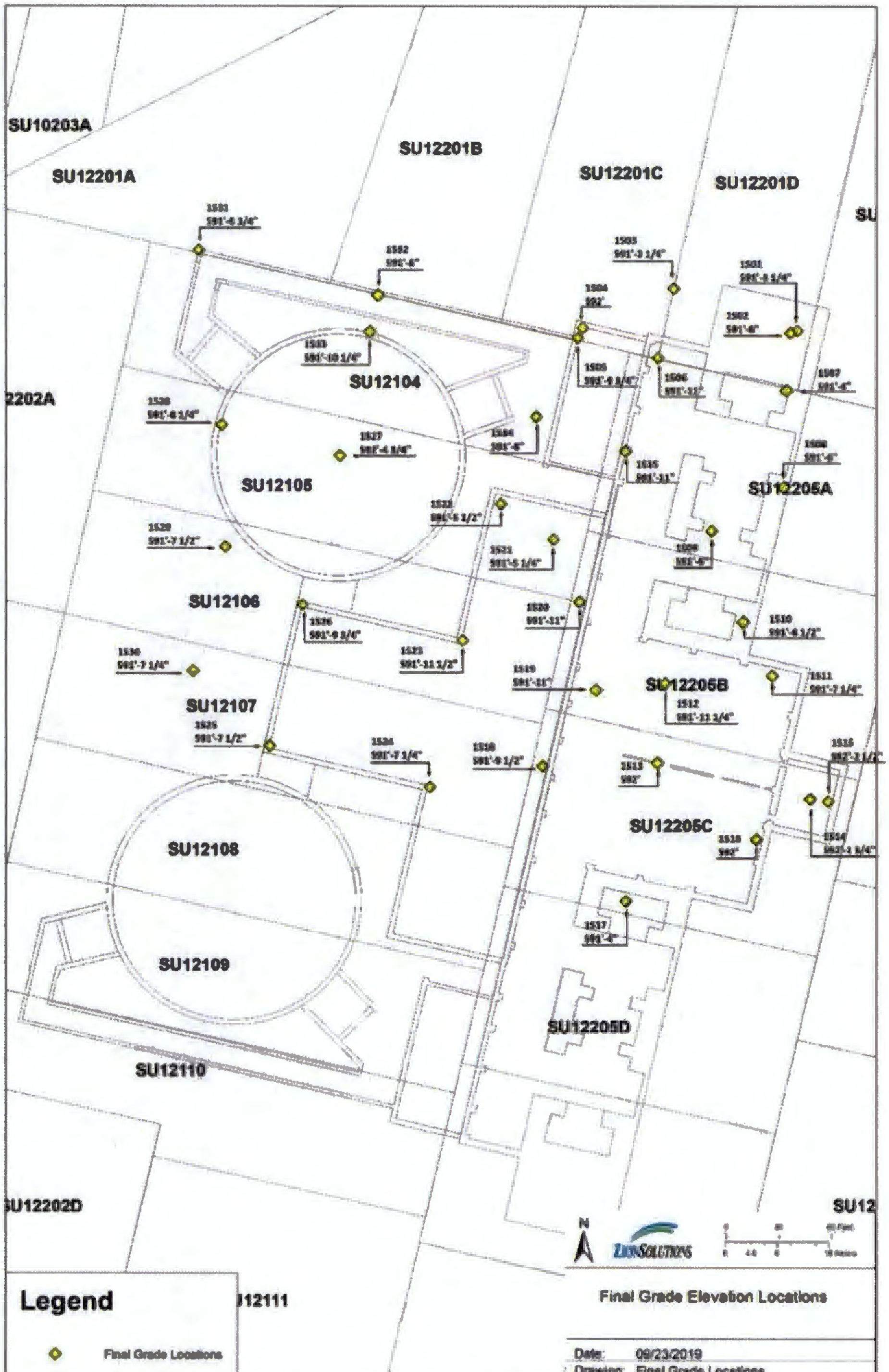
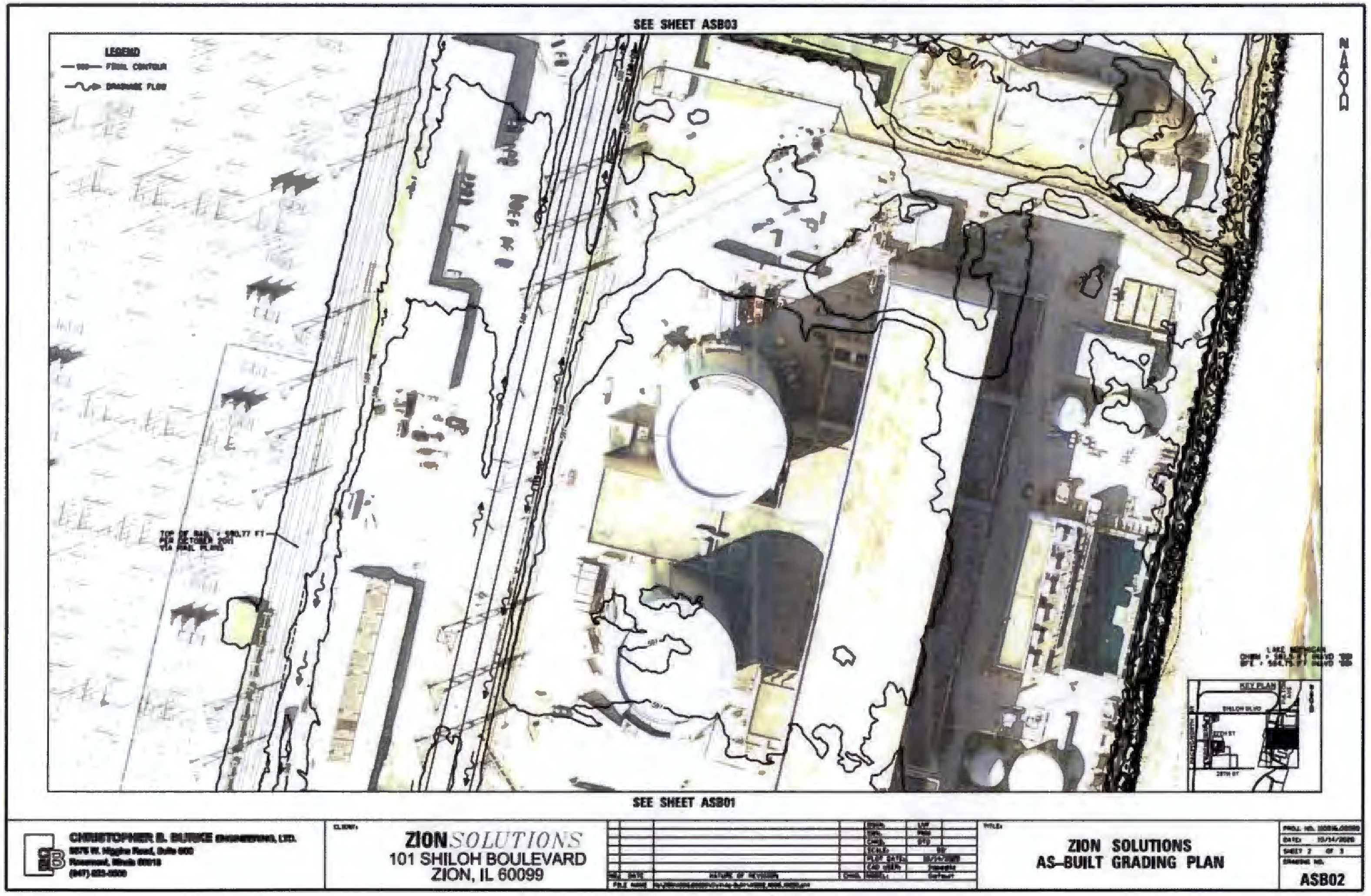


Figure 6 – October 2020 Elevation Survey



NRC RAI-8c:

Justify how current site conditions are consistent with Zion LTP. If the Zion site conditions are not consistent, discuss the intended path forward (e.g., a license amendment to revise the assumptions in the Zion LTP) to resolve the inconsistency.

ZION*SOLUTIONS* RESPONSE:

The following are the commitments to site conditions as detailed in the LTP:

- All on-site buildings, structures, and components must be demolished and removed to a depth of at least 3 feet below grade.
- The structures are backfilled with CCDD or soil from an off-site source.
- The Basement Fill Model applies to the backfilled basements which will have a minimum of three feet of cover and approximately 3 meters of clean fill above potential source term as defined by the equilibrium water level in the backfilled basements. The equilibrium water level is conservatively assumed to be at the natural water table elevation of 579 foot. Therefore, the dose from the water-independent exposure pathways is negligible.

Zion*Solutions* is confident that the final site conditions are consistent with the LTP. It is possible that, because of the times at which structures were backfilled (earlier in the decommissioning process in some cases), a piece of concrete or debris on the surface could have been inadvertently deposited on the surface and forced to a lower depth into the top 3-foot layer of clean soil fill through the movement of heavy vehicles. The presence of a small piece of concrete within the 3 feet of cover is not significant and would not require a license amendment to revise the assumptions in the Zion LTP.

Elevation surveys, as detailed in the response to RAI-8b, were performed to verify that basement structures were no higher than the 588 feet elevation. Elevation surveys were performed after backfill to verify the as-left soil elevations were at grade (3 feet above basement structure).

Additionally, section 6.6.1.1 of the LTP states, "For DUST-MS modeling, the initial source term in each basement is nominally assumed to be 1 pCi/m2 uniform activity over all walls and floor surfaces below 588-foot elevation." Section 6.6.1.2 states, "To accommodate any future perforation plans, and ensure conservatism, the mixing volume for the DUST-MS modeling is based on a basement water elevation equal to the 579-foot elevation of surrounding groundwater." The model assumed all of the activity on walls above the 579-foot elevation is instantly mixed with the water below the 579-foot elevation. Since there is no dose from walls in the unsaturated zone above the 579-foot elevation, a 3.6-meter cover was used in RESRAD. (591-579 = 12 feet = 3.6 m). Because the basement walls remain 3 feet below grade at the 588-foot elevation, and the grade is verified to be at the 591-foot elevation, the water-independent dose pathways used to determine compliance with the dose criteria for unrestricted release remain unchanged.

NRC RAI-8d:

If the thickness of the clean cover material is less than that assumed in the Zion LTP, or the erosion rate is greater than what was assumed in the RESRAD dose modeling for the Zion site, provide an evaluation of the dose resulting from the material in the Zion basements structures with the lower amount of shielding/dilution.

ZION*SOLUTIONS* RESPONSE:

As described above in the answers to 8a-c, the conditions at the site, including the thickness of the clean cover material, are as assumed in the Zion LTP. There has been no significant erosion since final site grading on September 23, 2020. Despite these circumstances, we have prepared the following analysis to demonstrate that even in the case of some future erosion, the depth of cover is adequate to provide for the health and safety of a hypothetical occupant.

The relative dose was calculated under three conditions to evaluate the effect of increased cover erosion rate and decreased cover thickness.

- Condition 1: BFM RESRAD model as applied in the LTP
- Condition 2: BFM RESRAD model with erosion rate increased to the 75th percentile (2.92E-03 m/y) and cover thickness reduced by 0.5 m
- Condition 3: BFM RESRAD model with erosion rate increased to the 75th percentile (2.92E-03 m/y) and cover thickness reduced by 1.0 m

The relative doses from the ROC under each condition were calculated using the following equation:

Equation 7 – Relative Dose

$$RD = \sum fA_i DSR_i$$

where RD = relative dose for ROC

fA_i = activity fraction for radionuclide i

DSR_i = dose to source ratio for radionuclide i (mrem/yr per pCi/g)

The ratio of relative doses from Condition 2/Condition 1 is 1.0 for both the Containment and Auxiliary mixtures. The ratio from Condition 3/Condition 1 is 1.10 for both mixtures. In summary, there is no change in dose when the cover thickness is reduced by 0.5 m. The dose is 10% higher when the cover is reduced by 1.0 m.

The relative dose results are provided in the three tables below:

Table 6 – Relative Dose LTP

Radionuclide	DSR	Relative Dose LTP	
	LTP	Containment Mix	Aux Mix
H-3	2.169E-01	1.619E-04	
Co-60	1.122E-01	5.291E-03	1.029E-03
Ni-63	1.573E-02	4.169E-03	3.729E-03
Sr-90	4.362E+01	1.188E-02	2.246E-02
Cs-134	1.935E+00	1.562E-04	1.954E-04
Cs-137	1.536E+00	1.047E+00	1.157E+00
Eu-152	3.801E-02	1.672E-04	
Eu-154	5.520E-02	3.230E-05	
	Sum	1.07E+00	1.18E+00

Table 7 – Relative Dose 75th Percentile Erosion and Cover Thickness Reduction of 1.0 m

Radionuclide	DSR	Relative Dose	
	75th Percentile erosion 1 m cover reduction	Containment Mix	Aux Mix
H-3	2.269E-01	1.69E-04	
Co-60	2.064E-01	9.73E-03	1.89E-03
Ni-63	1.869E-02	4.95E-03	4.43E-03
Sr-90	4.670E+01	1.27E-02	2.40E-02
Cs-134	2.122E+00	1.71E-04	2.14E-04
Cs-137	1.685E+00	1.15E+00	1.27E+00
Eu-152	3.833E-02	1.69E-04	
Eu-154	5.575E-02	3.26E-05	
	Sum	1.18E+00	1.30E+00

Table 8 - Relative Dose 75th Percentile Erosion and Cover Thickness Reduction of 0.5 m

Radionuclide	DSR	Relative Dose	
	75th Percentile erosion 0.5 m cover reduction	Containment Mix	Aux Mix
H-3	2.169E-01	1.62E-04	
Co-60	1.125E-01	5.31E-03	1.03E-03
Ni-63	1.574E-02	4.17E-03	3.73E-03
Sr-90	4.384E+01	1.19E-02	2.26E-02
Cs-134	1.935E+00	1.56E-04	1.95E-04
Cs-137	1.536E+00	1.05E+00	1.16E+00
Eu-152	3.797E-02	1.67E-04	
Eu-154	5.522E-02	3.23E-05	
	Sum	1.07E+00	1.18E+00

The actual erosion rate is less than what was assumed in the RESRAD dose modeling for the Zion site. One instance of significant erosion was identified in ES-ZION-CR-2020-0001 (included in the enclosure to this response), where the area south of the Forebay and Cribhouse basement appeared to have eroded approximately 2 feet. This area was backfilled to the 591 foot elevation during final site grading. There are no visible signs of erosion in this area or any other area above basements since final site grading.

NRC RAI-9a:

Describe how any soil reuse aligns with the commitments in the Zion LTP.

ZION*SOLUTIONS* RESPONSE:

Soil was stockpiled and reused only to support buried pipe or other commodity removal. In each of these instances, an RA was performed using the methodology outlined in Section 5.7.1.7 of the LTP. Soil was always reused in the excavation from where it came (i.e., soil that originated from site was never stockpiled and used as fill later on).

Soil reuse as performed during decommissioning aligns with Section 5.7.1.7 of the LTP. The response to NRC RAI Question 8a from the February 2021 RAI responses submittal is reiterated below.

Section 5.7.1.7 of the LTP states:

> ZSRP will not stockpile and store excavated soil for reuse as backfill in basements. However, overburden soils will be created to expose buried components (e.g. concrete pads, buried pipe, buried conduit, etc.) that will be removed and disposed of as waste or to install a new buried system. In these cases, the overburden soil will be removed, the component will be removed or installed, and the overburden soil will be replaced back into the excavation. In these cases, a RA will be performed. The footprint of the excavation, and areas adjacent to the excavation where the soil will be staged, will be scanned prior to the excavation. In addition, periodic scans will be performed on the soil as it is excavated, and the exposed surfaces of the excavated soil will be scanned after it is piled next to the excavation for reuse. Scanning will be performed in accordance with section 5.7.1.5.1. A soil sample will be acquired at any scan location that indicates activity in excess of 50% of the soil Operational DCGL. Any soil confirmed as containing residual radioactivity at concentrations exceeding 50% of the soil Operational DCGL will not be used to backfill the excavation and will be disposed of as waste.

All radiological surveys performed to evaluate soils from the excavations of buried pipe, including the grade footprint of the excavation, the grade footprint of the overburden laydown area, the bottom and sidewalls of the excavation, and acceptability of the overburden to be used to eventually backfill the excavation were performed in accordance with Section 5.7.1.7 of the LTP. RAs were designed, evaluated, and documented in accordance with Zion*Solutions* procedure ZS-LT-200-001-001, “Radiological Assessments and Remedial Action Support

Surveys."[15] For all media sampling performed to evaluate excavation soils, the OpDCGLs for subsurface soils from Table 5-8 of the LTP were used as the action level. The action level for scanning was set at the MDCR of the instrument plus background. The instrument and data quality requirements specified in procedure ZS-LT-200-001-001 for the performance of an RA are the same instrument and data quality requirements required for the performance of FSS. The results of the RAs in these cases were provided to NRC Region III who, after review, provided concurrence that the excavations were suitable for backfilling.

As outlined above, soil reuse aligns with the commitments in the Zion LTP.

NRC RAI-9b:

Provide justification and documentation of the process used to determine soil reuse as appropriate, including radiological scans for any soils that were reused from other parts of the Zion site and describe how the process aligns with what was discussed in the RAI response associated with the Zion LTP review dated February 27, 2017 (ADAMS Accession No. ML17208A121).

ZION*SOLUTIONS* RESPONSE:

The process used to determine when soil may be re-used on site is detailed in Section 5.7.1.7 of the LTP, as is reiterated in the response to RAI-9a. The soil must be surveyed under an RA and shown to have radionuclide concentrations below 50% of the soil OpDCGLs before it can be reused.

As stated in the response to RAI-9a, soils were excavated and reused only to support buried pipe or other commodity removal. Spoils from a particular excavation were placed back into the same excavation (and not transported around the site to be used in a different location) once the criteria for reuse of the soil was met as outlined in the RA. The acceptability of the soil to be reused as fill is determined by soil sampling and not scan measurements. The criteria for reuse of the soil is that the concentrations in the soil are below 50% of the soil OpDCGLs. Any soil confirmed as containing residual radioactivity at concentrations exceeding 50% of the soil OpDCGLs was not used to backfill the excavation and was disposed of as waste.

The RAI response associated with the Zion LTP review dated February 27, 2017 (ADAMS Accession No. ML17208A121) provided a basis of the language presented in Section 5.7.1.7 of the LTP and in ZS-LT-200-001-001.

The buried pipe removal RA results are not discussed in the relevant release records, and as such the RA results were provided to the NRC in the enclosure to the February 2021 RAI responses

[15] Zion*Solutions* ZS-LT-200-001-001, "Radiological Assessments and Remedial Action Support Surveys," Revision 6, May 2019.

submittal (a spreadsheet entitled "Buried Pipe RA Results"). The location and timing of circumstances where soil reuse occurred is provided in the above-mentioned spreadsheet and in the response to NRC Request 8a from the February 2021 RAI responses submittal. Radiological scan data for soils that were reused (RA data) were not digitally archived before being sent to long-term records storage. As such, the scan data are not readily available. In lieu of scan results, Zion*Solutions* has provided this comprehensive spreadsheet that details the soil sample results (i.e., compliance measurements to verify acceptability as fill) from every buried pipe RA.

NRC Additional NRC Comment, p. 34:

"These preliminary responses are not adequate for the NRC staff to verify that the reuse of excavated soil at the site is consistent with the commitments included in the Zion LTP."

ZION*SOLUTIONS* RESPONSE:

Zion*Solutions* wants to clarify that it was not the intent of the preliminary response to suggest that the 3-foot clean cover stratum above backfilled structures includes native soil or reused soil. The intent of the preliminary response was to demonstrate that the commitment to have the top 3 feet of each basement structure filled with clean soil from an off-site source was met and that *that criterion does not apply to the entire site*, only the footprint of backfilled structures. Zion*Solutions* would like to reiterate that spoils from a particular excavation for buried pipe or other commodity removal were placed back into the same excavation and not transported around the site to be used in a different location once the criteria for reuse of the soil were met as outlined in the RA and in Section 5.7.1.7 of the LTP.

NRC RAI-10 PATH FORWARD:

The licensee should demonstrate how its FSS meets 10 CFR 20.1402, or propose a revised survey plan specifically designed for detecting and removing discrete radioactive particles. Goals of this survey would be to: (1) detect discrete radioactive particles; (2) remediate detected discrete radioactive particles ; (3) determine the radionuclide composition and activity of the collected particles; (4) estimate the number of discrete radioactive particles that may remain at the site after the survey is completed (i.e., discrete radioactive particles either missed or below the MDA); and (5) facilitate collection of information necessary (physical and chemical properties) to estimate the radiation dose from discrete radioactive particles that may remain at the Zion site after the survey is completed. In developing its survey plan, the licensee should consider the information provided below, in addition to other applicable resources, as it applies to the Zion facility. In this approach, it is expected that the licensee would collect discrete radioactive particles that were detected during the survey, and then analyze them to better understand their characteristics and impact on the final site assumptions.

Due to the lack of specific NRC guidance on planning and conducting surveys for discrete radioactive particles at this time, the staff is providing the following information that the licensee may consider when developing its survey plan, if it chooses to develop a survey plan. Overall, the licensee should consider using the Data Quality Objectives Process, as recommended in the existing NRC guidance for planning decommissioning surveys. In addition, the survey plan should take into account the results from the limited-scope NRC confirmatory conducted in April 2021 and describe which portions of the site are to be surveyed, along with the rationale for any portions of the site not included in the survey. This rationale should consider information on the source and transport of the discrete radioactive particles provided in response to RAI-1 in the NRC letter dated August 19, 2021 (ADAMS Accession No. ML21231A187). Also, when designing the survey plan and determining the MDA for discrete radioactive particles, the licensee should consider the investigation levels that may require a change to the Zion LTP (i.e., ZNPS License Condition 2.C.(17) Criterion F).

ZION*SOLUTIONS* OVERVIEW FOR RAI-10

Zion*Solutions* has designed and implemented a revised survey plan, *Survey Plan for Discrete Radioactive Particle Identification and Remediation*, ZS-LT-07, Revision 1 (the "DRP Survey Plan"), specifically for the purpose of detecting and removing discrete radioactive particles (DRPs). The DRP Survey Plan[16] is included as part of the Zion*Solutions* response to RAI-10.

The objective of the DRP Survey Plan is to identify and remediate all the DRPs identified. This will provide reasonable assurance that there will be no DRPs remaining on the Zion site that could pose an unacceptably high risk to a member of the public. Based on the completion of the survey and investigations, an estimate of the number and activity of DRPs that may hypothetically remain has been made and the dose and risk from the hypothetical DRPs has been estimated.

Zion*Solutions* has performed an extensive dose evaluation, described in detail in response to Specific Consideration 3b, that evaluates all potential effective doses and exposure pathways from particles with Co-60 or Cs-137 activities exceeding the 50^{th} percentile *a posteriori* MDAs of the survey. This includes potential doses if the particles' physical or chemical properties change over time. Cs-137 is used as a surrogate isotope for transuranics in spent fuel particles.

The DRP exposure scenario has been evaluated as a less likely but plausible (LLBP) scenario due to the low probability of DRP exposure occurring. In accordance with Section 5.5.2 of NUREG-1757, an LLBP is used to "...better risk inform the decision" and to ensure that

[16] References to the DRP Survey Plan also include the material described in the accompanying technical support document (TSD), "Calibration and Discrete Radioactive Particle Detection Sensitivity and Performance Assessment for a Ludlum 44-10 Six-Detector Array," TSD 21-001, Revision 2.

"...unacceptably high risks would not result." Zion*Solutions*' approach is to demonstrate that the risk from the hypothetically remaining DRPs is not unacceptably high. Consistent with the designation as an LLBP exposure scenario, the dose from the hypothetical DRPs will not be added to the Zion site boundary dose for demonstrating compliance with 10 CFR 20 Subpart E.

The dose evaluation demonstrates that ingesting an irradiated fuel particle with an activity corresponding to the 50thpercentile *a posteriori* Cs-137 MDA would not result in an unacceptably high risk. The dose from this hypothetical particle would be 59.0 mrem (CEDE), which is acceptable for an LLBP scenario. The use of the 50thpercentile *a posteriori* MDA is reasonable for an LLBP scenario. NUREG-1757 Vol. 2, Appendix I, Section I.3.3.3.7 states that: "Analyses of less likely but plausible scenarios are not meant to be 'worst-case' analyses and should not utilize a set of 'worst-case' parameters."

A technical support document (TSD) that describes the results of the survey, the dose calculations, and the risk calculations, will be submitted to the NRC staff. This approach, i.e., submitting dose modeling results either in the LTP or in another document, in this case a TSD, is consistent with the guidance in NUREG-1757.[17]

The DRP Survey Plan

In the absence of NRC guidance for how to devise a survey plan with the objective of identifying DRPs over a large area such as a nuclear power plant decommissioning site, Zion*Solutions* devised and implemented a survey that was focused on covering a large area to identify DRPs. The survey approach relied on proven technology and incorporated available industry experience in conducting field surveys. It also took into consideration the information provided by staff in the October 14, 2021, RAI letter. Zion*Solutions* believes that this approach provides a high level of confidence that remaining DRPs will be detected and remediated. The DQOs of this survey plan and the equipment used supplement the FSS and provide confidence that any remaining DRPs that might pose an unacceptably high risk to a member of the public have been identified and remediated.

Relevant License Termination Cases

Zion*Solutions* also considered the approach taken by other licensees. There are at least three notable and relevant examples where DRPs also were a concern.

During ORISE confirmatory surveys following FSS at Rancho Seco, areas of elevated activity were identified that were due to DRPs. Since ORISE only surveyed portions of applicable survey units that potentially could have DRPs, NRC requested Rancho Seco perform additional surveys. Rancho Seco developed a particle scan protocol based on the ability to detect a 1 μCi Co-60 particle. The licensee conducted additional surveys and provided a description of its actions in

[17] NUREG-1757, Vol. 2, Rev. 2, Draft, Section 5.1, Introduction, p. 5-1, November 2020.

response to the DRPs and a dose analysis in its site release request.[18] Rancho Seco identified 32 elevated activity items in its re-surveys and remediated any identified areas of elevated radioactivity. The NRC staff reviewed the licensee's actions and determined that they were acceptable. In August 2018, the NRC terminated the license. As shown in the response to Specific Consideration 1b, the towed array used for the Zion DRP survey *a posteriori* MDA value for Co-60 is 0.12 μCi. This is significantly more conservative than the Ranch Seco detection capability.

The license termination of the Shelwell Services site in Hebron, Ohio provides another example of acceptable methodologies for license termination where DRPs are concerned. The NRC staff used a probabilistic approach to calculate an "expectation dose" for particles potentially remaining on the site after license termination. The surveys used for site release utilized μR dose rate meters. The approach approved by the Commission for the termination of the Shelwell license is summarized in SECY-98-117. The NRC terminated the license in July 1999. Our response to Specific Consideration 3b provides the expectation dose calculations for the Zion site using this methodology.

In 2005, Yankee Rowe performed an evaluation to evaluate the effectiveness of in-situ gamma spectroscopy to detect DRPs (YA-REPT-00-018-05). A concentration of 1.0 pCi/g (Co-60) was found to correlate to a discrete point source of approximately 3.2 μCi. This activity value was considered as the discrete particle of concern. Discrete particles exceeding this magnitude were considered to be readily detected during characterization or investigation surveys. The MDCs associated with handheld field instruments used for scan surveys were considered capable of detecting very small areas of elevated radioactivity that could be present in the form of discrete point sources. Yankee Rowe determined that the minimum detectable particle activity for these scanning instruments and methods corresponded to a small fraction of the TEDE limit provided in 10 CFR 20 Subpart E.

The approach taken in the DRP Survey Plan is more conservative than the ones implemented at Rancho Seco, Shelwell, or Yankee Rowe. This section provides an overview of the approach. A complete description is contained in the DRP Survey Plan; responses to NRC's specific considerations posed in the RAI letter are given below.

The Towed Array

Zion*Solutions* devised a survey approach that used a towed 62 inch-wide array of six Ludlum Model 44-10 2" x 2" NaI(Tl) detectors mounted on a utility terrain vehicle (UTV) and attached

[18] Letter, Einar Ronningen to U.S. NRC, "Phased Release of the Rancho Seco Site," Sacramento Municipal Utility District, ADAMS Accession No. ML 091670511, June 8, 2009.

to a Ludlum Model 4612, a 12-channel counter data logger (the "towed array").[19] The unit was equipped with a single Trimble GA810 GPS receiver and antenna combined with a high-accuracy inertial measurement unit (IMU). The Ludlum Model 4612, Trimble GPS receiver, and the IMU are integrated using an on-board tablet or laptop computer (control computer) running the scanning software.

The towed array has significant advantages over hand scanning. It provides the ability to cover a large area far more efficiently than hand scanning. This is consistent with the proposed guidance in the update to MARSSIM (Draft Rev. 2) where the NRC staff was involved. While we recognize this draft is not to be cited or quoted, we believe it is informative because it recognizes that major advances in technology have occurred since the last revision. These advances have encouraged the use of automated scanning as a viable option for large area surveys. In addition, MARSSIM (Draft Rev. 2) also recognizes that hand-held surveying remains the more economical choice for a small area, but as the area increases, the cost of an automated system becomes an increasingly worthwhile investment to reduce manual labor costs associated with surveying as the case for the Zion DRP survey.

Key Features of the Towed Array

Some key features of the survey methodology are:

- **Scan parameters.** The towed array will be operated on a continuous basis at a speed not to exceed 0.6 m/sec (1.34 mph). The detectors will be approximately 4" from the soil surface.
- **Detection efficiency.** The *a priori* MDAs for the towed array are described in Section 3.4.1, *Gamma Scan Survey with Towed Array*, of the DRP Survey Plan.
- **Hard to detect radionuclides.** Hard-to-detect (HTD) radionuclide concentrations will be determined by direct analysis. Any identified non-Co-60 DRPs will be sent to the off-site laboratory for analysis of the full suite of radionuclides.
- **Area to be surveyed.** 100% of the accessible surface area of the survey units listed in the DRP Survey Plan were scanned using the towed array. Areas inaccessible[20] to the towed array were surveyed using hand-scanning methods.

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[19] The towed array and other aspects of the approach are described in detail in Section 3.4, *Description of Planned DRP Survey Activities*, of the DRP Survey Plan.

[20] The term inaccessible in this context means that the towed array survey could not be performed within the parameters that were determined in the probabilistic modelling in TSD 21-001, Revision 2.

Basis for Selecting Areas to Survey

Thirty-six survey units were selected for surveying using the DRP Survey Plan. The detailed justification for selecting these areas is provided below in the response to Specific Consideration 4a. These areas were selected because they were considered at higher risk for the presence of DRPs based on decommissioning project experience (e.g., a location where clean concrete demolition debris (CCDD) was temporarily stored or transported through), or where previous surveys identified particles or areas of elevated activity.

The areas within the scope of the DRP Survey Plan would be expanded, as necessary, as a result of investigations performed to bound areas of elevated radioactivity or as a result of remediation.

The rationale for areas *not* included in the DRP Survey Plan is that based on process knowledge and the results of previous radiological surveys, including but not limited to successful performance of FSS and ORISE independent verification surveys, there is a low potential for the presence of DRPs.

Detailed Investigation of Elevated Activity Detected by the Towed Array

The investigation was designed to identify and remove DRPs that potentially were the source of the elevated reading by the towed array. Any time the investigation level was exceeded during the towed array survey, a detailed investigation was performed. A summary of how the detailed investigation was conducted[21] is as follows:

- Scan the elevated area using a hand-held NaI detector to locate the precise area of the elevated activity. Mark the location in the field with a flag or similar. If the area of elevated activity cannot be duplicated, then make a notation in the field notes and no further actions are necessary.
- If an area of elevated activity is detected, obtain a measurement using a portable gamma spectroscopy instrument and a 10-minute count.
- If a plant-related radionuclide is identified, collect a soil sample in the location down to a depth of 12 inches, capturing at least 2 liters of soil to remediate the potential DRP.
- Spread the soil sample out into a pan or other appropriate container to an approximate 1-inch thickness. Use the hand-held NaI detector to try to isolate a potential DRP. Any DRPs identified will be captured and those containing non-Co-60 plant-related radionuclides will be sent to an off-site laboratory for full suite radionuclide analysis.

[21] The detailed investigation process, including the isolation and collection of DRPs and surrounding soil, is described in Section 3.4.3, *Scan Investigations*, of the DRP Survey Plan.

- If a DRP was captured in an investigative soil sample, rescan the sample void using the hand-held NaI detector to verify that the location has been successfully remediated.
- If additional elevated readings are encountered, collect additional samples for screening, as described above.

Hand Scanning

Areas inaccessible to the towed array were surveyed using hand-scanning methods. The protocols for gamma scanning with hand-held detectors are delineated in the DRP Survey Plan and summarized below:

- Technicians will scan slowly (0.25 m/sec or slower) in a serpentine fashion while maintaining the detector end cap no more than 2" from the soil surface.
- Technicians will pause during the survey when the audible output signal from the detector indicates elevated activity, such as from the presence of suspect DRPs.
- The investigation level for hand-held scanning is minimum detectable count rate (MDCR) plus background. This investigation level is a secondary consideration to the monitoring for variation of detector audio output.

In the event that elevated activity was detected by hand scanning, a detailed investigation, as described in the previous section, would be conducted.

Systematic Soil Sampling

Zion*Solutions* designed a systematic soil sampling plan as recommended by NRC staff in RAI-10, Specific Consideration 2a, to augment the surveys described above. The sampling plan (described in detail in the DRP Survey Plan) is intended to provide additional confidence that potential DRPs have been identified and remediated by selecting areas for analysis that have *not* been identified by scanning as containing elevated activity. This sampling plan uses a "presence/absence" survey design to select additional survey areas for detailed investigation. This investigation supplements the investigatory sampling conducted in areas of elevated activity.

The area of interest (the 36 survey units) was divided into 103,529 grid cells 1 m^2 in size. Grid cell sizes for presence/absence survey design correspond to the footprint of the sampling methodology; in this case, the sampling footprint is a 1 m^2 area where 5 total soil samples were collected. For each grid cell, 1 sample was collected at the center of the grid cell and 4 samples were collected at each of the cardinal directions (N, S, E, W) 0.5 m equidistant from the center sample.

Zion*Solutions* sampled 155 grid cells using this approach. Visual Sample Plan (VSP), a software tool for survey design and data assessment used to design the presence/absence sampling plan, determined that if 155 of the 103,529 grid cells are sampled and 3 or fewer of the 155 sampled grid cells contain DRPs, then there will be at least a 95.4% confidence that at least 95% of the grid cells do not contain DRPs. Additionally, if no more than 0.5% of the grid cells in the population are assumed to contain DRPs, then there will be no more than a 0.8% probability of concluding that the population contains DRPs.

Estimate of DRP Risk

The exposures from the inhalation, ingestion, and skin exposure (including the effective dose equivalent) of the hypothetical DRP source term are treated as LLBP scenarios due to their low probability of occurrence. Treating the low-probability DRP exposure as an LLBP scenario is consistent with the approach approved in the Zion LTP for assessing the low-probability scenario of the well driller contacting the Auxiliary Building drains, which was also designated as an LLBP scenario.

In accordance with NUREG-1757, the evaluation of LLBP exposure scenarios ensures that "unacceptably high risks would not result," but are not considered compliance scenarios. Accordingly, the dose from the hypothetical DRPs will not be added to the Zion compliance dose. Rather, the hypothetical DRP dose will be used to better risk inform the decision to terminate the license.

An unacceptably high risk is viewed as that corresponding to the public dose limit of 100 mrem/year TEDE which represents a lifetime fatal cancer risk[22] of $4x10^{-3}$. Issued in support of the promulgation of the license termination rule (LTR), SECY-97-046A states that the fatal cancer risk corresponding to the 25 mrem/year unrestricted use criterion is an order of magnitude lower at $4x10^{-4}$ and that this risk is estimated assuming a risk coefficient of $5x10^{-4}$ per rem and a 30-year lifetime exposure.

To justify the designation of the hypothetical DRP exposure pathway as an LLBP scenario, the probabilities of DRP ingestion and inhalation were compared to the probability of drilling into the Auxiliary Building drains, which was accepted by NRC as an LLBP scenario in the Zion LTP. The probability of a drill contacting the Auxiliary Building drains was calculated to be $1.5x10^{-3}$ for a single well drilled on the site.

The probability of a future site resident ingesting or inhaling a single DRP is much lower than drilling into an Auxiliary Building drain; Zion*Solutions* has calculated these probabilities to be $1.6x10^{-8}$ and $1.7x10^{-10}$, respectively,[23] assuming a single DRP is present. The site resident is assumed to occupy the site for a 30-year period in accordance with SECY-97-046A.

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[22] SECY-97-046A, "Final Rule on Radiological Criteria for License Termination," March 31, 1997.
[23] See the response to RAI-10, Specific Consideration 3b, below, for the calculation of these probabilities.

The expectation dose is calculated by multiplying the probability of inhaling or ingesting a particle in a given year by the dose from the particle[12]. Inhalation and ingestion effective dose equivalents have been calculated for particles with Co-60 or Cs-137 that correspond to the 50^{th} percentile *a posteriori* MDAs. The final lifetime probability of a single DRP being deposited in the skin is $1.2x10^{-7}$. The DRP direct skin exposure effective dose equivalents were calculated using the EPRI 1002823 guidance. This guidance allows for direct comparison to the license termination criteria of 25 mrem TEDE/yr assuming that the exposure *will occur* (i.e., ignoring the low probability of an exposure event).

The dose to the average member of the critical group from DRP exposure is a low probability, once in a lifetime event, as compared to the assumed 30-year lifetime exposure from disperse source terms such as soil. Therefore, the dose (TEDE) from the hypothetical DRP will be multiplied by the risk coefficient applied in SECY-97-046A, i.e., $5x10^{-4}$ per rem, and compared to the risk of $4x10^{-4}$ that represents the 25 mrem/year unrestricted use criterion. If the risks from the LLBP DRP ingestion and inhalation exposure scenarios are below $4x10^{-4}$, they are not considered unacceptably high.

NRC SPECIFIC CONSIDERATION 1:

The NRC staff offers the following information relevant to scan sensitivity of survey instruments for surveying the Zion discrete radioactive particles:

NRC SPECIFIC CONSIDERATION 1a:

The results of the limited-scope NRC confirmatory survey in April 2021 identified three types of discrete radioactive particles at the site: (1) cobalt-60 primarily, with other activation products, in the form of activated metal; (2) potentially activated bioshield concrete; and (3) potentially irradiated fuel fragments. One of the objectives of scoping for the revised survey should be a determination of an appropriate surrogate ratio that is based on adequate characterization information. For each particle type, consider the use of surrogates for hard-to-detect radionuclides and for the calculation of total activity. In addition, consider how differences in radionuclide composition of the bioshield concrete and irradiated fuel fragments would be taken into account for calculating the scan MDAs. Relevant information from the licensee's RAI responses to the NRC letter dated August 19, 2021 (ADAMS Accession No. ML21231A187) should also be taken into account.

ZION*SOLUTIONS* RESPONSE:

A survey plan, the "Survey Plan for Discrete Radioactive Particle Identification and Remediation," ZS-LT-07, Revision 1 (the "DRP Survey Plan"), was designed specifically for detecting and removing discrete radioactive particles. The DRP Survey Plan is included as part of the Zion*Solutions* response to RAI-10.

In preparation for performing the DRP scan, each of the six 2"X2" NaI detectors to be used for the towed array was calibrated using two NIST-traceable point sources, Cs-137, which is an HTD surrogate, and Co-60. The calibration involved the determination of detection efficiency versus distance, *x*, between the sources and the detector ranging from contact to approximately 20 inches. As part of the system capability evaluation, a mathematical Monte Carlo model was developed to determine a distribution of detection efficiencies and MDAs for DRPs while varying the 3-dimensional hypothetical particle locations relative to the detectors. The model uses a curve-fit of the calibration efficiency (*E*) data (from 4 of the lowest efficiency detectors for the *a posteriori* evaluation) of the following mathematical form to determine the mean detection efficiency during each collection interval (1 sec):

Equation 8 – Calibration Efficiency

$$E = ax^b$$

The DRP Survey Plan addresses the need to account for HTD nuclides in Section 3.5, *Data Evaluation*:

> Transuranic hard-to-detect (HTD) radionuclides will be determined by ratio to Am-241, and other HTD radionuclides will be determined by ratio to Cs-137, based on the ratios identified in particle S0126 identified by ORISE during the April 2021 survey.

We believe that the efficiency and MDA distributions for Cs-137 are reasonably representative of other gamma-emitting radionuclides that may be present in DRPs given the moderate gamma energy range of Cs-137 compared to these other radionuclides.

Those portions of the responses to the NRC's August 19, 2021, Request for Additional Information that are relevant have been incorporated into the DRP Survey Plan and are called out here as necessary.

NRC SPECIFIC CONSIDERATION 1b:

For estimating the revised scan sensitivity of the survey instruments, expressed as a scan MDA, the scan MDA equation should be adjusted for a decreased observation interval for a particle in comparison to a diffuse source of residual radioactivity.

ZION*SOLUTIONS* RESPONSE:

The detection efficiency and MDA model developed for the towed-array account for the scan observation interval (1 sec) used for the scan survey conducted at a nominal transit velocity not to exceed 0.6 m/sec (1.34 mph). The *a priori* MDAs for the towed array are described in Section 3.4.1, *Gamma Scan Survey with Towed Array*, of the DRP Survey Plan. The details of system calibration and the sensitivity are described in TSD 21-001, Revision 2, "Calibration and Discrete Radioactive Particle Detection Sensitivity and Performance Assessment for a Ludlum

44-10 Six-Detector Array." The calculated 50th percentile *a priori* MDA values from TSD 21-001, the post-process (*a posteriori*) data assessment sensitivity based on a seven sigma criterion, and the array drive-over tests are shown in the following table.

The Array Drive-Over Test. An additional empirical test was performed to demonstrate the ability of the towed array to detect actual elevated activity items that were collected during prior survey activities at Zion. The Co-60 activity of the DRPs were determined by laboratory gamma spectroscopy analysis. The items were selected based on the closeness of their activities to the calculated *a priori* MDAs. One piece of elevated activity concrete rubble (L1-12203B-FJGS-211-CV) and 2 DRPs (LI-12112A-FJGS-211-DP and LI-12113A-FJGS-211-DP) were selected for this evaluation. These items were analyzed by gamma spectroscopy at GEL Laboratories.

The tests were conducted on-site in actual field conditions. The items were placed one at a time onto the ground and the array was driven over the target item. The three items used in the test were successfully located by the system operator during the live time monitoring. The files were then post-processed using off-the-shelf ESRI ARCMap 10.8 GIS software for data analysis and reporting.

An assessment was also done of the DRP detection sensitivity for the identification of potential locations for follow-up investigations using Arc-GIS post-processing. The results of the data interpretation using Arc-GIS for two of the three items showed that the system can identify the presence of these particles during a scan array survey with these DRPs at the ground surface.

Items L1-12203B-FJGS-211-CVand LI-12112A-FJGS-211-DP were detected in the post-processing analysis.

The third item (Sample LI-12113A-FJGS-211-DP) was not identified during post-processing. This particle was determined to have 0.08 μCi of Co-60 by laboratory gamma spectroscopy, which is 20% below the activity of particle LI-12112A-FJGS-211-DP. The likely cause of the missed detection was the position of the particle relative to the start of the 1-second acquisition, t. For example, if t2 (the probabilistic time from detector array centerline to end count end-time) were at or near zero, the detection efficiency would be at a low value potentially causing a non-detection.

The detection of item LI-12112A-FJGS-211-DP with an activity of 0.10 μCi is close to the theoretical predictions of both the probabilistic model and the post-survey data assessment.

This test clearly shows that the system is able to detect DRPs of 0.10 μCi of Co-60 and 0.04 μCi of Cs-137. Both of these values are below the *a posteriori* MDC. The activity and the corresponding doses of these detected particles well below the activity of dose significant particles.

Table 9 – DRP Detection Sensitivity

Methodology	Co-60 Sensitivity (µCi)	Cs-137 Sensitivity (µCi)
a priori Probabilistic Model, 50th Percentile MDA	0.06	0.15
Post-Process data Assessment, 7 sigma	0.12	0.41
Array Drive-Over Test	0.10	0.04

NRC SPECIFIC CONSIDERATION 1c:

The detector speed over the land surface during the survey (e.g., 0.25 meter per second or other value) and the transect width of the survey path should be factored into the scan MDA calculation and the survey design, accordingly.

ZION*SOLUTIONS* RESPONSE:

The range of detector speeds and the transect width of the survey path have been factored into the scan MDA as probabilistic parameters as described in the DRP Survey Plan and in TSD 21-001. In addition, for the *a posteriori* sensitivity evaluation, we incorporated the detection efficiency, scan speed, and the ranges of detector height from the ground as probabilistic parameters.

NRC SPECIFIC CONSIDERATION 1d:

If collimators are used on the detectors, an estimate of the change in detector response (e.g., axial response and reduced background), as well as how the collimated detectors are addressed in the survey plan and scan MDA equation, should be considered. Additional factors, such as a shorter observation interval as noted in item 1B above, should be considered for estimating the revised scan MDA if detectors with collimators are used for the survey.

ZION*SOLUTIONS* RESPONSE:

As described in the DRP Survey Plan, collimators were not used during scanning.

NRC SPECIFIC CONSIDERATION 1e:

The method for calculating the efficiency of the detector should be described in the survey plan. If collimators are used on the detectors, the calculation method should account for the detector response, as noted in item 1D above.

ZION*SOLUTIONS* RESPONSE:

TSD 21-001 provides a summary of the methods for determining the mean detector efficiency distributions for calibration and assessment of the system performance. The *a priori* analysis model used the mean of all detector efficiencies for each distance whereas the *a posteriori* model used the four lowest detector efficiencies as a conservative estimate of system sensitivity. Collimators were not used on the detectors.

NRC SPECIFIC CONSIDERATION 1f:

A range of scan sensitivities for discrete radioactive particles located between the land surface and six inches or deeper below the land surface should be considered in the survey design. The assumed depth of particles informing the survey design should take into account the likely actual depth of the particles given the site history and prior survey results. For example, a "worst-case" scan MDA may be calculated for discrete radioactive particles located at 6 inches or deeper below the land surface, and/or the depth below which a discrete radioactive particle of nominal activity cannot be detected. Then, an upper bound on the range of scan sensitivity and discrete radioactive particle detection may be calculated as a "best-case" scan MDA, where the discrete radioactive particle is located on the land surface.

ZION*SOLUTIONS* RESPONSE:

To estimate the effect of increased DRP depth in soil, Microshield v8.03 was used to calculate relative reduction/attenuation factors by modeling a point source for various distances and ratioing the results to the DRP location on the ground surface at a distance to the detector's centerline of 4 inches for only Cs-137. Co-60 was not used in the assessment, because the factors would be less conservative due to Co-60's higher gamma energy. The analysis modeled soil as concrete with a density of 1.6 g/cc and the dose rates used to determine the reduction factor associated with gamma ray build-up. The results of the analysis are summarized in the table below.

Table 10 – Cs-137 Response Reduction at Depth

Distance Below the Surface (in)	Cs-137 Response Reduction Factor
1	2.6
2	4.0
4	8.0
6	16.2
8	32.2
10	59.3
12	101.0

This analysis shows that for a DRP at 6 inches below the surface, the detector's efficiency will decrease by a factor of 16, resulting in an increase in the DRP MDA by the same factor for Cs-137. These reduction factors can be applied to the MDA distribution for Cs-137 to assess the overall impact of DRPs MDAs below the soil surface. This range includes MDAs from "worst-case" to "best-case."

NRC SPECIFIC CONSIDERATION 1g:

The survey protocol should consider how the surveyor will pause during the survey, using the output signal from the detector to identify suspect discrete radioactive particles. Also, the survey protocol should consider the investigation level as a second stage, in units of counts per minute above the background count rate.

ZION*SOLUTIONS* RESPONSE:

The towed array is designed to operate in a continuous manner, and as such the survey protocol does not account for an operator to pause based on output signal.

100% of the accessible surface area of the survey units listed in the DRP Survey Plan were scanned using the towed array. Areas inaccessible to the towed array were surveyed using hand-scanning methods.

The following protocols for gamma scanning with hand-held detectors are delineated in the DRP Survey Plan:

- Technicians will scan slowly (0.25 m/sec or slower) in a serpentine fashion while maintaining the detector end cap no more than 2" from the soil surface.
- Collimators will not be utilized.
- Technicians will pause during the survey when the audible output signal from the detector indicates elevated activity, such as from the presence of suspect DRPs.
- The investigation level for hand-held scanning is minimum detectable count rate (MDCR) plus background, but this investigation level is a secondary consideration to the monitoring for variation of detector audio output.

NRC SPECIFIC CONSIDERATION 1h:

In addition to surveyors monitoring survey instrument physical meter movements and pre-set alarms, the existing NRC guidance on survey techniques recommends the use of additional methods to improve the human performance factors, such as headphones, to aid the surveyor's efficiency and ability to identify areas of concern when performing surveys. The revised survey plan should consider the use of headphones or other means for improving the surveyor performance for detecting discrete particles or other areas of concern.

ZION*SOLUTIONS* RESPONSE:

Instrument headphones were not utilized under the DRP Survey Plan, because the detectors used in the survey, Model 2350-1s, do not have headphone jacks. Zion*Solutions* instructed technicians, as part of the training for the DRP Survey Plan, to closely monitor the audible output from the instrument. Zion*Solutions* believes that because D&D operations are no longer in progress and the background noise at the site is nominal (normal environmental ambient levels), technicians will be easily able to detect changes in audible output.

NRC SPECIFIC CONSIDERATION 1i:

Personnel training should be considered to ensure that surveyors can achieve the performance bases of the survey protocol (e.g., the assigned surveyor efficiency, maintaining detector distance to the land surface at the assigned scan speed, etc.).

ZION*SOLUTIONS* RESPONSE:

Zion*Solutions* conducted personnel training for each surveyor who participated in the implementation of the DRP Survey Plan. Individuals performing field survey and sampling activities and reviewing collected data from field measurements or laboratory data reports were trained in the use of instruments, devices, and procedures, as applicable to the tasks they will be performing.

Operators of the towed array are trained to operate the vehicle at a constant speed, not to exceed 0.6 m/sec (1.34 mph). The detector to ground distance remains nominally constant, and variability is accounted for as a probabilistic parameter. For hand scanning, prior to being qualified, a technician was observed by a subject matter expert during training to verify that they are maintaining the correct scan speed and detector distance specific to hand scanning in the DRP Survey Plan (maximum 0.25 m/sec and maximum 2" from surface).

NRC SPECIFIC CONSIDERATION 2:

The NRC staff offers the following considerations for developing a revised sample collection and laboratory analysis procedure relevant to the Zion discrete radioactive particles to be collected during the surveys:

NRC SPECIFIC CONSIDERATION 2a:

A systematic soil sampling plan should take into account a chosen confidence level for the purpose of performing statistical tests to determine what proportions of the investigation areas are impacted/not impacted by the presence of discrete radioactive particles and below the scan sensitivity of the survey.

ZIONSOLUTIONS RESPONSE:

A systematic soil sampling plan was developed in the DRP Survey Plan that utilized a "presence/absence" survey design. The area of interest (36 survey units denoted in Table 3 of the DRP Survey Plan) was divided into 103,529 grid cells 1 m^2 in size. Grid cell sizes for presence/absence survey design correspond to the footprint of the sampling methodology; in this case, the sampling footprint is the 1 m^2 area where 5 total soil samples will be collected. For each grid cell, 1 sample was collected at the center of the grid cell and 4 samples were collected at each of the cardinal directions (N, S, E, W) 0.5 m equidistant from the center sample.

Visual Sample Plan (VSP), a software tool for survey design and data assessment that was used to design the DRP Survey Plan, determined that if 155 of the 103,529 grid cells are sampled and 3 or fewer of the 155 sampled grid cells contain DRPs, then there will be at least a 95.4% confidence that at least 95% of the grid cells do not contain DRPs. Additionally, if no more than 0.5% of the grid cells in the population contain DRPs, then there will be no more than a 0.8% probability of concluding that the population contains DRPs (i.e., observing more than 3 grid cells assumed to contain DRPs in the sample size of 155).

NRC SPECIFIC CONSIDERATION 2b:

The revised sample collection procedures should consider how discrete radioactive particles will be isolated and collected during the survey. In addition, this procedure should consider the process used for collecting soil around any discrete radioactive particles identified, and separate laboratory analyses of those soils.

ZIONSOLUTIONS RESPONSE:

Elevated Activity Investigations. Detailed investigations were performed any time the investigation level was exceeded during the scan survey. The detailed investigation process, including the isolation and collection of DRPs and surrounding soil, is described in Section 3.4.3, *Scan Investigations*, of the DRP Survey Plan and summarized below:

- Scan the elevated area using a hand-held NaI detector to locate the precise area of the elevated activity. Mark the location in the field with a flag or similar. If the area of elevated activity cannot be duplicated, then make a notation in the field notes and no further actions are necessary.
- If an area of elevated activity is detected, obtain a measurement using a portable gamma spectroscopy instrument and a 10-minute count.
- If a plant-related radionuclide is identified, collect a soil sample in the location down to a depth of 12 inches, capturing at least 2 liters of soil. This will remediate the potential DRP.

- If the sample has been detected in an area of elevated background, notify the radiological engineer to consider moving the sample to an area of lower background for further analysis.
- Spread the soil sample out into a pan or other appropriate container to an approximate 1-inch thickness. Use the hand-held NaI detector to try to isolate a potential DRP.
  - If no DRP is identified, denote as such in the field notes. No further action is required.
  - If a DRP containing only Co-60 is identified, capture the DRP and archive the sample. No further action is required.
  - If a DRP containing any non-Co-60 plant-related radionuclides is identified, then capture the DRP and send the sample to GEL Laboratories for full suite radionuclide analysis.
- If a DRP was captured in an investigative soil sample, rescan the sample void using the hand-held NaI detector to verify that the location has been successfully remediated.
  - If additional elevated readings are encountered, collect additional samples for screening, as described above.

Systematic Soil Sampling Plan. The following process will be used to screen systematic samples:

- If the sample has been detected in an area of elevated background, notify the radiological engineer to consider moving the sample to an area of lower background for further analysis.
- Spread each of the five soil samples out to an approximate 1-inch thickness. In order to ensure the location from which the sample was taken, carefully segregate each of the five piles from one another. Use a hand-held NaI detector (with the protocols outlined in Section 3.4.2 of the Survey Plan) to try to isolate a potential DRP.
- If no elevated area/potential DRP is identified, denote as such in the field notes. Place the soil back in the hole and no further action is required.
- If an elevated area/potential DRP is identified, obtain a measurement using a portable gamma spectroscopy instrument and a 10-minute count.
  - If plant-related radionuclides are not identified, denote the naturally occurring radioactive material radionuclides in the field notes. Place the soil back in the hole and no further action is required.

- If the portable gamma spectroscopy instrument identifies plant-related radionuclides, then collect the soil in an appropriate container, remediating the potential DRP.
    - If only Co-60 is identified by the portable gamma spectroscopy instrument, denote as such in the field notes and archive the sample.
    - If any non-Co-60 plant-related radionuclides are identified by the portable gamma spectroscopy instrument, the sample will be sent to GEL Laboratories for full suite radionuclide analysis.

- If a DRP was captured in a soil sample, rescan the sample void using the hand-held NaI detector to verify that the location has been successfully remediated.
    - If additional elevated readings are encountered, collect additional soil material for screening, as described above.

Justification for use of the Portable Gamma Spectroscopy Instrument. The use of a portable gamma spectroscopy instrument to investigate elevated gamma scan readings is an industry standard that has been used in numerous past decommissioning projects. Qualitative measurements obtained by the instrument can provide real-time indications in the field of whether an elevated reading is due to plant-related radioactivity or NORM. Although there may be concerns that some NORM (e.g., K-40) may mask plant-related gamma emitters such as Cs-137, this would not be an issue when implementing the DRP survey. During a standard FSS of a land survey unit, where the release criteria are typically established at near background levels, it may be possible for K-40 to mask low levels of Cs-137. However, during the DRP survey, the portable gamma spectroscopy instrument would have sufficient sensitivity to detect DRPs that could pose unacceptably high risks to a future occupant of the site.

The effectiveness of the portable gamma spectroscopy instrument in detecting DRPs was validated using actual DRPs in an empirical investigation. This empirical study is documented in TSD 21-001, "Calibration and Discrete Radioactive Particle Detection Sensitivity and Performance Assessment for a Ludlum 44-10 Six-Detector Array." In this investigation the portable gamma spectrometer was shown to be capable of identifying plant-related radionuclides from dose significant particles within a background containing naturally occurring radionuclides.

NRC SPECIFIC CONSIDERATION 2c:

Revised sample collection procedures and planned laboratory analyses for discrete radioactive particles found during the survey should consider additional identification measures, such as labeling of sample containers with discrete radioactive particles, for the protection of laboratory personnel.

ZION*SOLUTIONS* RESPONSE:

Samples containing DRPs were properly labeled as such on the chain of custody form for the protection of laboratory personnel. Zion*Solutions* formally notified GEL Laboratories that every sample they received during the implementation of the DRP Survey Plan contained a DRP. This notification enabled GEL Laboratories personnel to implement the appropriate internal procedures to ensure protection of their personnel.

NRC SPECIFIC CONSIDERATION 2d:

Revised laboratory analysis procedures should consider the radionuclide composition and radioactivity levels of the discrete radioactive particles, taking into account relevant information from the licensee's RAI responses to the NRC letter dated August 19, 2021 (ADAMS Accession No. ML21231A187). The licensee should direct laboratory analyses to include the range of radionuclides potentially present based on operational and decommissioning history, and not rely solely on the radionuclide compositions identified in the limited-scope April 2021 survey.

ZION*SOLUTIONS* RESPONSE:

Because the DRP Survey Plan was designed to identify and retrieve DRPs and not compare quantitative results to release criteria, determining the concentrations of radioactivity in each sample is not necessary to demonstrate compliance with 10 CFR 20. However, any identified DRPs were sent to GEL Laboratories for gamma spectroscopy analysis. No fuel-fragment particles have been identified in executing the DRP Survey Plan.

The process for identifying the radionuclides potentially present at Zion is summarized in the Zion*Solutions*' response to RAI-3a. Zion*Solutions* relied upon operational and decommissioning history at Zion (including samples collected at the site) and industry reference material to develop the radionuclides of concern (ROC) lists that are contained in TSD 11-001, "Potential Radionuclides of Concern During the Decommissioning of the Zion Station," and TSD 14-019, "Radionuclides of Concern for Soil and Basement Fill Model Source Terms."

The information in the TSDs identified above is further informed by the results of the limited-scope April 2021 inspection survey. Taken together, these analyses (as documented in the cited TSDs and ORISE report) provide the basis for defining the approach in the DRP Survey Plan, which is submitted as part of this response to RAI-10. They are also relied upon in the formulation of the approach for developing a dose estimate for DRPs as described below in Zion*Solutions*' response to Specific Consideration 3. The data from the ORISE report receives additional emphasis in the dose formulation because it is the only data that exists regarding certain DRPs (i.e., fuel fragments).

NRC SPECIFIC CONSIDERATION 2e:

In addition to the radioanalytical procedures described above, the licensee should consider obtaining information on the physical and chemical characterization of collected discrete radioactive particles that are relevant to internal dosimetry calculations (e.g., the size of each particle, as well as the chemical solubility in simulated lung and digestive-tract fluids). Note that in the absence of specific information on discrete radioactive particle size and solubility characteristics, default assumptions from ICRP-30 (i.e., *f1* values and inhalation class) are applied for internal dose calculations.

ZION*SOLUTIONS* RESPONSE:

Zion*Solutions* does not propose to subject samples to chemical analysis. We will use data from literature and, when necessary, use the default assumptions from ICRP-30 to perform internal dose calculations. Additional detail regarding dose calculations, including the justification for this approach, is provided below in the response to Specific Consideration 3b.

Zion*Solutions* proposes to use alternate f_1 values from the literature for insoluble DRPs, including irradiated fuel particles. While we understand that the use of organ dose weighting factors other than those in ICRP-30 would require an exemption, it is our understanding that using alternate f_1 values is allowable under 10 CFR 20.

Specifically, 10 CFR 20.1204 (c) states:

> When specific information on the physical and biochemical properties of the radionuclides taken into the body or the behavior or the material in an individual is known, the licensee may—
>
> (1) Use that information to calculate the committed effective dose equivalent…

Our selection of the f_1 value for Cs-137 and the actinides in estimating the ingestion dose is consistent with the approach used in terminating the Shelwell license, where Dr. Keith Eckerman of Oak Ridge National Laboratory calculated dose coefficients for insoluble Cs-137. New dose coefficients were needed since the primary NRC sources for this information, Federal Guidance Report No. 11[24] and 10 CFR 20, did not contain coefficients for insoluble Cs-137.

This methodology is also supported by Regulatory Guide 8.9, *Acceptable Concepts, Models, Equations, and Assumptions for a Bioassay Program*. The use of alternate biokinetic models is discussed and stated to be acceptable to the NRC. Regulatory Position 4.6 states:

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[24] "Limiting Values Of Radionuclide Intake And Air Concentration And Dose Conversion Factors For Inhalation, Submersion, And Ingestion," U.S. Environmental Protection Agency, Federal Guidance Report No. 11, 520-1-88-020, September 1988.

Individual specific retention and excretion rates may be used in developing biokinetic models that differ from the reference man modeling (10 CFR 20.1204(c)). The quality and quantity of data used for this type of individual specific modeling should be sufficient to justify the revised model.

NRC SPECIFIC CONSIDERATION 3:

The revised survey plan should consider the following information for developing a dose estimate for discrete radioactive particles at the MDA:

NRC SPECIFIC CONSIDERATION 3a:

Consider the range of potential discrete radioactive particles that were not detected during the survey (below MDA), taking into account the likely radionuclide composition, activity, physical size, depth beneath the surface, and chemical composition. See item 1F above for information concerning MDA ranges and detection capability. Also see RAI-1 in the NRC letter dated August 19, 2021, for additional information on origin of the particles and potential source terms (ADAMS Accession No. ML21231A187). The NRC staff notes that the Zion LTP dose modeling uses dose coefficients from FGR-11, which is based on ICRP-30.

The information described below for each of the responses to Specific Consideration 3 also will be included in the TSD that documents the survey results.

ZION*SOLUTIONS* RESPONSE:

The DRP Survey Plan provides the *a priori* MDAs for the detection of DRPs that could pose unacceptably high risk to a future occupant on and near the surface. Zion*Solutions* believes that the *a priori* MDAs described in the DRP Survey Plan are adequate to address the range of potential DRPs not previously detected. It has been designed to take into account the range of radionuclide composition, activity, physical size, and chemical composition of potential DRPs remaining at the site. This approach takes into account all potential DRPs regardless of origin. As stated in the DRP Survey Plan, dose estimates from the particles that may remain at the Zion site after the survey is completed will be documented in a TSD and submitted to the NRC along with the results of the surveys. The post-survey TSD will also include an *a posteriori* probabilistic MDA evaluation using the same parameters in identifying areas for further investigation.

NRC SPECIFIC CONSIDERATION 3b:

Scenarios that should be considered include inhalation, ingestion, and skin exposures to remaining discrete radioactive particles. For inhalation and ingestion, the anticipated particle size ranges should account for particle size change over the 1,000-year compliance period. For ingestion, the technical basis for selection of the *f1* value (fraction of ingested element absorbed directly into the body fluids) should be provided, based on the chemical compositions of activated metal, activated bioshield concrete, and irradiated fuel fragments. For skin exposures, the shallow dose equivalent and deep dose equivalent from discrete radioactive particle exposures to the skin for 24 hours should be considered. The calculations should consider the range of cobalt-60 (only) discrete radioactive particles, as well as the radionuclide mixes that comprise activated concrete from the bioshield and irradiated fuel fragments. VARSKIN Version 6.2.1 should be used for these calculations.

ZION*SOLUTIONS* RESPONSE:

The exposures from the inhalation, ingestion, and skin exposure of the hypothetical DRP source term have been assessed as LLBP scenarios due to their low probability of occurrence. Treating the low-probability DRP exposure as an LLBP scenario is consistent with the NRC-approved approach used in the Zion LTP for assessing the low-probability scenario of a well driller contacting the Auxiliary Building drains, which was also designated as an LLBP scenario. In accordance with NUREG-1757, the evaluation of LLBP exposure scenarios ensures that "unacceptably high risks would not result," but are not considered compliance scenarios. Accordingly, the dose from the hypothetical DRPs will not be added to the Zion compliance dose.

An unacceptably high risk is viewed as that corresponding to the public dose limit of 100 mrem/year TEDE which represents a lifetime fatal cancer risk of about 4×10^{-3}. SECY-97-046A also states that the fatal cancer risk corresponding to the 25 mrem/year unrestricted use criteria is an order of magnitude lower at 4×10^{-4} and that this risk is estimated assuming a risk coefficient of 5×10^{-4} per rem and a 30-year lifetime exposure.

To justify the designation of the hypothetical DRP exposure pathway as an LLBP scenario, the probabilities of DRP ingestion and inhalation are compared to the probability of drilling into the Auxiliary Building drains, which was accepted by NRC as an LLBP scenario in the Zion LTP. The probability of a drill contacting the Auxiliary Building drains is 1.5×10^{-3} for a single well drilled on the site as calculated by the equation below.

Equation 9 – Probability of Auxiliary Building Drain Contact by Drilling

$$P_{drain} = \frac{SA_{drain}}{A_{cz}}$$

Where:

P_{drain} = probability of drill contacting Auxiliary Building drain

SA_{drain} = projected surface area of Auxiliary Building drains (96.2 m^2)

A_{cz} = area of contaminated zone (64,500 m^2)

The probability of a future site resident ingesting or inhaling a single DRP at 1.6×10^{-8} and 1.7×10^{-10}, respectively, is much lower than drilling into an Auxiliary Building drain. The probability of a particle ingestion and inhalation from the Zion end state is calculated using the equation below. The resident is assumed to occupy the site for a 30-year period in accordance with SECY-97-046A.

Equation 10 – Probability of Single Particle Inhalation and Ingestion

$$P_{DRP} = \frac{30 IR_s}{(A_{cz} t_{cz} CF_{cm^3/m^3} d_s)}$$

Where:

P_{DRP} = probability of ingesting or inhaling one DRP

IR_s = soil mass ingestion rate (18.3 g/y) or inhalation rate 0.2 (g/y)

A_{cz} = area of Zion contaminated zone (64,500 m^2)

t_{cz} = thickness of soil layer affected by DRP (0.3048 m)

$CF_{cm3\ m3}$ = conversion factor (1.00E+06 cm^3/m^3)

d_s = density of soil (1.8 g/cm^3) (see LTP 5.8.4.4)

30 = 30-year lifetime exposure period to the average member of the critical group per SECY-97-04A

The final probability of DRP inhalation and ingestion exposure is calculated by multiplying the hypothetical number of DRPs estimated to remain by the single DRP probability. As described in the response to Specific Consideration 3c, 31 DRPs are estimated to hypothetically remain. The final lifetime probability of ingestion or inhalation of a DRP is therefore 4.8×10^{-7} and 5.2×10^{-9}, respectively.

The probability of a DRP being deposited on the skin during the lifetime of a future site resident is 1.2×10^{-7}, which is calculated using the equation below, assuming one DRP remains on the site. The single DRP probability is multiplied by 31, the approximate number of DRPs projected to hypothetically remain resulting in a final lifetime probability of 3.7×10^{-6} that a DRP will contact the skin of a future site resident. The dermal deposition parameters in the equation are from the EPA's Risk Assessment Guidance for Superfund.[25]

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[25] "Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual, Part E, Supplemental Guidance for Dermal Risk Assessment," U.S. Environmental Protection Agency, EPA/540/R/99/005, Exhibit 3-5, July 2004.

Equation 11 – Probability of Single Particle Skin Deposition

$$P_{DRP} = \frac{M_{skin}T_e}{(A_{cz}t_{cz}CF_{cm^3/m^3}d_s)}$$

Where:

P_{DRP} = lifetime probability of skin exposure to assuming one DRP present on site

A_{cz} = area of Zion contaminated zone (64,500 m^2)

t_{cz} = thickness of soil layer affected by DRP (0.3048 m)

$CF_{cm3/m3}$ = conversion factor (1.00E+06 cm^3/m^3)

d_s = density of soil (1.8 g/cm^3)

T_e = time that resident occupies the site (30 y)

M_{skin} = mass loading of soil on skin (g)

Where: $M_{skin} = f_{skin\ mass\ loading\ event} Ef_{event\ frequency} Af_{soil} CF_{g/mg} A_{skin}$

$f_{skin\ mass\ loading\ event}$ = mass loading frequency (1 event/d)

$Ef_{event\ frequency}$ = frequency of event per year (350 d/y)

Af_{soil} = soil adherence factor for resident gardener (0.07 mg/cm^2)

$CF_{g/mg}$ = conversion factor (1.00E-03 g/mg)

A_{skin} = skin surface area (5,700 cm^2)

The dose to the average member of the critical group from DRP exposure is a low probability, once in a lifetime event, as compared to the assumed 30-year lifetime exposure from disperse source terms such as soil. Therefore, the dose (TEDE, CEDE, or EDE) from the hypothetical DRP will be multiplied by the fatal cancer risk coefficient applied in SECY-97-046A, i.e., 5×10^{-4} per rem, and compared to the risk of 4×10^{-4} that represents the 25 mrem/year unrestricted use criterion. If the risks from the LLBP DRP ingestion and inhalation exposure scenarios are below 4×10^{-4}, they are not considered unacceptably high.

In order to provide a comprehensive and thorough evaluation of the potential dose to future occupants from DRPs in the end state land areas, we have evaluated potential doses associated with particles at the 50th percentile *a posteriori* MDAs of the towed scanning array of 0.12 µCi Co-60 and 0.41 µCi Cs-137. The 50th percentile MDA was chosen because it represents the median and most likely detectable particle activities that would be encountered and thus the most likely doses that would result from exposure to DRPs.

The exposure pathways evaluated include:

1. Estimated particle sizes at the 50th percentile MDAs, and potential doses from ingestion of large non-respirable particles with activities scaled to the 50th percentile MDAs to account for hard-to-detect radionuclides that may be present.
2. Fractionation of 50th percentile particles to 1 μm AMAD and calculated activities and inhalation doses from the smaller particles.
3. Complete dissolution of the 50th percentile MDA particles and the resulting localized distributed soil concentrations, and potential doses using newly calculated area factors and $DCGL_{EMC}$s for the nuclides of concern in the particles.
4. Potential shallow, deep dose equivalents, effective dose equivalents (EDE) for particles on the skin with a 24-hour exposure period at the scaled 50th percentile MDA activities.

DRP Size Estimates

Particle sizes are estimated for each of the DRP types that have been detected: activated steel, activated concrete, and irradiated fuel. In addition, anticipated particles sizes accounting for changes in size over the 1,000-year compliance period have been estimated.

Activated Steel

A minimum DRP diameter, d_e, for activated metal can be calculated using the highest activated source-term from decommissioning activities, which is well represented by the activation calculations of the concentrations of the reactor vessel internals.[26] The table below summarizes the Co-60 concentrations, $C_{Co\text{-}60}$, for the various reactor internals components for each of the two reactors as of January 1, 2021. This shows that the highest concentrations are from the baffle plates in Unit 1 as 4.06E-02 Ci/cc or 4.06E+10 pCi/cc.

[26] WMG 07-046D-RE-088, "Zion Units 1 and 2 Activation Analysis and Component Characterization," January 2008.

Table 11 - Reactor Internal Component Activities

Component	Unit 1 C_{Co-60} (Ci/cc)	Unit 2 C_{Co-60} (Ci/cc)
Upper Core Plate	1.15E-03	1.84E-05
Lower Core Barrel	1.78E-03	1.73E-03
Thermal Shield	2.60E-04	2.52E-04
Baffle Plates	4.06E-02	3.98E-02
Baffle Formers	2.92E-02	2.84E-02
Lower Core Plate	1.03E-02	1.01E-02
Balance of Lowers	1.67E-04	1.64E-04
Vessel Wall	1.55E-06	9.50E-08
Vessel Clad	5.61E-05	5.48E-05

The maximum concentration from the above table is for the Unit 1 baffle plate, which is used to estimate a minimum DRP volume, *V*, for DRP activities corresponding to the 50th percentile of the *a posteriori* distribution for the probabilistic parameters from TSD 21-001 Rev. 2 using the following:

Equation 12 – DRP Volume Corresponding to the 50th Percentile a posteriori Distribution

$$V(cc) = \frac{MDA_{50,Co-60}(pCi)}{C_{Co-60}(\frac{pCi}{cc})}$$

Using the above, with the Unit 1 baffle plate concentration of 4.06E-02 Ci/cc, the DRP volume for 50th percentile scan MDA activity (0.12 µCi Co-60), the MDA is 2.90E-06 cc.

From this volume, the DRP physical diameter, d_e, can be estimated assuming a spherical geometry using:

Equation 13 – Volume of a Sphere

$$V = \frac{4}{3}\pi r^3$$

Rearranging yields:

Equation 14 – DRP Physical Diameter

$$d_e = 2 \times \left(\frac{0.75}{\pi} V\right)^{(1/3)}$$

Where:

V = the spherical volume of the DRP based on the concentration in the base material (pCi/cc) and the activity of the DRP (pCi)

r = the radius of the spherical volume of the DRP

d_e = the physical diameter of the DRP

Using the above equation, the particle diameter for the 50th percentile Co-60 MDA particle diameter is 124 μm.

The equation to calculate aerodynamic equivalent diameter (d_{ae}) equivalent to AMAD for a distribution of particle sizes weighted by activity, from the physical equivalent volume diameter (d_e) below, is taken from Equation 2-1 on page 2-2 in a report prepared for the NRC.[27]

Equation 15 – Aerodynamic Equivalent Diameter

$$d_{ae} = d_e\sqrt{\frac{\rho}{x}}$$

Where:

d_{ae} = the aerodynamic equivalent diameter

d_e = the equivalent volume diameter (physical diameter) of the DRP

ρ = the density of the particle material 8 g/cc steel, 2.35 g/cc activated concrete, 10.97 g/cc uranium dioxide

x = the particle shape factor, usually between 1 and 2. Typical value of 1.5 is used for a spherical geometry

Therefore, rearranging this and solving for d_e yields:

Equation 16 – Physical Diameter of 1 μm Particle

$$d_e = \frac{1\,\mu m\, d_{ae}}{\sqrt{\frac{p}{x}}}$$

The sperical volume of 1 μm particle, V(1μm d_{ae}), is calculated using the following:

Equation 17 – Spherical Volume of 1 μm Particle

$$V(1\mu m\, d_{ae}) = \frac{4}{3}\pi\left(\frac{de}{2}\right)^3$$

Therefore, the intact particle aerodynamic equivalent diameter for an 8 g/cc density sphere with a 1.5 shape factor for the 50th percentile is 287 μm, respectively. Thus, intact particles detected at the MDAs far exceed the 10 μm respirable particle threshold. Also, since the particle would not likely be truly spherical the median aerodynamic diameter could be substantially larger.

[27] "Airborne Particle Resuspension and Inhalation Radiological Dose Estimation Following Volcanic Events," prepared for U.S. Nuclear Regulatory Commission, Contract NRC–02–07–006, September 2011.

The ICRP-30 lung model is based upon 1 μm AMAD particles. The spherical volume of 1 μm AMAD d_{ae} activated steel particle is 4.25E-14 cc. The volumes and correspondingly the activities of the 1 micron particles at the 50th percentile Co-60 MDA (i.e., 2.90E-06 cc) would be reduced by a factor of 8.63E-09, resulting in a Co-60 particle activity of 1.02E-03 pCi for an equivalent volume diameter of 1 μm AMAD. The doses from inhalation of these particles created by fractionation of larger particles at the Co-60 MDAs would be at this activity level and the doses would be insignificant. Thus, even if over time the activated metal particle sizes are reduced to respirable particle sizes, the dose from inhalation would be inconsequential.

Activated Concrete

Similar to the activated metal, the estimated particle size of the activated concrete particle S0124AEu is based on the highest concentration activated concrete detected in the under vessel during characterization (core B102106-CJFCCV-002) of 397 pCi/g Eu-152[28]. This sample was collected between June 2012 and January 2013 and is not decay-corrected for the purpose of this analysis. At a concentration of 397 pCi/g, the Eu-154 activity (344,000 pCi) observed on the S0124AEu particle corresponds to an 867 gram piece of activated concrete. Using a density of 2.35 g/cc, this is a 369 cc piece of concrete. This is an unreasonably large estimate of the size because it is based on the highest Eu-152 pCi/g activity observed in a concrete core. The core location is from the incore under vessel area floor, which is not necessarily the highest activated concrete present in the concrete surrounding the reactor vessel.

A more reasonable particle size estimate can be made by using the Co-60 data. The highest concentration of Co-60 observed in the activated concrete characterization samples was 1.09E+03 pCi/g in core B102110-CJFCCV-001[28]. The Co-60 level in the particle was 30,000 pCi. At this activity level and assuming a density of 2.35 g/cc the size of this particle is 27.5 grams or 11.7 cc. Assuming a theoretical particle was present with a Co-60 activity equal to the towed array scan MDA, the size of the particle would be 183 grams or 78 cc.

Table 12 - Concrete Particle Size Analysis

Co-60 pCi	30,000	2.00E+05
Co-60	**S204AEu**	**50th Percentile Scan MDA**
grams	2.75E+01	1.83E+02
cc	1.17E+01	7.81E+01

Particles of this size are not respirable. A reduction in the particle size would produce a corresponding reduction in the particle activity. As such, a 1 μm AMAD particle fragment

[28] Zion*Solutions* TSD 14-028, "Radiological Characterization Report," Revision 0, December 2014.

generated over time from the original particles or concrete pieces is likely to contain minimal activity.

Irradiated Fuel Particle

For the fuel particle (S0126), the mass of Pu-239 is estimated from the reported activity (7,450 pCi) along with the specific activity of Pu-239 of 6.2E10 pCi/g resulting in a Pu mass of 1.22E-07 g. Using this Pu mass, the fuel mass can be estimated using data from Figure 2, which shows 5 kg Pu-239 per tonne of fuel at a two-year irradiation interval resulting in a fuel mass of 2.16E-05 g. Using the same methodology described above and accounting for the U-238 mass to fuel-mass ratio of 0.941, this fuel mass corresponds to a physical spherical diameter of 155 μm and an aerodynamic equivalent diameter, d_{ae}, of 420 μm AMAD using a density of 10.97 g/cc and a shape factor of 1.5, well above the size considered respirable.

When the S0126 radionuclide mix is scaled to the Cs-137 Scan MDAs, the following Pu-239 concentrations, particle volumes and diameters result.

Table 13 - Cs-137 Scan MDA Irradiated Fuel Particle Size

S0126 @ MDAs	Pu-239 Activity (pCi)	Pu-239 Mass (g)	SF	U-238 Mass (g)	U-238 Volume (cc)	Particle Sphere Diameter (d_e) (μm)
Pu-239 50th	3.15E+04	5.08E-07	1.62E-04	9.02E-05	8.20E-06	1.76E+02

A 1 μm AMAD fuel particle has a spherical volume of 2.65E-14 cc. Thus, the activity of a 1 μm AMAD particle derived from a particle at the 50th percentile Cs-137 scan MDA would be reduced by a factor of 1.90E-09.

DRP Internal Dose Analysis

As discussed in the prior sections, the only likely internal dose pathway from the identified DRPs is from ingestion since the particle size estimate for each DRP type is substantially larger than a respirable size limit of 10 μm. This internal dose analysis is performed for each of the DRP types identified to date (activated metal, activated concrete, and irradiated fuel).

For each particle type, we have assumed that each is best represented by the most insoluble form since the particles have been exposed to weathering and have likely become stable since the particle's creation. Also, there appears to be no available data within the literature for absorption of radionuclides within the GI tract for activated particles (i.e., concrete and steel) but it is reasonable to expect that this absorption will be very low. However, there is some data for irradiated fuel fragments as discussed in more detail below.

Therefore, to represent these insoluble states, we have selected forms with the lowest value of the parameter that represents absorption from the GI tract (alimentary tract) to the blood stream following a hypothetical ingestion event. In each case, the calculated internal dose follows the methodology from ICRP-30, the basis of the methods represented in 10 CFR 20, including the tissue weighting factors. The ingestion internal doses are calculated using IMBA Professional Plus Version 4.1.11 using parameters from ICRP-26/30 or directly from Federal Guidance Report No. 11 (FGR11) as noted in each section.

Activated Metal Particle Activities and Doses

For the first part of this analysis, we have considered particle number S0124 since it represents the particle with the highest reported activity of Co-60 found by ORISE. In order to account for the remainder of the activation radionuclides that were not measured in the particle assessment, we have scaled these to Co-60 from the mean component activity of the calculations of the reactor internals activation. In addition, we then scaled the Co-60 activities to the 50th percentile of the DRP scan MDA distribution. The ingestion dose calculations for this particle are shown in the tables below. For this particle type we have used the lowest f_1 value and its corresponding dose conversion factor from FGR11.

Table 14 - Activated Metal DRP Scan MDA Activity

Nuclide	Activation Activity Calculation for U1 (Ci)	Activity Ratio to Co-60	Particle Activity Scaled to 50th Percentile MDA (pCi)
H-3	2.53E+02	2.53E-03	3.04E+02
C-14	3.59E+02	3.59E-03	4.31E+02
Mn-54	2.85E+01	2.85E-04	3.42E+01
Fe-55	7.15E+03	7.14E-02	8.57E+03
Co-60	1.00E+05	1.00E+00	1.20E+05
Ni-59	1.66E+03	1.66E-02	1.99E+03
Ni-63	2.27E+05	2.27E+00	2.72E+05
Nb-94	5.54E+00	5.53E-05	6.64E+00
Tc-99	1.18E+00	1.17E-05	1.40E+00

Table 15 - Activated Metal DRP Scan MDA Dose

Nuclide	FGR 11 f_1	FGR 11 Ingestion Dose Factor (mrem/pCi)	Particle Ingestion Dose Equivalent Scaled to 50th Percentile MDA (mrem)
H-3	1.00E+00	6.40E-08	1.91E-05
C-14	1.00E+00	2.09E-06	8.84E-04
Mn-54	1.00E-01	2.77E-06	9.32E-05
Fe-55	1.00E-01	6.07E-07	5.11E-03
Co-60	5.00E-02	1.02E-05	1.20E+00
Ni-59	5.00E-02	2.10E-07	4.11E-04
Ni-63	5.00E-02	5.77E-07	1.54E-01
Nb-94	1.00E-02	7.14E-06	4.66E-05
Tc-99	8.00E-01	1.46E-06	2.02E-06
Total			**1.36E+00**

One particle was found during the DRP survey. This DRP (Sample IA8IA104P) was analyzed by gamma spectroscopy at GEL and had a Co-60 activity of 0.167 µCi. The calculated dose from ingestion of this DRP is shown in the table below.

Table 16 - DRP IA8IA104P Ingestion Dose

Nuclide	FGR 11 Ingestion Dose Factor, mrem/pCi	Co-60 Scaling Factor	Ingestion Dose (mrem)
H-3	6.40E-08	2.53E-03	2.70E-05
C-14	2.09E-06	3.59E-03	1.25E-03
Mn-54	2.77E-06	2.85E-04	1.32E-04
Fe-55	6.07E-07	7.14E-02	7.24E-03
Co-60	1.02E-05	1.00E+00	1.70E+00
Ni-59	2.10E-07	1.66E-02	5.82E-04
Ni-63	5.77E-07	2.27E+00	2.19E-01
Nb-94	7.14E-06	5.53E-05	6.60E-05
Tc-99	1.46E-06	1.17E-05	2.86E-06
		Total	**1.93E+00**

Activated Concrete

The activity in a piece of activated concrete at the 50th percentile of the Co-60 DRP scan MDA is shown below. The Co-60 scaling factors for Ba-133, Eu-152, and Eu-154 were derived from the results of Sample S204EU. The remaining nuclides have been scaled to Co-60 using the activated metal scaling factors described above. The basis for using the activated metal scaling factors is the assumption that these nuclides are from the activation of rebar in the concrete. We then scaled the Co-60 activities to the 50th percentile of the DRP scan MDA. The ingestion dose calculations for this particle as shown in the tables below. For this particle type, we have used the lowest f_1 value and its corresponding dose conversion factor from FGR11.

Table 17 - Activated Concrete Particle Activity

Nuclide	Activity Ratio to Co-60	Particle Activity Scaled to 50th Percentile MDA (pCi)
H-3	2.53E-03	3.04E+02
C-14	3.59E-03	4.31E+02
Mn-54	2.85E-04	3.42E+01
Fe-55	7.14E-02	8.57E+03
Co-60	1.00E+00	1.20E+05
Ni-59	1.66E-02	1.99E+03
Ni-63	2.27E+00	2.72E+05
Nb-94	5.53E-05	6.64E+00
Tc-99	1.17E-05	1.40E+00
Ba-133	5.07E-02	6.08E+03
Eu-152	1.15E+01	1.38E+06
Eu-154	5.40E-01	6.48E+04

Table 18 - Activated Concrete Particle Ingestion Dose

Nuclide	FGR 11 f_1	FGR 11 Ingestion Dose Factor (mrem/pCi)	Particle Ingestion Dose Equivalent Scaled to Co-60 50th Percentile MDA (mrem)
H-3	1.00E+00	6.40E-08	1.91E-05
C-14	1.00E+00	2.09E-06	8.84E-04
Mn-54	1.00E-01	2.77E-06	9.32E-05
Fe-55	1.00E-01	6.07E-07	5.11E-03
Co-60	5.00E-02	1.02E-05	1.20E+00
Ni-59	5.00E-02	2.10E-07	4.11E-04
Ni-63	5.00E-02	5.77E-07	1.54E-01
Nb-94	1.00E-02	7.14E-06	4.66E-05
Tc-99	8.00E-01	1.46E-06	2.02E-06
Ba-133	1.00E-01	3.60E-05	2.03E-02
Eu-152	1.00E-03	6.48E-06	8.78E+00
Eu-154	1.00E-03	9.55E-06	6.07E-01
Total			**1.08E+01**

Irradiated Fuel Activity and Ingestion Dose

For this particle type, we identified two sources of estimating absorption from the GI (i.e., alimentary) tract. The first is from ICRP-137 which provides the following:

> In Publication 30 (ICRP, 1979), an absorption value of $2X10^{-4}$ was recommended on the basis of the study of Maletskos et al. (1969). In Publications 67 (ICRP, 1993) and 69 (ICRP, 1995a), because similar values have been obtained in more recent human studies on the absorption of plutonium, americium, neptunium, and curium, a general absorption value of $5X10^{-4}$ was adopted for dietary intake by adults for all actinides other than uranium. In Publication 68 (1994b), a value of $2X10^{-4}$ was applied to oxides and hydroxides. with $5X10^{-4}$ applied for all other chemical forms. An f_A value of $5X10^{-4}$ is adopted here for all chemical forms.

However, this section of ICRP-137 does not provide direct guidance for ingestion exposure to irradiated fuel particles for the actinides. ICRP-137 does provide an in-depth discussion on Cs-137 in irradiated fuel particles. Table 6.2 shows that for ingestion of all forms of Cs, except irradiated fuel, the f_a value (same as f_1 for ICRP-30) is 1.0, but for irradiated fuel, the value is 0.1 or a factor of 10 reduction. Since the discussion on the actinides value of f_a in ICRP-137 does not include irradiated fuel particles, but *is* included for Cs-137, a very soluble element, using this factor of 10 reduction is applicable to the f_a value of $5X10^{-4}$ for a final value of $5X10^{-5}$.

This value is consistent with the work reported in *Environment Health Perspectives*[29] with a value of $3X10^{-5}$ for the fractional absorption by ingestion of radionuclides within irradiated fuel fragments. Additionally, this reference states, in regard to ingestion absorption of elements within a fuel fragment: "...fission products in the fused particulate form renders them virtually inert in metabolic terms and the radionuclides are not metabolized along biological pathways characteristic for the elementary form."

Therefore, in this internal dose analysis we used a value for f_1 of $5X10^{-5}$ for the actinides. We applied a reduction factor of 10 in the lowest f_1 values listed in FGR11 for the other radionuclides identified in this particle except for Sr-90 and Eu-155, for which the lowest f_1 value from FGR11 is used. It is likely that the f_1 value of $5X10^{-5}$ applies to all radionuclides contained within the fuel DRP; however, this approach introduces a conservative margin into the dose calculation resulting in a higher CEDE than would otherwise be calculated. We consider this approach to be appropriate and conservative for the hypothetical doses shown below for this

[29] *Environmental Health Perspectives*, Review, Volume 103, No. 10, October 1995, p. 920 - 934: "Biokinetics of Nuclear Fuel Compounds and Biological Effects of Nonuniform Radiation," Sakari Lang (Department of Environmental Sciences, University of Kuopio, Kuopio, Finland), Kristina Servomaa (Department of Research, Finnish Centre for Radiation and Nuclear Safety, Helsinki, Finland), Veli-Matte Kosma (Department of Pathology, University of Kuopio, Kuopio, Finland), and Tapio Rytomaa (Finnish Centre for Radiation and Nuclear Safety).

fuel particle since it appears that an f_1 value of zero may actually apply to such an exposure, which would further lower the calculated CEDE.

The ingestion dose from this particle was calculated using IMBA for the f_1 values shown in the table below along with the source of the f_1, the Cs-137 scaling factor, and the CEDE using the ICRP-26/30 tissue weighting factors for the 50th percentile of the MDA distribution for Cs-137.

The ingestion dose of the recovered fuel DRP, which containted .098 µCi of Cs-137, is 14 mrem as shown in the table below.

Table 19 – Fuel Particle Ingestion Dose

Nuclide	pCi	f_1	Source	S0126 Ingestion Dose (mrem)
Eu-155	838	0.001	FGR11	9.40E-04
Am-241	79900	0.00005	ICRP 137 modified	1.24E+01
Cm-244	14800	0.00005	ICRP 137 modified	2.63E-01
Cs-137	98900	0.1	ICRP 137	4.53E-01
Np-237	3.9	0.00005	ICRP 137 modified	6.14E-05
Pu-238	26188	0.00005	ICRP 137 modified	4.41E-01
Pu-239	7540	0.00005	ICRP 137 modified	1.19E-01
Sr-90	157043	0.01	FGR11	4.53E-01
Total	**385212.9**			**1.42E+01**

Table 20 - Irradiated Fuel Particle at Scan MDA Activities

Radionuclide	Activity Ratio to Cs-137	Particle Activity Scaled to 50th Percentile MDA (pCi)
Eu-155	8.47E-03	3.47E+03
Am-241	8.08E-01	3.31E+05
Cm-244	1.50E-01	6.15E+04
Cs-137	1.00E+00	4.10E+05
Np-237	3.94E-05	1.62E+01
Pu-238	2.65E-01	1.09E+05
Pu-239	7.62E-02	3.12E+04
Sr-90	1.59E+00	6.52E+05

Table 21 - Irradiated Fuel Particle at Scan MDA Ingestion Dose

Radionuclide	f_1	**Source of f_1**	**Particle Ingestion CEDE Scaled to 50th Percentile MDA (mrem)**
Eu-155	1.00E-03	FGR11	3.91E-03
Am-241	5.00E-05	ICRP 137 modified	5.18E+01
Cm-244	5.00E-05	ICRP 137 modified	1.10E+00
Cs-137	1.00E-01	ICRP 137	1.89E+00
Np-237	5.00E-05	ICRP 137 modified	2.55E-04
Pu-238	5.00E-05	ICRP 137 modified	1.83E+00
Pu-239	5.00E-05	ICRP 137 modified	4.95E-01
Sr-90	1.00E-02	FGR11	1.89E+00
Total			**5.90E+01**

Irradiated Fuel DRP Reduced Size over 1,000 years

It is not possible to evaluate a rate at which particle sizes may change over the 1,000-year period because there is limited data on how stainless steel, concrete, and irradiated fuel particle sizes change with time. Size changes also depend on the natural processes such as weathering and corrosion, and site use such as grinding or pulverization from heavy equipment. The ICRP internal dose models are based on 1 µm AMAD.

Zion*Solutions* considered the potential for a particle that has been reduced in size over time and calculated the potential dose from the S0126 fuel particle that had been size-reduced to a respirable size. To do so, we evaluated the dose impact from a fuel particle that was reduced in size to 1 µm AMAD over time. The spherical physical volume of the size-reduced particle is calculated to be 2.65E-14 cc, as compared to the 155 µm particle volume of 2.09E-06 cc. The ratio of these volumes (1.35E-08) would also represent the ratio of the activities for particle S0126 to a hypothetical 1 µm d_{ae} particle, resulting in a Cs-137 activity of 1.33E-03 pCi for the 1 µm particle. The scaled mix and estimated dose from inhalation of a 1 µm d_{ae} particle is 5.26E-05 mrem as summarized in the following table.

Table 22 - 1 µm AMAD S0126 Irradiated Fuel Particle Activities and Doses

Radionuclide	Original Particle Activity (pCi)	1 µm AMAD Particle Activity (pCi)	Inhalation TEDE (mrem)
Eu-155	8.38E+02	1.13E-05	1.25E-10
Am-241	7.99E+04	1.08E-03	3.71E-05
Cm-244	1.48E+04	1.99E-04	4.68E-06
Cs-137	9.89E+04	1.33E-03	9.08E-08
Np-237	3.90E+00	5.26E-08	9.66E-10
Pu-238	2.62E+04	3.53E-04	8.01E-06
Pu-239	7.54E+03	1.02E-04	2.11E-06
Sr-90	1.57E+05	2.12E-03	5.90E-07
		Total	**5.26E-05**

Doses from Complete Dissolution of Particles

Doses were also evaluated for complete dissolution of particles over time into distributed residual radioactivity in soil over areas of 0.01, 0.1, and 1 m^2 and at soil depths of 15 cm deep using Surface Area Factors and $DCGL_{EMC}$s from the Zion LTP Chapter 6.11. Surface Area Factors for all the activated metal nuclides and the nuclide identified in DRP S204AEu and S0126 along with a soil density of 1.8 g/cc was used to calculate the dilution mass of the soil within these areas. The particle activities in pCi were divided by the masses associated with areas of 0.01, 0.1, and 1 m^2 to calculate the distributed contamination soil concentration in pCi/g. The results are shown below. This analysis takes no credit for radioactive decay and is thus very conservative since complete dissolution would likely occur over many years, if at all.

Table 23 - Activated Metal DRP Dissolution Dose

Area (m^2)	Activated Metal 50th Percentile Co-60 MDA CEDE (mrem)
0.01	2.10E-03
0.1	2.10E-04
1	2.10E-05

Table 24 - Activated Concrete DRP Dissolution Dose

Area (m^2)	Activated Concrete 50th Percentile Co-60 MDA CEDE (mrem)
0.01	1.40E-02
0.1	1.40E-03
1	1.40E-04

Table 25 - Fuel DRP Dissolution Dose

Area (m^2)	**Irradiated Fuel 50th Percentile Cs-137 MDA CEDE (mrem)**
0.01	3.41E-03
0.1	2.06E-04
1	1.89E-05

DRP External Doses

Varskin Version 6.2.1 was used to calculate skin and deep dose (SDE and DDE). However, the 25 mrem/year dose criterion in 10 CFR 20 Subpart E applies to TEDE, not skin dose, and therefore direct comparison of SDE and DDE to the 25 mrem/year criterion is not appropriate. To allow comparison of SDE to the 25 mrem/year dose limit, the SDE was multiplied by a risk factor to calculate fatal cancer risk and compared to the risk corresponding to the 25 mrem/year TEDE criterion as provided in SECY-97-046A, which is $4x10^{-4}$/y. The fatal cancer risk factor applied to the SDE dose is from the 2002 Final Rule for Revision of the Skin Dose Limit[30]. The risk factor from DRP SDE exposure is given as $6.6x10^{-10}$/rem. To compare the DDE skin dose to the 25 mrem/year criterion, the DDE could be multiplied by the skin tissue weighting factor of 0.01. However, this factor is not used in the DDE doses reported below. This is a highly conservative approach given that the exposure from DRPs are assumed to be limited to a 10 cm^2 area as opposed to the entire skin surface area.

Two types of DRPs were evaluated, activated metal and irradiated fuel, using the 50th percentile of the Co-60 and Cs-137 scan MDA distributions, respectively. For each of the activities, the equivalent volume diameter, d_e, was calculated as described above. This diameter for a spherical particle was used in Varskin as the variable that accounts for the self-attenuation of beta particles within each DRP. Also, for the activated metal DRPs, only Co-60 was used since this nuclide clearly dominates the activity profile. The particle equivalent volume diameter is 124 μm with a density of 8 g/cc. For this particle, the associated Co-60 activity is 0.12 μCi and the SDE and DDE rates are 9.08 and 0.61 mrad per hour, respectively, corresponding to 24-hour doses of 218 and 14.6 mrad.

For the fuel DRP, the 50th percentile particle diameter is 176 μm and the density is 10.97 g/cc. Only Sr-90 and Cs-137 are included in the calculations since the alpha emitters would make an insignificant contribution to SDE and DDE. Varskin includes the doses from progeny nuclides. Therefore, the calculated dose includes the contribution from Y-90. Lastly, the calculated dose rates are converted to a total dose for a 24-hour period as provided in the table below.

[30] Final Rule, *Revision of the Skin Dose Limit*, 67 FR 16298, April 5, 2002.

Table 26 - Irradiated Fuel Particle External Doses

Nuclide	50th Percentile Activity (µCi)	50th SDE Rate (mrad/hr)	50th DDE Rate (mrad/hr)	24-hr SDE (mrad)	24-hr DDE (mrad)
Sr-90	6.52E-01	5.44E+02	5.31E-02	1.31E+04	1.31E+00
Cs-137	4.10E-01	2.79E+02	6.31E-01	6.72E+03	4.32E+00
Total	1.06E+00	8.25E+02	6.84E-01	1.98E+04	5.62E+00
SDE Risk of Fatal Cancer/year				1.19E-08	

As shown above, the risks of a fatal cancer at the calculated 24-hour SDEs are well below the 4.00E-04/year that is commensurate with the 25 mrem/year site release criteria.

To better evaluate the dose relative to the 25 mrem/year site release criteria, Zion*Solutions* used EPRI guidance for calculating a DRP Effective Dose Equivalent.[31] This approach, authorized by the NRC in RIS-2003-04,[32] was used to calculate the worst-case effective dose equivalents for Co-60 and Cs-137 at the 50th percentile MDAs.

The NRC issued RIS-2003-04 to provide guidance regarding the use of EDE in place of DDE "...in showing compliance with regulatory requirements." The RIS goes on to state:

> Licensees are encouraged to use the effective dose equivalent in place of the DDE in all situations that do not involve direct monitoring of external exposures using personnel dosimetry. Such situations include, but are not limited to: [...] (2) calculating doses from contaminated soils and buildings; [...] (5) making calculations in connection with license termination and release of sites; (6) assessing doses resulting from localized skin contaminations...

The EPRI methodology is useful because it provides a more accurate method for calculating dose from DRP exposures. In particular, the EPRI data show that dose can vary dependent upon the location of the DRP on the body. For both Cs-137 and Co-60, the highest dose EDE conversion factors are for a particle located in the center chest area at 11.904 rem/hr per Ci for Cs-137 and 48.631 rem/hr per Ci for Co-60.

Using the Cs-137 and Co-60 EDE dose conversion factors, the EDE for particles at the 50th percentile *a posteriori* MDAs are calculated and provided in the table below.

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[31] "Implementing the EPRI Effective Dose Equivalent (EDE) Methodology for Discrete Radioactive Particles on the Skin," Electric Power Research Institute, EPRI 1002823, October 2004.
[32] "Use Of The Effective Dose Equivalent In Place Of The Deep Dose Equivalent In Dose Assessments," U.S. Nuclear Regulatory Commission, Regulatory Issue Summary (RIS) 2003-04, February 13, 2003.

Table 27 - 50th Percentile a posteriori EDE

	a posteriori 50th percentile MDA (µCi)	*a posteriori* 50th percentile MDA (Ci)	Max rem/hr EDE	mrem/24 hr
50th % Co-60 Scan MDA	0.12	1.20E-07	5.74E-06	1.37E-01
50th % Cs-137 Scan MDA	0.41	4.10E-07	4.91E-06	1.18E-01

The effective dose equivalents from a particle on the skin are well below the license termination criteria.

Expectation Doses

A risk-based approach was used to calculate the potential dose from a DRP hypothetically remaining at the site. The approach follows that approved by the Commission for the termination of the Shelwell license (SECY-98-117), in which thousands of residual DRPs were estimated to remain at license termination. The risk from particles in the soil was estimated by determining the annual expectation dose. The expectation dose is calculated by multiplying the probability of encountering, inhaling or ingesting a particle in a given year by the dose from the particle.

The probabilities for particle ingestion, inhalation and skin adherence were calculated at the beginning of this response. Multiplying these probabilities by the doses for the various scenarios presented earlier yields the expectation doses shown in the following table.

The expectation dose for the doses calculated above are summarized below. The highest annual expectation dose for the 24-hr skin dose fuel particle SDE is 2.64E-03 mrem; however, the corresponding annual EDE expectation dose is 1.57E-08 mrem.

Table 28 – Expectation Doses

Dose Calculation Case	Annual Expectation Dose (mrem)
Ingestion Activated Metal at 50th percentile	2.18E-08
Ingestion Activated Concrete at 50th percentile	1.72E-07
Ingestion Fuel Particle at 50th percentile	9.43E-07
Ingestion of 0.167 μCi Co-60 Particle	3.09E-08
Ingestion of SO126 Fuel Particle	2.27E-07
Inhalation of 1μm Fuel Particle	9.12E-15
Fuel Particle 24-hour SDE	2.64E-03
Fuel Particle 24-hour DDE	7.49E-07
EDE Activated Metal at 50th percentile	1.83E-08
EDE Fuel at 50th percentile	1.57E-08

NRC SPECIFIC CONSIDERATION 3c:

Consider updating the previous estimate of the number of discrete radioactive particles that may remain after the survey and collection activities are completed, which was based on the presence of one particle in every 50 centimeters (diameter) of the land surface (see the licensee's response to RAI-11 d in the letter dated February 10, 2021 (ADAMS Accession No. ML21067A225). The estimate of the number of particles should consider the potential for discrete radioactive particles remaining below the surface and should consider the likely location of the particles given their origin and transport mechanisms (see RAI-1 in the NRC letter dated August 19, 2021 (ADAMS Accession No. ML21231A187).

ZION*SOLUTIONS* RESPONSE:

All of the DRPs identified during the scan survey and volumetric sampling were remediated. There will be no known DRP source term remaining. An estimate of the number of DRPs that may remain is hypothetical. The most reasonable method for making an estimate of the number of DRPs that hypothetically may remain is to use the results of the scan surveys. The results of the volumetric sampling could be used but the presence/absence test used in survey design provides only an upper-bounding estimate of DRPs that could remain, which is unrealistic.

The number of unidentified DRPs that could hypothetically remain will be calculated by conservatively assuming that all of the DRPs identified during the scan survey were contained in a 1.0 cm layer of soil, regardless of the actual depth at which they were found, and that the range of DRP radionuclide activities and mixtures identified is representative of the DRPs that could hypothetically remain. In addition, the hypothetical DRPs are assumed to be limited to the first

30.5 cm (1 foot) layer of soil. Given these assumptions, the estimate of the number of DRPs that could hypothetically remain was made by multiplying the number of DRPs identified during the scan survey (i.e., one) by 30.5. Accordingly, the hypothetical number of particles projected to remain on the site is 31 (30.5 x 1).

The likely locations of the particles, i.e., those locations where DRPs hypothetically remaining would be most likely to be found, were considered in identifying areas that were included in the DRP Survey Plan. The methodology does not ascribe location within that area; rather, it estimates the number that could remain anywhere within that area.

NRC SPECIFIC CONSIDERATION 4:

The revised survey plan, if developed, should consider the following information for addressing the survey area coverage during a future survey:

NRC SPECIFIC CONSIDERATION 4a:

A description of the areas surveyed and the rationale for not performing additional surveys of specific site areas. The rationale should consider information for any areas not surveyed previously, as well as relevant information from the licensee's RAI responses to the NRC letter dated August 19, 2021 (ADAMS Accession No. ML21231A187).

ZION*SOLUTIONS* RESPONSE:

Within the DRP Survey Plan, Zion*Solutions* targeted 36 survey units that had the potential to contain DRPs. In determining what survey units to target, Zion*Solutions* selected survey units:

- where clean concrete demolition debris (CCDD) was temporarily staged or transported through after completion of FSS
- where waste loadout areas resided
- with areas of elevated activity identified by ORISE during the April 2021 inspection survey
- that were adjacent to Class 1 survey units (e.g., survey units 10214, 10213, 10212) where particles or elevated areas had been previously identified

The rationale for survey units *not* included in the DRP Survey Plan includes a combination of the following:

- Based on Zion*Solutions* assessment of the source and transport of the DRPs that have been identified, the survey unit was not expected to contain DRPs.
- The survey unit had no history of DRPs.
- FSS was performed in the survey unit with no identification of DRPs.

- ORISE performed an FSS confirmatory survey or other independent verification survey in the survey unit with no identification of DRPs.
- Surveys performed during final site grading did not identify DRPs.

NRC SPECIFIC CONSIDERATION 4b:

The scan coverage for each of the survey units and whether survey unit coverage will increase if a discrete radioactive particle is detected in a survey unit.

ZION*SOLUTIONS* RESPONSE:

In the event that a DRP is detected, adjacent survey units will be added to the survey plan unless already included or other considerations obviate the need for expanding the survey area. In that event, the overriding considerations will be documented. Scan coverage is addressed in the DRP Survey Plan.

NRC SPECIFIC CONSIDERATION 5:

The results of the survey and calculations should be submitted to the NRC. The licensee should provide a commitment to share the survey results with the NRC staff in the form of an FSS Record after the surveys and calculations have been completed. The result of the survey should include, as a minimum, the following information consistent with the considerations described in this RAI:

NRC SPECIFIC CONSIDERATION 5a:

The number of discrete radioactive particles detected during the licensee's survey activities and their location.

ZION*SOLUTIONS* RESPONSE:

One DRP containing 1.60 μCi of Co-60 was detected during the DRP Survey. The particle was located in SU 10221D.

The complete results of the survey and calculations will be submitted to the NRC in a TSD upon completion of the work described in the DRP Survey Plan.

NRC SPECIFIC CONSIDERATION 5b:

The radionuclide composition and activity of the collected particles, along with a description of the laboratory analyses performed Particles collected during the survey should be analyzed by an offsite laboratory for their radionuclide composition. This information is necessary given the discovery of unexpected particles of initially undetermined origin and radiological composition during the April 2021 survey.

ZION*SOLUTIONS* RESPONSE:

No Cs-137 particles were identified during the survey. The DRP found during the survey was sent to GEL laboratories for gamma spectroscopy analysis. The only gamma emitting nuclide detected was Co-60. In addition, dose calculations for activated steel scaled the HTD nuclides based on Co-60 activity using the most highly activated reactor internals, the baffle plates.

NRC SPECIFIC CONSIDERATION 5c:

An estimate of the number of discrete radioactive particles that may remain at the Zion site after the survey is completed (i.e., discrete radioactive particles either missed or below the MDA).

ZION*SOLUTIONS* RESPONSE:

See the response to Specific Consideration 3c for the description of the method to be used to estimate the number of DRPs that could hypothetically remain. The results will be provided to the NRC in the TSD that documents the survey results.

NRC SPECIFIC CONSIDERATION 5d:

An estimate of the radiation dose from the particles that may remain at the Zion site after the survey is completed. In developing its survey plan, the licensee should consider, as a minimum, the information provided in this RAI, as it may apply to the Zion facility.

ZION*SOLUTIONS* RESPONSE:

The DRP dose assessment method is described in the response to Specific Consideration 3b. The results will be provided to the NRC in the TSD that documents the survey results.

NRC RAI-11a:

Justification that the licensee statement that the 2018 URS surveys confirmed that the concrete on the outside of containment meets the "free release" criteria given the reported remediation and detections of contamination recently provided to the NRC. This justification should address remediation that appears to have been performed on the containment building exterior concrete in 2018 and scan alarms and smear measurements that appear to be above the MDA in the 2018 URS survey results for the containment building exterior concrete. This justification should also include an evaluation of how the 2018 URS results compared to the 2016 URS results.

ZION*SOLUTIONS* RESPONSE:

The statement that "…the concrete on the outside of containment meets the 'free release' criteria…" is in reference to its status after remediation. The fact that contamination was detected and remediated should not be interpreted to mean that the material did not meet the free release criteria before it was reused or disposed off-site.

The survey data from the 2018 URS that was provided in the enclosure to the February 10, 2021, responses included pre-remediation results that indicated that plant-derived radioactivity was detected as well as post-remediation data which showed no detectable radioactivity above background. For each instance in which a static alarm was recorded and/or where smear results were above L_D, the area was remediated or removed and subsequently resurveyed. In each occurrence, the loose surface contamination was wiped clean, or the elevated material was removed in its entirety, and the area was resurveyed to verify there was no longer any plant-derived radioactivity above background. These results are consistent with the text included in the February 10, 2021, RAI response in which Zion*Solutions* states that this concrete meets the "free release" criteria.

The 2018 URS, in comparison with the 2016 URS, found more elevated areas above background. This was expected, as more D&D work was conducted adjacent to the Containment Buildings (installation of waste loadout tents, creation of access hatches in the Containments, significant demolition of radioactive structures adjacent to the Containments). The level of survey was significantly increased for the 2018 URS to account for the changing conditions of the site.

NRC RAI-11b:

A description of the extent of contamination observed on the exterior containment building concrete after that area was put under isolation and control (i.e., 2016). This description should include:

- summary of the areas identified as potentially above background from scan alarms or smear sample measurements in the 2018 URS survey, including the measured activity and the approximate location (e.g., elevation [less than 3 meters or above 3 meters], the proximity of the location to key features [such as equipment hatches, tent enclosures], and whether the area was located on the Zion Unit 1 or Unit 2;
- summary of the area of the containment building exterior concrete remediated during or after the 2018 URS surveys;
- post-remediation data for the Zion containment building concrete that has not already been provided and/or a description of where the post-remediation data is located if it has been provided (e.g., which pages of the "2018 Unit 1 and Unit 2 Containment Exterior URS" attachment contain the post-remediation data).

ZION*SOLUTIONS* RESPONSE:

The exterior surfaces of the Unit 1 and Unit 2 Containment Buildings were put under isolation and control measures during the 2016 URS. The isolation and control measures remained in place until January and February of 2017 when the tents were constructed. The isolation and control measures remained in place for all other areas of the Containment Building exteriors outside of the tent enclosure. Because the isolation and control measures were no longer in place within the tents, the exterior surfaces of Containment within the tents, as well as other areas outside of the tent, were subject to a more extensive URS in 2018.

All areas identified as potentially above background were either remediated by wiping clean or removed in its entirety as shown in Table 29.

The following table provides a summary of the static beta measurements that exceeded the alarm set-points during the 2018 URS for the exteriors of the Unit 1 and Unit 2 Containment Buildings. The table also identifies whether the area was located on Zion Unit 1 or Unit 2, the elevation, and the proximity of the location to key features.

Table 29 – 2018 URS Elevated Beta Static Measurement Summary

Unit	Scan Area ID	Scan Area Location	Number of Alarms	Alarmed Readings (cpm)	Alarm Set-Point (cpm)	Remediation
1	1	3-9 m height	1	1750	477	decontamination by wiping
1	3	3-9 m height, near containment access hatch	2	3215, 2494	787	decontamination by wiping
1	4	3-9 m height, near tent opening	3	540, 650, 750	477	decontamination by wiping
1	8	3-9 m height, near containment access hatch	2	2703, 1150	787	decontamination by wiping
1	13	0-3 m height, near tent opening	2	728, 777	507	decontamination by wiping
1	15	3-9 m height, near tent opening	1	1050	723	decontamination by wiping
1	16	3-9 m height, near tent opening	1	980	723	decontamination by wiping
1	24	0-3 m height, near tent opening	1	4616	763	decontamination by wiping
1	47	0-3 m height, near containment access hatch	2	3400, 2075	762	complete removal of scan area

Unit	Scan Area ID	Scan Area Location	Number of Alarms	Alarmed Readings (cpm)	Alarm Set-Point (cpm)	Remediation
1	48	0-3 m height, near containment access hatch	3	1122, 2089, 1947	762	complete removal of scan area
1	58	0-3 m height	2	648, 939	494	decontamination by wiping
1	59	0-3 m height	1	810	543	decontamination by wiping
2	1, 2	3-9 m height, near tent opening	6	564, 525, 580, 409, 466, 975	394	decontamination by wiping
2	13	0-3 m height, near tent opening	2	486, 542	371	decontamination by wiping
2	15	3-9 m height, near tent opening	1	1990	392	complete removal of scan area
2	18	0-3 m height, near tent opening	2	798, 528	371	decontamination by wiping
2	41	0-3 m height, near containment access hatch	1	599	543	decontamination by wiping
2	42	0-3 m height, near containment access hatch	1	577	543	decontamination by wiping
2	43	0-3 m height, near containment access hatch	1	566	543	decontamination by wiping
2	44	0-3 m height, near containment access hatch	1	661	543	decontamination by wiping
2	45	0-3 m height, near containment access hatch	1	609	543	decontamination by wiping

The following table provides a list of all the smears that were identified as above L_D.

Table 30 – 2018 URS Elevated Smear Summary

Unit	Smear ID	Count Number	Beta Activity (dpm)	Beta L_D (cpm)
1	1	1	35.99	9.08
1	1	2	**6.74**	9.08
1	57	1	9.66	9.08
1	57	2	**0.89**	9.08
1	8	1	9.66	9.08
1	8	2	**3.81**	9.08
1	13	1	9.66	9.08
1	13	2	12.59	9.08
1	13	3	**0.89**	9.08
1	59A	1	21.36	9.08
1	59A	2	**3.81**	9.08
1	59	1	12.59	9.08
1	59	2	**-4.96**	9.08
1	52	1	9.65	8.9
1	52	2	**3.97**	8.9
1	23	1	12.48	8.9
1	23	2	29.51	8.9
1	23	3	**-1.71**	8.9
1	24A	1	9.65	8.9
1	24A	2	**-4.54**	8.9
1	25	1	15.32	8.9
1	25	2	9.65	8.9
1	25	3	**1.13**	8.9
1	15	1	21	8.9
1	15	2	46.54	8.9
1	15	3	**-4.54**	8.9
1	15A	1	18.16	8.9
1	15A	2	21	8.9
1	15A	3	**-4.54**	8.9
1	1	1	21	8.9
1	1	2	**3.97**	8.9

Unit	Smear ID	Count Number	Beta Activity (dpm)	Beta L_D (cpm)
1	52	1	9.65	8.9
1	52	2	**3.97**	8.9
1	3A	1	76.75	8.9
1	3A	2	**77.25**	8.9
1	3B	1	188.75	8.9
1	3B	2	**184.58**	8.9
1	8A	1	21	8.9
1	8A	2	**21**	8.9
1	8B	1	46.03	8.9
1	8B	2	**37.52**	8.9
1	1	1	8.33	7.65
1	1	2	8.33	7.65
1	1	3	**3.81**	9.08
1	13	1	40.96	7.65
1	13	2	30.48	7.65
1	13	3	44.76	9.08
1	13	4	**35.99**	9.08
1	4A	1	11.1	7.65
1	4A	2	19.4	7.65
1	4A	3	9.66	9.08
1	4A	4	**27.21**	9.08
1	4B	1	27.71	7.65
1	4B	2	19.4	7.65
1	4B	3	24.29	9.08
1	4B	4	**15.51**	9.08
1	4C	1	30.48	7.65
1	4C	2	40.96	7.65
1	4C	3	12.06	9.08
1	4C	4	**12.59**	9.08
1	4	1	27.71	7.65
1	4	2	19.4	7.65

Unit	Smear ID	Count Number	Beta Activity (dpm)	Beta L_D (cpm)
1	4	3	14.99	9.08
1	4	4	**12.59**	9.08
1	1A	1	44.32	7.65
1	1A	2	41.84	9.08
1	1A	3	**74.01**	9.08
2	34	1	9.65	8.9
2	34	2	9.65	8.9
2	34	3	**6.81**	8.9
2	35	1	9.65	8.9
2	35	2	**-4.54**	8.9
2	40	1	12.48	8.9
2	40	2	12.49	8.9
2	41	1	35.19	8.9
2	41	2	**21.09**	8.9
2	44	1	52.21	8.9
2	44	2	**32.56**	8.9
2	10	1	8.33	7.65
2	10	2	16.64	7.65
2	10	3	**2.79**	7.65
2	7	1	519.81	8.99
2	7	2	559.93	8.99
2	7	3	**15.36**	8.99
2	2	1	17.71	8.99
2	2	2	**9.63**	8.99
2	15	1	21	8.9
2	15	2	29.51	8.9
2	15	3	57.89	8.9
2	15	4	**38.02**	8.9
2	13	1	8.05 (alpha)	4.2 (alpha)
2	13	2	**3.89 (alpha)**	4.2 (alpha)
2	3	1	3.95 (alpha)	3.93 (alpha)

Unit	Smear ID	Count Number	Beta Activity (dpm)	Beta L_D (cpm)
2	3	2	**-0.18 (alpha)**	3.93 (alpha)
2	4	1	7.74	7.65
2	4	2	**3.81**	7.65
2	1 (A3)	1	119.07	7.65
2	1 (A3)	2	121.84	7.65
2	1 (A3)	3	52.04	7.65
2	1 (A3)	4	72.01	7.65
2	1 (A3)	5	96.92	7.65
2	1 (A3)	6	**94.16**	7.65
2	2 (A24)	1	13.28	7.65
2	2 (A24)	2	**2.2**	7.65
2	2 (A9)	1	18.82	7.65
2	2 (A9)	2	16.64	7.65
2	2 (A9)	3	30.48	7.65
2	2 (A9)	4	24.94	7.65
2	2 (A9)	5	13.87	7.65
2	2 (A9)	6	**32.66**	7.65
2	1 (A17)	1	4.97	7.65
2	1 (A17)	2	22.17	7.65
2	1 (A17)	3	5.56	7.65
2	1 (A17)	4	13.87	7.65
2	1 (A17)	5	36.02	7.65
2	1 (A17)	6	**8.33**	7.65

Post-remediation data for the survey performed on the Unit 1 exterior is included in the "2018 Unit 1 and Unit 2 Containment Exterior URS" report on pages 124-128. Post-remediation data for grids 1, 2, 13, and 18 in the Unit 2 survey is included in the report on page 202. Additional post-remediation data for the Unit 2 survey was not included in the submitted report and was inadvertently not digitally archived before being sent to long-term records storage. As such, the data is not readily available. Zion*Solutions* is confident that remediation and resurvey of the remaining Unit 2 elevated scan areas was performed satisfactorily based on the following:

- Multiple stages of professional review and approval of the surveys are required and were executed prior to the structure being deemed ready for open air demolition.

- The manager responsible for the work has confirmed that this process was followed under his supervision.
- The same review and approval process was required for Unit 1, which is documented by the scan provided previously.

To the extent there is any question regarding the level of contamination of the CCDD, all of survey units in which the containment exterior CCDD was temporarily stored, transported through, or loaded into railcars are included within the scope of the DRP Survey Plan and were surveyed. The only exceptions to this are those survey units that went through FSS and ORISE confirmation following the removal of the CCDD.

NRC RAI-11c:

Justification that the process for the URS surveys and the determination that material met the "free release criteria" is consistent with commitments in the LTP:

- a description of the process used to determine which areas to remediate and how large of an area to remediate (i.e., once radioactivity was detected, how large of an area around the detection point was remediated and/or excluded from being part of the "free release" concrete material);
- an evaluation of whether the process for including or excluding concrete from being considered as "free release material" is consistent with the LTP conditions on URS.

ZION*SOLUTIONS* RESPONSE:

Process Description. The process used to determine which areas to remediate, that is, for the URS performed on the exterior surfaces of the Unit 1 and Unit 2 Containment Buildings and the determination that the material met the free release criteria, is described in Section 5.7.1.12 of the Zion LTP, which states:

> The decommissioning approach for ZSRP calls for the beneficial reuse of concrete from building demolition as clean fill. CCDD is defined as uncontaminated broken concrete without protruding metal bars, bricks, rock, stone, reclaimed or other asphalt pavement or soil generated from construction or demolition activities. Only concrete debris that meets the definition of CCDD will be considered for use as clean hard fill and only when surveys have demonstrated that the concrete is free of detectable residual radioactivity.

If an elevated reading was observed, the area was bounded and marked with paint. The painted area was remediated, and all remediated material was controlled and disposed of as radioactive waste. The entire area that was remediated was rescanned to verify that it was suitable for free release. All areas with detectable radioactivity above background were remediated and resurveyed to verify suitability for free release and use as fill material (i.e., CCDD). A description of the approximate area remediated for each elevated measurement was not always provided in the field logs; as such, exact sizes for remediation areas is unknown. Regardless of how large an area to remediate was, the entire area was resurveyed following remediation.

There are no instances where CCDD that was used as fill material or other concrete that was released from the site had detectable plant-related radioactivity above background. A list of the areas that were remediated is provided in Table 29. All scan areas listed in the table were either decontaminated by wiping or completely removed. A description of the approximate area remediated for each elevated measurement was not always provided in the field logs; as such, exact sizes for remediation areas is unknown.

Consistency with LTP. For CCDD remaining on-site as fill material, the process for surveying and applying dose is fully consistent with the LTP as evidenced by the answer to the previous question. This approach was approved by the NRC during the LTP submittal and review process (see the response to RAI-4a and RAI-4d on Enclosure 1 to ZS-2017-0084 (ADAMS Accession No. ML17215A095) dated July 20, 2017).

NRC RAI-11d:

Justification that the URS surveys were performed adequately, including:

- a description of the process used to analyze the smear sample results, including: the method for determining if radioactivity above background was found in the sample (i.e., whether "Unc", the MDA, or some other criteria was used and a description of what "Unc" represents if "Unc" was used as the basis), a description of the process for determining whether smear samples were recounted, a description of which data was used in the evaluation of whether radioactivity above background was present when a sample was counted multiple times, and a justification for excluding data from the evaluation if any data was excluded.
- justification that concrete that had been located above 3 meters on the containment building exterior does not contain any residual contamination given the survey scan coverage of 10%.

ZION*SOLUTIONS* RESPONSE:

Process for analyzing smear sample results. The method for determining if radioactivity above background was found in the sample was to determine if the activity exceeds L_D. "Unc" represents the uncertainty. The uncertainty was not used as a basis for determining if activity was above background.

Process for determining whether smear samples were recounted and which data was used. Smear samples were recounted if either the alpha or beta activity exceeded L_D. Smear samples were recounted to verify if the activity remained the same or decreased. A decrease in activity over a short period of time indicated the presence of radon or NORM. The last count of a smear sample, if it was counted multiple times, was used for evaluation. This aligns with standard industry practice when the presence of radon or NORM is a factor.

Justification for excluding data. The only data that were excluded from evaluation were those superseded by further counts. In these cases, the higher activity of the original smear was influenced by the presence of radon or NORM. It is a standard industry practice to recount the smear after allowing time for decay and to discount the results of the original analysis.

Justification for reduced survey scan coverage above 3 meters. The pathway for contamination below 3 meters would be contact by personnel or equipment or by airborne material within the tent enclosures. Because it is not normal for personnel or equipment to come into contact with building surfaces above 3 meters, it was determined that there was a low potential for those surfaces to contain contamination above background. Because there was a low probability of finding surface contamination above background, the surfaces above 3 meters were designated as Class 2, and per procedure 10% scan coverage was prescribed. In exception to this, the exterior surfaces above 3 meters within the waste tent were designated as Class 1 because of the greater potential for airborne contamination. As such, 100% of the surfaces within the waste tent enclosure were surveyed.

NRC RAI-11e:

Evaluation of whether the containment building exterior concrete contamination (and/or the processes responsible for the contamination) could be a source of particles observed by the NRC, its contractor ORISE, and the licensee on the Zion site. This evaluation should include:

- an evaluation of the root cause for radioactivity being detected in 2018 but not 2016 (i.e., was the initial survey inadequate, or was there a breakdown in isolation and control measures?);
- a description of the containment structure concrete, if any, from an area with detectable radioactivity above background that was included in the "free release material" (i.e., CCDD) that was disposed of on-site or that was moved through areas of the site post FSS;
- an evaluation of whether the factors that led to the detection of contamination on the Zion containment building concrete could have led to similar problems elsewhere on the site and, if so, a description of corrective actions that were taken or will be taken by the licensee to address the problem.

ZION*SOLUTIONS* RESPONSE:

Root cause for time of detection. Zion*Solutions* does not believe that the radioactivity being detected in 2018 but not 2016 is the result of inadequate initial surveys, a breakdown in isolation and control measures, or any other process failure. Rather, Zion*Solutions* believes it is a result of the sequencing of remediation. Several areas of remediation in 2018 occurred near the Unit 1 and Unit 2 Containment Building equipment hatch openings which resided within the waste loadout tents, where airborne contamination was a common occurrence. The loadout tents were not present during the 2016 URS. It is not unexpected that areas surveyed (correctly) as clean during the 2016 URS might have been found to contain contamination in 2018. Regardless of the time at which activity was detected, the surface was decontaminated if contamination was detected.

Description of concrete included in CCDD. No portions of either containment structure with detectable activity were used as CCDD or released from the site without prior decontamination. The contamination identified on the exteriors of Unit 1 and Unit 2 containment in 2018 was low-level loose-surface contamination due to airborne radioactivity. All areas with detectable radioactivity above background were remediated and resurveyed to verify suitability for free release and use as fill material (i.e., CCDD). There are no instances where CCDD that was used as fill material or other concrete that was released from the site had detectable plant-related radioactivity above background.

Evaluation of factors that led to contamination of concrete structures. Potential factors that led to the detection of contamination on the Unit 1 and Unit 2 Containment Building exteriors were waste handling activities within the waste loadout enclosure or cross-contamination from personnel or equipment. Waste loadout enclosures were not used or associated with other site buildings, and all other site buildings had been demolished prior to the demolition of the Unit 1 and Unit 2 Containment Buildings. As such, Zion*Solutions* does not believe that these factors could have led to similar problems elsewhere on the site. Thus, no corrective actions have been taken or planned.

Zion*Solutions* believes that the foregoing response also addresses the NRC comment on p. 35 of the RAI letter, which states, "The measurement of radioactivity above background in the 2018 URS survey appears to be inconsistent with the text in in the February 2021 RAI response (i.e., that the 2018 survey confirmed previous measurements)."