

**ZION STATION RESTORATION PROJECT  
LICENSE TERMINATION PLAN  
CHAPTER 4, REVISION 1  
REMEDIATION PLAN**

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**LIST OF ACRONYMS AND ABBREVIATIONS**

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2	AF	Area Factor
3	ALARA	As Low As Reasonably Achievable
4	AMCG	Average Member of the Critical Group
5	BFM	Basement Fill Model
6	CFR	Code of Federal Regulations
7	<u>CVS</u>	<u>Contamination Verification Survey</u>
8	DCGL	Derived Concentration Guideline Levels
9	DSAR	Defueled Safety Analysis Report
10	EMC	Elevated Measurement Comparison
11	<u>FSS</u>	<u>Final Status Survey</u>
12	HEPA	High Efficiency Particulate Air
13	<u>ISOCS</u>	<u>In Situ Object Counting System</u>
14	LLRW	Low Level Radioactive Waste
15	LSA	Limited Specific Activity
16	LTP	License Termination Plan
17	MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
18	NRC	Nuclear Regulatory Commission
19	ODCM	Off Site Dose Calculation Manual
20	ROC	Radionuclides of Concern
21	RPT	Radiation Protection Technician
22	SAFSTOR	SAFeSTORage
23	SFP	Spent Fuel Pool
24	TEDE	Total Effective Dose Equivalent
25	WWTF	Waste Water Treatment Facility
26	ZNPS	Zion Nuclear Power Station
27	ZSRP	Zion Station Restoration Project

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## 30 4. SITE REMEDIATION PLAN

31 In accordance with 10 CFR 50.82(a)(9)(ii)(C), the License Termination Plan (LTP) must provide  
32 the “plans for site remediation.” These plans must include the provisions to meet the criteria  
33 from Subpart E of 10 CFR 20 before the site may be released for unrestricted use. The two  
34 radiological criteria for unrestricted use specified in 10 CFR 20.1402 are: (1) the Total Effective  
35 Dose Equivalent (TEDE) from residual radioactivity that is distinguishable from background  
36 radiation must not be greater than 25 mrem/yr to the Average Member of the Critical Group  
37 (AMCG) and (2) residual radioactivity levels must be As-Low-As-Reasonably-Achievable  
38 (ALARA).

39 Decontamination and dismantlement activities will be conducted in accordance with established  
40 Radiation Protection, Safety and Waste Management programs which include approved written  
41 procedures. These programs and procedures are frequently audited for technical content and  
42 compliance. Revisions have, and will continue to be made to these programs and procedures to  
43 accommodate the changing work environment inherent to reactor decommissioning and,  
44 documented, processed and approved in accordance with existing administrative procedures  
45 using 10 CFR 50.59 and Regulatory Guide 1.187, “*Guidance for Implementation of*  
46 *10 CFR 50.59 Changes, Tests and Experiments*” (Reference 4-1) as guidance. Consistent with  
47 Regulatory Guide 1.179, “*Standard Format and Contents for License Termination Plans for*  
48 *Nuclear Power Reactors*” (Reference 4-2), details regarding changes to the Radiation Protection  
49 Program to address remediation and decommissioning activities are not provided in this LTP, but  
50 periodic updates to the Zion Station “*Defueled Safety Analysis Report*” (DSAR) (Reference 4-3)  
51 will provide such details.

52 This chapter describes the methods that may be used to remediate contaminated systems,  
53 components and structures. The methods for demonstrating compliance with the ALARA  
54 criterion in 10 CFR 20.1402 is also described. Note that Chapter 6 provides the methods for  
55 demonstrating compliance with the 25 mrem/yr dose criterion. ~~Also~~Also, note that Chapter 3  
56 describes in detail the remaining site remediation and dismantlement activities and the order in  
57 which they will occur for each structure, system and/or component.

58 This chapter also provides a summary of the radiation protection methods and control procedures  
59 that will be employed during site dismantlement and remediation.

### 60 4.1. Remediation Actions and ALARA Evaluations

61 When dismantlement and decontamination actions are completed, residual radioactivity may  
62 remain on building surfaces and in site soils at concentrations that correspond to the maximum  
63 annual dose criterion of 25 mrem/yr. The remaining residual radioactivity must also satisfy the  
64 ALARA criterion, which requires an evaluation as to whether it is feasible to further reduce  
65 residual radioactivity to levels below those necessary to meet the dose criterion (i.e., to levels  
66 that are ALARA).

67 The ALARA evaluation calculates the concentration at which the averted collective radiation  
68 dose, converted into dollars, is equal to the costs of continued remediation (e.g., risk of  
69 transportation accidents converted into dollars, worker and public doses associated with the  
70 remediation action converted into dollars, and the actual costs to perform the remediation

71 activity). If this concentration is below the concentrations that correspond to the maximum  
72 annual dose criterion, then further reduction of residual radioactivity is justified by ALARA.

73 Regardless of the outcome of the quantified cost/benefit calculation provided in this chapter, the  
74 final dose from residual radioactivity is expected to be well below the dose criterion. The  
75 majority of the basement surfaces to be backfilled have minimal contamination. In addition, any  
76 areas that are identified as potentially containing activity at levels that could exceeding the  
77 Derived Concentration Guideline Level (DCGL), as measured during Final Status Survey (FSS)  
78 by the *In Situ* Object Counting System (ISOCS), will be remediated. Industry standard  
79 remediation methods have been shown to remove contamination to levels significantly below the  
80 target levels, in this case the DCGL, and this result is expected for any remediation. The  
81 combination of low contamination levels over the majority of the basement surfaces combined  
82 with remediated areas likely containing activity well below the DCGL, ensures that the final  
83 dose from residual radioactivity at license termination will be well below the 25 mrem/yr dose  
84 criterion. Based on characterization results, there is limited contamination expected in soil,  
85 buried pipe or end-state structures, ~~or above grade buildings~~ with a corresponding dose that is  
86 also expected to be well below 25 mrem/yr.

#### 87 **4.2. Remediation Actions**

88 Remediation actions are performed throughout the decommissioning process and the techniques,  
89 methods and technologies are standard to the commercial nuclear industry. All of the  
90 remediation actions described may not necessarily be required, but are listed as possible actions  
91 that may be taken during the decommissioning of Zion Nuclear Power Station (ZNPS). The  
92 appropriate remediation technique(s), method(s) and/or technologies that will be employed is  
93 dependent on the physical composition and configuration of the contaminated media requiring  
94 remediation. At ZNPS, the principal media that will be subjected to remediation are concrete  
95 structural surfaces. Characterization survey results and historical survey data indicate that there  
96 is minimal soil contamination and no groundwater contamination identified to date.

#### 97 **4.2.1. Structures**

98 The general approach to structure remediation at Zion Station Restoration Project (ZSRP) is  
99 driven by section 8.5 of Exhibit C, Lease Agreement, "Removal of Improvements; Site  
100 Restoration" integral to the "*Zion Nuclear Power Station, Units 1 and 2 Asset Sale Agreement*"  
101 (Reference 4-4) which requires the demolition and removal of all on-site buildings, structures,  
102 and components to a depth of at least three feet below grade. Consequently, the only structures  
103 that will remain at license termination are the concrete walls and floors below 588 foot elevation  
104 in the Unit 1 Containment Building, Unit 2 Containment Building, Auxiliary Building, Turbine  
105 Building, Fuel Handling Building, Crib House/Forebay, Waste Water Treatment Facility  
106 (WWTF), Circulating Water Intake Piping and Circulating Water Discharge Tunnels. All  
107 impacted systems, components and structures above the 588 foot elevation will be removed  
108 during the decommissioning process and disposed of as a waste stream. The current  
109 decommissioning approach for ZSRP also calls for the beneficial reuse of clean concrete from  
110 building demolition as clean fill. The only concrete structures that will be considered are those  
111 where the probability of the presence of residual contamination is minimal and surveys  
112 demonstrate that the concrete is free of plant derived radionuclides and hazardous paint coatings.

113 The remaining structural surfaces that will remain at ZNPS following the termination of the  
114 license are solid concrete structures which will be covered by at least three 3 feet of soil and  
115 physically altered to a condition which would not allow the remaining structural surfaces, if  
116 excavated, to be realistically occupied. ~~Consequently, the only applicable dose pathway is from~~  
117 ~~the leaching of residual radioactivity concentrations in the concrete to groundwater. The dose~~  
118 ~~model that will be used to calculate and quantify the future dose to groundwater is referred to as~~  
119 ~~the “Basement Fill Model” (BFM).~~

120 Scan measurements, static measurements and/or the analysis of volumetric sample(s) ~~of the~~  
121 ~~remaining concrete media~~ will be used to calculate the remaining total concentration of residual  
122 activity ~~remaining in the subsurface concrete structures and the corresponding dose to~~  
123 ~~groundwater. The concrete walls and floors of the basements will be remediated to levels that~~  
124 ~~will provide high confidence that FSS measurements with ISOCS will not exceed radionuclide-~~  
125 ~~specific DCGLs that represent the annual dose criterion for unrestricted use specified in~~  
126 ~~10 CFR 20.1402. Rather than using an adjusted gross Derived Concentration Guideline Level~~  
127 ~~(DCGL), the concrete walls and floors from the remaining subsurface basements will be~~  
128 ~~remediated to action levels commensurate with volumetric concentration limits that represent the~~  
129 ~~maximum annual dose criterion for unrestricted release specified in 10 CFR 20.1402.~~

130 Remediation techniques that may be used for the structural surfaces below 588 foot elevation  
131 include washing, wiping, pressure washing, vacuuming, scabbling, chipping, and sponge or  
132 abrasive blasting. Cost estimates for these techniques also include the amount of water  
133 generated and the cost to process, package and ship this waste. Concrete removal may include  
134 using machines with hydraulic-assisted, remote-operated, articulating tools. These machines  
135 have the ability to exchange scabbling, shear, chisel and other tool heads.

#### 136 4.2.1.1. Scabbling and Shaving

137 The principal remediation method expected to be used for removing contaminants from concrete  
138 surfaces is scabbling and shaving. Scabbling entails the removal of concrete from a surface by  
139 the high-velocity impact of a tool with the concrete surface which transforms the solid surface to  
140 a volumetric particulate which can be removed. One method of scabbling is a surface removal  
141 process that uses pneumatically operated air pistons with tungsten-carbide tips that fracture the  
142 concrete surface to a nominal depth of 0.125 inches at a nominal rate of about 130 ft<sup>2</sup> or  
143 12.07 m<sup>2</sup> per hour. The scabbling pistons (feet) are contained in a close-capture enclosure that is  
144 connected by hoses to a sealed vacuum and collector system. Shaving uses a series of diamond  
145 cutting wheels on a spindle, and performs at similar rates to scabbling. The wheels are also  
146 contained in a close capture enclosure similar to scabbling equipment. The fractured media and  
147 dusts from both methods are deposited into a sealed removable container. The exhaust air passes  
148 through both roughing and absolute High Efficiency Particulate Air (HEPA) filtration devices.  
149 Dust and debris generated through these remediation processes is collected and controlled during  
150 the operation.

#### 151 4.2.1.2. Needle Guns

152 A second method of scabbling is accomplished using needle guns. The needle gun is a  
153 pneumatic air-operated tool containing a series of tungsten-carbide or hardened steel rods  
154 enclosed in housing. The rods are connected to an air-driven piston to abrade and fracture the

155 media surface. The media removal depth is a function of the residence time of the rods over the  
156 surface. Typically, one to two millimeters are removed per pass. Generated debris collection,  
157 transport and dust control are accomplished in the same manner as other scabbling methods. Use  
158 of needle guns for removal and chipping of media is usually reserved for areas not accessible to  
159 normal scabbling operations. These include, but are not limited to, inside corners, cracks, joints  
160 and crevices. Needle gunning techniques can also be applied to painted and oxidized surfaces.

161 4.2.1.3. Chipping

162 Chipping includes the use of pneumatically operated chisels and similar tools coupled to  
163 vacuum-assisted collection devices. Chipping activities are usually reserved for cracks and  
164 crevices. This action is also a form of scabbling.

165 4.2.1.4. Sponge and Abrasive Blasting

166 Sponge and abrasive blasting are similar techniques that use media or materials coated with  
167 abrasive compounds such as silica sands, garnet, aluminum oxide, and walnut hulls. Sponge  
168 blasting is less aggressive, incorporating a foam media that, upon impact and compression,  
169 absorbs contaminants. The medium is collected by vacuum and the contaminants are washed  
170 from the medium so the medium may be reused. Abrasive blasting is more aggressive than  
171 sponge blasting but less aggressive than scabbling. Both operations use intermediate air  
172 pressures. Sponge and abrasive blasting are intended for the removal of surface films and paints.

173 4.2.1.5. Pressure Washing

174 Pressure washing uses a nozzle of intermediate water pressure to direct a jet of pressurized water  
175 that removes superficial materials from the suspect surface. A header may be used to minimize  
176 over-spray. A wet vacuum system is used to suction the potentially contaminated water into  
177 containers for filtration or processing.

178 4.2.1.6. Washing and Wiping

179 Washing and wiping decontamination techniques are actions that are typically performed during  
180 the course of remediation activities for housekeeping and to minimize the spread of loose surface  
181 contamination. ZSRP will implement good housekeeping throughout decommissioning to  
182 ensure ALARA, to ~~It is not anticipated that this remediation approach will be employed at ZSRP~~  
183 ~~to reduce the residual activity in structural surfaces for the purpose of meeting the 25 mrem/yr~~  
184 ~~dose criterion but rather,~~ to comply with the open air demolition criteria in ZionSolutions  
185 TSD 10-002, "Technical Basis for Radiological Limits for Structure/Building Open Air  
186 Demolition" (Reference 4-5) and, to ensure that loose surface contamination is removed prior to  
187 evaluating the surface for acceptable concentrations of residual activity.

188 Washing and wiping techniques are actions that are normally performed during the course of  
189 remediation activities and will not always be evaluated as a separate ALARA action. When  
190 washing and wiping techniques are used as the sole means to reduce residual contamination  
191 below DCGL levels, ALARA evaluations will be performed. Washing and wiping techniques  
192 used as housekeeping or good practice measures will not be evaluated.

193 4.2.1.7. High-Pressure Water Blasting

194 Most contaminated piping will be removed and disposed of as radioactive waste. Any pipe  
195 systems or sections of pipe systems that reside below the 588 foot elevation that will be  
196 abandoned in place will be inspected and surveyed as described in Chapter 5. If radiological  
197 conditions inside the pipe are in excess of the release criteria, then *in situ* remediation will be  
198 performed. One method that may be used to remediate the pipe interior surfaces is high pressure  
199 water blasting. A High-Pressure Liquid-Jetting System has a high pressure water pump capable  
200 of producing a water pressure of 10,000 psi to 20,000 psi at an actual flow rate that ranges from  
201 44 gallons per minute at 10,000 psi to 23 gallons per minute at 20,000 psi. A rotating jet-mole  
202 tip is used for 360 degree coverage of pipe interiors. The jet-mole is attached to a lance and  
203 high-pressure hose. The lance is manually advanced through the interior of the pipe. As the  
204 lance is advanced, the high-pressure water abrades the interior surface of the pipe, removing the  
205 corrosive layer, internal debris and radiological contamination. The waste water containing the  
206 removed contamination is then collected and stored for processing as liquid radiological waste.

207 4.2.1.8. Grit Blasting

208 Another approach that may be used to remediate the surfaces of pipe interior surfaces is grit  
209 blasting. Grit blasting uses grit media such as garnet or sand under intermediate air pressure  
210 directed through a nozzle that is pulled through the closed piping at a fixed rate. The grit  
211 blasting action removes the interior surface layer of the piping. A HEPA vacuum system  
212 maintains the sections being cleaned under negative pressure and collects the media for reuse or  
213 disposal. The final system pass is performed with clean grit to remove any residual  
214 contamination.

215 4.2.1.9. Removal of Activated/Contaminated Concrete

216 As previously stated, the principal means of remediating concrete surfaces is scabbling/shaving.  
217 If the concrete structure is designated for complete removal, such as interior concrete walls or the  
218 Bio-Shield, the primary method that will be used to completely remove the concrete is through  
219 large scale demolition using hydraulic-operated crushing shears and jack-hammers fitted to large  
220 tracked excavators. Concrete structures will be fractured and crushed by these tools. As the  
221 concrete is reduced to rubble, the embedded rebar will be exposed and segregated from the  
222 concrete rubble. In situations where a more surgical removal is required, activated and/or  
223 contaminated concrete removal may be accomplished using a machine mounted, remote-  
224 operated articulating arm with interchangeable tooling heads. As concrete is fractured and rebar  
225 exposed, the metal is cut using flame cutting equipment. The concrete rubble and exposed rebar  
226 is collected and transferred into containers for later disposal in both techniques. Dusts, fumes  
227 and generated debris are locally collected and as necessary, controlled using temporary  
228 enclosures coupled with close-capture HEPA systems or controlled water misting systems. Bulk  
229 concrete such as floors and walls may be removed as intact sections after sawing with blades,  
230 wires or other cutting methods.

231 4.2.1.10. Additional Remedial Actions

232 Mechanical abrasive equipment, such as hones, may be used to remove contamination from the  
233 surfaces of embedded/buried piping. Chemical removal means may be used, as appropriate, for  
234 the removal of certain contaminants.

235 **4.2.2. Soil**

236 The surface and subsurface soil DCGL<sub>w</sub> that will be used to demonstrate compliance with the  
237 dose-based criteria of 10 CFR 20, Subpart E for the unrestricted release of open land survey units  
238 are provided in Tables 5-4 and 5-5 of Chapter 5. Section 2.5.1.1 of NUREG-1575, “*Multi-*  
239 *Agency Radiation Survey and Site Investigation Manual (MARSSIM)*” (Reference 4-6)  
240 addresses the concern for the presence of small areas of elevated radioactivity. A simple  
241 comparison to an investigation level is used to assess the dose impact of potential elevated areas.  
242 This is referred to as the Elevated Measurement Comparison (EMC). The investigation level for  
243 this comparison is the DCGL<sub>EMC</sub>, which is the DCGL<sub>w</sub> modified by an Area Factor (AF) to  
244 account for the small area of the elevated radioactivity. Any radiological contamination in soils  
245 identified in concentrations greater than the DCGL<sub>EMC</sub> will be removed and disposed of as  
246 radioactive waste.

247 The site characterization process has established the location and extent of soil contamination at  
248 ZNPS. Characterization survey results and historical survey data indicate that there is minimal  
249 residual radioactivity in soil and no groundwater contamination identified to date. As needed,  
250 additional investigations will be performed to ensure that any changing soil radiological  
251 contamination profile during the remediation actions is adequately identified and addressed.  
252 Chapter 5 discusses soil sampling and survey methods.

253 Soil remediation equipment will include, but not be limited to, shovels, back hoe and track hoe  
254 excavators. Other equipment including soil dredges and vacuum trucks may also be used. As  
255 practical, when the remediation depth approaches the soil interface region between unacceptable  
256 and acceptable contamination, a squared edge excavator bucket design or similar technique may  
257 be used. This simple methodology minimizes the mixing of contaminated soils with acceptable  
258 lower soil layers as would occur with a toothed excavator bucket.

259 Remediation of soils will be performed using established excavation safety and environmental  
260 control procedures. Operational constraints and dust control will be addressed in site excavation  
261 and soil control procedures. In addition, work package instructions for remediation of soil may  
262 include additional constraints and mitigation or control methods to ensure adequate erosion,  
263 sediment, and air emission controls during soil remediation.

264 **4.3. Remediation Activities Impact on the Radiation Protection Program**

265 The Radiation Protection Program approved for decommissioning at ZSRP is similar to the  
266 regulatory approved program that was implemented during commercial power operation and the  
267 subsequent SAFSTOR period. During these periods, in a manner similar to remediation  
268 activities during decommissioning, contaminated structures, systems and components were  
269 decontaminated in order to perform maintenance or repair actions.

270 The current approved Radiation Protection Program at ZSRP is adequate to comply with all  
271 federal and state regulatory requirements for the protection of occupational personnel from

272 radiological hazards encountered or expected to be encountered during the decommissioning of a  
273 two unit commercial reactor facility. In addition, the program ensures the protection of the  
274 public from radiological hazards and ensures occupational, effluent and environmental dose from  
275 exposure to radioactive materials is, and remains ALARA. To ensure that adequate and proper  
276 engineering controls and hazard mitigation techniques are employed, work control programs and  
277 procedural requirements allow radiation protection personnel to integrate radiation protection  
278 and radiological hazard mitigation measures directly into the work planning and scheduling  
279 process. Consequently, the necessary radiological controls are correctly implemented to  
280 accommodate each remediation technology as appropriate.

281 The spread of loose surface contamination is mitigated by the routine remediation of work areas  
282 by washing and wiping. Water washing with a detergent is effective in reducing low levels of  
283 loose surface contamination over large surface areas. Wiping with detergent soaked or oil-  
284 impregnated media is an effective technique to reduce loose surface contamination on small  
285 items, overhead spaces and small hand tools. These same techniques are also effective in  
286 reducing low levels of surface contamination on structural surfaces.

287 For intermediate levels of surface contamination, more aggressive methods such as pressure  
288 washing, high-pressure water blasting and grit blasting may be more appropriate. Pipes, surfaces  
289 and drain lines can be cleaned and hot spots removed using these techniques and technologies.  
290 Small tools, hoses and cables can also be pressure washed in a containment to reduce  
291 contamination levels. A paint coating may be applied after surface cleaning to prevent surface  
292 contamination from drying out and becoming airborne.

293 To mitigate high levels of fixed surface contamination embedded in concrete, scabbling or other  
294 surface removal techniques may be appropriate. A combination of mechanical and flame cutting  
295 will be used to section the reactor vessel and its internals.

296 The Radiation Protection Program approved for decommissioning is similar to the program in  
297 place during commercial power operation. During power operations, contaminated structures,  
298 systems and components were decontaminated in order to perform maintenance or repair actions.  
299 These techniques are the same or similar to the radiological controls implemented at ZSRP for  
300 the decommissioning to reduce personnel exposure to radiation and contamination and to prevent  
301 the spread of contamination from established contaminated areas. Concrete cutting or surface  
302 scabbling, mechanical cutting, abrasive water jet cutting, hydrolazing and grit blasting has been  
303 used at ZNPS in the past during operations. The current Radiation Protection Program provides  
304 adequate controls for these actions.

305 Decommissioning does not present any new challenge to the Radiation Protection Program  
306 above those encountered during normal plant operation and refueling. Decommissioning  
307 planning allows radiation protection personnel to focus on each area of the site and plan each  
308 activity well before execution of the remediation technique.

309 The decommissioning organization is experienced in and capable of applying these remediation  
310 techniques on contaminated systems, structures or components during decommissioning. The  
311 Radiation Protection Program is adequate to safely control the radiological aspects of this work.  
312 Because the activities expected during decommissioning are the same or similar to those  
313 encountered during operations, as described above, the approval of any changes to the existing  
314 approved Radiation Protection Program as described in the Nuclear Regulatory Commission

315 (NRC) Docket Number 50-295, “*Facility Operating License Number DPR-39 (for Unit One)*”  
316 (Reference 4-7), NRC Docket Number 50-304, “*Facility Operating License Number DPR-48*  
317 *for Unit Two*” (Reference 4-8) is not requested in this LTP.

#### 318 **4.4. ALARA Evaluation**

319 Guidance for conducting ALARA analyses is provided in Appendix N of NUREG-1757,  
320 Volume 2, Revision 1, “*Consolidated Decommissioning Guidance - Characterization, Survey,*  
321 *and Determination of Radiological Criteria, Final Report*” (Reference 4-9), which describes  
322 acceptable methods for determining when further reduction of residual radioactivity is required  
323 to concentrations below the levels necessary to satisfy the 25 mrem/yr dose criterion.

324 The surface and subsurface soil DCGL<sub>w</sub> that will be used to demonstrate compliance with the  
325 25 mrem/yr dose criterion are provided in Tables 5-4 and 5-5 of Chapter 5. Characterization  
326 survey results and historical survey data indicate that there is minimal residual radioactivity in  
327 soil at ZNPS. Throughout the course of the decommissioning and through to site closure, ZSRP  
328 will continue to survey and characterize soils as they are exposed by excavation during building  
329 demolition or made accessible by the removal of structures or components. If residual  
330 radioactivity is discovered at concentrations greater than the DCGL<sub>EMC</sub> in surface or subsurface  
331 soils, ZSRP will excavate, package and dispose of the soil as Low-Level Radioactive Waste  
332 (LLRW).

333 Section N.1.5 of NUREG-1757 states that “*For residual radioactivity in soil at sites that may*  
334 *have unrestricted release, generic analyses show that shipping soil to a low-level waste disposal*  
335 *facility is unlikely to be cost effective for unrestricted release, largely because of the high costs*  
336 *of waste disposal. Therefore shipping soil to a low-level waste disposal facility generally does*  
337 *not have to be evaluated for unrestricted release.*” To illustrate that this is a reasonable  
338 approach and applicable to ZSRP, a simple ALARA analysis for the excavation and disposal of  
339 soils as low-level radioactive waste is provided in section 4.4.1.

340 For the subsurface structures that will remain at license termination, the ALARA analysis will  
341 determine whether further concrete remediation is necessary by comparing the desired beneficial  
342 effects to the undesired costs. Benefits are the averted collective radiation dose (converted into  
343 dollars) following the removal of radioactivity. The costs of remediation include transportation  
344 accidents, worker and public dose associated with remedial action, and the actual costs to  
345 perform the remediation (converted into dollars). If the costs exceed the benefits, then the dose  
346 reduction achieved by further remediation is not ALARA.

347 The ALARA criterion specified in 10 CFR 20.1402 is not met by solely performing remediation.  
348 The ALARA analysis is a planning tool to justify that further remediation is not necessary.  
349 When remediation is performed, there is no need to analyze whether the action was necessary to  
350 meet the ALARA requirement. The remediation required to meet the open air demolition criteria  
351 specified in TSD 10-002, including cleaning loose surface contamination to concentrations  
352 below 1,000 dpm/100cm<sup>2</sup> and the remediation of concrete surfaces to meet the 2 mR/h exposure  
353 rate criteria, will be performed regardless of the outcome of the ALARA evaluation.  
354 Consequently, this is an example of when a remediation action is not required to be evaluated for  
355 ALARA.

356 The methods and results of the ALARA evaluation for concrete remediation in structures below  
357 588 foot elevation is provided in section 4.4.2.

#### 358 4.4.1. ALARA Analysis of Soil Remediation

359 In order to determine if additional remedial action is warranted by ALARA analysis, the desired  
360 beneficial effects (benefits) and the undesirable effects (costs) must be calculated. If the benefits  
361 from remedial action will be greater than the costs, then the remedial action is warranted and  
362 should be performed. However, if the costs exceed the benefit, then the remedial action is  
363 considered to be not ALARA and should not be performed.

364 Based upon a simple ALARA analysis, the only benefit of reducing residual radioactivity in soil  
365 is the monetary value of the collective averted dose to future occupants of the site. For soils, the  
366 averted dose is based upon the “resident farmer” scenario.

##### 367 4.4.1.1. Calculation of Benefits

368 The benefit from collective averted dose ( $B_{AD}$ ) is calculated by determining the present worth of  
369 future collective averted dose and multiplying by a factor to convert the dose to a monetary  
370 value. In accordance with Appendix N of NUREG-1757, the equation is as follows;

371 **Equation 4-1**

$$372 B_{AD} = \$2,000 \times PW(AD_{Collective})$$

373 where;

374  $B_{AD}$  = benefit from an averted dose for a remediation action, in  
375 US dollars,

376  $\$2,000$  = value in dollars of a person-rem averted and,

377  $PW(AD_{Collective})$  = present worth of a future collective averted dose.

378 The present worth of future collective averted dose  $PW(AD_{Collective})$  is then expressed in  
379 accordance with the following equation;

380 **Equation 4-2**

$$381 PW(AD_{Collective}) = (P_D)(A)(0.025)(F) \left( \frac{Conc}{DCGL_w} \right) \left( \frac{1 - e^{-(r+\lambda)N}}{r + \lambda} \right)$$

382 where;

383  $P_D$  = population density for the critical group scenario in  
384 people/m<sup>2</sup>,

385  $A$  = area being evaluated in square meters (m<sup>2</sup>),

386  $0.025$  = annual dose to an AMCG from residual radioactivity at the  
387 DCGL<sub>w</sub> concentration in rem/yr,

388  $F$  = effectiveness, or fraction of the residual radioactivity  
389 removed by the remediation action,

390	<i>Conc</i>	=	average concentration of residual radioactivity in the area
391			being evaluated in units of activity per unit volume (pCi/g),
392	<i>DCGL<sub>w</sub></i>	=	derived concentration equivalent to the average
393			concentration of residual radioactivity that would give a
394			dose of 25 mrem/yr to the AMCG (pCi/g),
395	<i>r</i>	=	monetary discount rate in units per year (yr <sup>-1</sup> ),
396	<i>λ</i>	=	radiological decay constant for the radionuclide in units per
397			year and,
398	<i>N</i>	=	number of years over which the collective dose will be
399			calculated.

400 4.4.1.2. ALARA Analysis Parameters

401 In accordance with Table N.2 of Appendix N of NUREG-1757, the acceptable and relevant  
 402 parameters for use in performing ALARA analysis are as follows;

- 403 • Dollars per person-~~Rem-rem~~ - \$2,000.00/person-rem (per NUREG/BR-0058, “Regulatory  
 404 *Analysis Guidelines of the U.S. Nuclear Regulatory Commission*” [Reference 4-10])
- 405 • Population density (*P<sub>D</sub>*) for the critical group (persons/m<sup>2</sup>) - 0.0004 person/m<sup>2</sup> for land (per  
 406 NUREG-1496, “Final Generic Environmental Impact Statement in Support of Rulemaking  
 407 on Radiological Criteria for License Termination of NRC-Licensed Nuclear Facilities,”  
 408 Volume 2, [Reference 4-11] Appendix B, Table A.1)

409 • ~~Monetary discount rate (*r*) - 0.03 yr<sup>-1</sup> for soil~~ Monetary discount rate (*r*) — 0.03 yr<sup>-1</sup> for soil  
 410 ~~(per NUREG/BR-0058)~~

411 (Note: This variable was established at 0.03 yr<sup>-1</sup> for soil in Table N.2 of Appendix N of  
 412 NUREG-1757. The monetary discount for the ALARA analysis was removed from the  
 413 equation through Federal Register Notice 72 FR 46102 – August 16, 2007. Consequently,  
 414 the *r* variable has been conservatively set at 0.00 yr<sup>-1</sup> for soil, i.e., no monetary discount for  
 415 soils as well as basements.)

- 416 • Area (*A*) used to calculate the population density (m<sup>2</sup>) – 10,000 m<sup>2</sup> (size of reference area  
 417 that was evaluated)
- 418 • Number of years (*N*) over which the collective averted dose is calculated (yr) - 1,000 yrs (per  
 419 NUREG-1496, Volume 2, Appendix B, Table A.1)

420 4.4.1.3. Calculation of Costs

421 The total cost, (*Cost<sub>T</sub>*) which is balanced against the benefits; has several components and may  
 422 be evaluated according to Equation N-3 of NUREG-1757, Appendix N below:

**Equation 4-3**

424 
$$Cost_T = Cost_R + Cost_{WD} + Cost_{ACC} + Cost_{TF} + Cost_{WDose} + Cost_{PDose}$$

425 where:

426	$Cost_R$	=	monetary cost of the remediation action (including mobilization costs);
427			
428	$Cost_{WD}$	=	monetary cost for transport and disposal of the waste generated by the action;
429			
430	$Cost_{ACC}$	=	monetary cost of worker accidents during the remediation action;
431			
432	$Cost_{TF}$	=	monetary cost of traffic fatalities during transportation of the waste;
433			
434	$Cost_{WDose}$	=	monetary cost of traffic fatalities during transportation of the waste;
435			
436	$Cost_{PDose}$	=	monetary cost of dose to the public from excavation, transport and disposal of the waste;
437			

438 4.4.1.4. Calculation of Total Cost for Soil Remediation by Excavation and Disposal

439 For the analysis of soil excavation and disposal as low-level radioactive waste, the variables for  
 440  $Cost_R$ ,  $Cost_{ACC}$ ,  $Cost_{WDose}$  and  $Cost_{PDose}$  were not calculated for this evaluation based upon their  
 441 anticipated unlikely impact on the total cost ( $Cost_T$ ). This is consistent with the guidance  
 442 provided in NUREG-1757 which states that if one or two of the costs can be shown to exceed the  
 443 benefit, then the remediation cost is shown to be unnecessary without calculating all of the costs.

444 4.4.1.4.1. Transport and Disposal of the Waste ( $Cost_{WD}$ )

445 The cost of waste transport and disposal ( $Cost_{WD}$ ) was calculated using Equation N-4 of  
 446 NUREG-1757, Appendix N which is expressed as follows:

447 **Equation 4-4**

448 
$$Cost_{WD} = V_A \times Cost_V$$

449 where:

450  $V_A$  = volume of waste produced, remediated in units of  $m^3$ ;

451  $Cost_V$  = cost of waste disposal per unit volume, including  
 452 transportation cost, in units of  $\$/m^3$ .

453 Disposal costs for generated waste were based on an average total disposal cost of  $\$2,500/m^3$ .  
 454 This average cost includes packaging, transportation and disposal fees. The transportation  
 455 component of this average cost is based on the average transportation cost of using either rail or  
 456 highway hauling from the Zion site to Clive, Utah (EnergySolutions radioactive waste disposal  
 457 facility). The details of the average total disposal cost ( $Cost_V$ ) of  $\$2,500/m^3$  of waste are  
 458 considered proprietary values defined by negotiated contract.

459 The volume of waste produced by remediation ( $V_A$ ) assumes that the reference area of  $10,000 m^2$   
 460 ( $A$ ) is remediated to a depth of 0.15 meters. This results in a value for waste volume ( $V_A$ ) of  
 461  $1,500 m^3$ , which produces a value for  $Cost_{WD}$  of  $\$3,750,000.00$ .

462 4.4.1.4.2. Transportation Risks ( $Cost_{TF}$ )

463 The cost of traffic fatalities incurred during the transportation of waste ( $Cost_{TF}$ ) was calculated  
 464 using Equation N-6 of NUREG-1757, Appendix N which is expressed as follows:

465 **Equation 4-5**

466 
$$Cost_{TF} = \$3,000,000 \times \frac{V_A}{V_{SHIP}} \times F_T \times D_T$$

467 where:

468  $\$3,000,000$  = monetary value of a fatality equivalent to \$2000/person-  
 469 rem (NUREG-1530 "Reassessment of NRC's Dollar per  
 470 Person-Rem Conversion Factor Policy" [Reference 4-12])

471  $V_A$  = volume of waste produced in units of  $m^3$ ;

472  $V_{SHIP}$  = volume of a truck shipment in  $m^3$ ;

473  $F_T$  = fatality rate per truck-kilometer traveled in units of  
 474 fatalities/truck-km;

475  $D_T$  = distance traveled in km.

476 For this evaluation, the waste volume ( $V_A$ ) is assumed to be 1,500  $m^3$  and the haul volume of an  
 477 overland truck shipment per NUREG-1757 is assumed to be 13.6  $m^3$  ( $V_{SHIP}$ ).

478 In accordance with NUREG-1496, Appendix B, Table A.1, a value of 3.8 E-08/hr was used for  
 479  $F_T$ .

480 The Clive, Utah round trip distance from the Zion site by highway is 1,463 miles (2,355 km).  
 481 The distance for rail shipments is further than that for highway shipments because of the route  
 482 rail shipments must follow, however the difference as it pertains to the calculation is  
 483 insignificant. The highway shipment distance of 2,355 km ( $D_T$ ) was used for the calculation of  
 484  $Cost_{TF}$ . For this evaluation, the value for the  $Cost_{TF}$  variable is \$29,610.66.

485 4.4.1.4.3. Total Cost ( $Cost_T$ )

486 The total cost, ( $Cost_T$ ) assumed for this evaluation is \$3,779,610.66.

487 4.4.1.5. Residual Radioactivity in Soils that are ALARA

488 Determination of residual radioactivity in soils that are ALARA is the concentration at which  
 489 benefit equals or exceeds the costs of removal and waste disposal. When the total cost ( $Cost_T$ ) is  
 490 set equal to the dose averted, the ratio of the concentration to the  $DCGL_w$  is calculated as  
 491 follows;

492 **Equation 4-6**

493 
$$\frac{Conc}{DCGL_w} = \frac{(Cost_T)(r + \lambda)}{(\$2,000)(P_D)(0.025)(F)(A)(1 - e^{-(r+\lambda)N})}$$

494 Assuming the following values for the remaining variables;

- 495 • the default parameter values from section 4.4.1.2,
- 496 • a value of one for remediation effectiveness ( $F$ ), assuming all residual radioactivity is
- 497 removed during the excavation,
- 498 • a surface soil DCGL<sub>w</sub> of ~~15~~14.18 pCi/g for Cs-137 from Table 5-4 of Chapter 5,

499 **Equation 4-7**

$$500 \quad \frac{Conc}{DCGL_w} = \frac{(\$3,779,610.66) \left( 0.0\del{30} + \frac{0.693}{30.17} \right)}{(\$2,000)(0.0004)(0.025)(1)(10,000) \left( 1 - e^{-\left( 0.0\del{30} + \frac{0.693}{30.17} \right) 1,000} \right)}$$

501 the ratio of the concentration to the DCGL<sub>w</sub> when the total cost ( $Cost_T$ ) is equal to the dose  
 502 averted is ~~1,001.03~~434.08.

503 Assuming a concentration set at 50% of the DCGL<sub>w</sub> (based on the investigation level for a  
 504 Class 3 area), the present worth of future collective averted dose PW( $AD_{Collective}$ ) can be  
 505 calculated as follows;

506 **Equation 4-8**

$$507 \quad PW(AD_{Collective}) = (0.0004)(10,000)(0.025)(1) \left( \frac{7.09}{\del{15.8}14.2} \right) \left( \frac{1 - e^{-\left( 0.0\del{30} + \frac{0.693}{30.17} \right) (1,000)}}{0.0\del{30} + \frac{0.693}{30.17}} \right)$$

509 resulting in a value for PW( $AD_{Collective}$ ) of ~~0.942~~.18 person rems. The benefit from collective  
 510 averted dose ( $B_{AD}$ ) is then calculated as follows;

511 **Equation 4-9**

$$512 \quad B_{AD} = \$2,000 \times \del{0.942}18 = \del{\$14,880,353.00}54$$

513 This simple analysis confirms the statement in section N.1.5 of NUREG-1757 that the cost of  
 514 disposing excavated soil as low-level radioactive waste is clearly greater than the benefit of  
 515 removing and disposing of soil with residual radioactivity concentrations less than the dose  
 516 criterion. Since the cost is greater than the benefit, it is not ALARA to excavate and dispose of  
 517 soils with residual radioactivity concentrations below the DCGL<sub>w</sub>.

#### 518 4.4.2. ALARA Analysis for Remediation of Basement Structures

519 With the exception of some penetrations, embedded and buried piping, all contaminated and  
 520 non-contaminated systems will be disassembled, removed, packaged and shipped off-site as a  
 521 waste stream commodity. The list of penetrations and embedded piping to remain is provided in  
 522 ZionSolutions TSD 14-016, 14-016, "Description of Embedded Pipe, Penetrations, and Buried  
 523 Pipe to Remain in Zion End State" (Reference 4-13). Once commodity removal is complete,  
 524 structural surfaces will be remediated as necessary to meet the open air demolition criteria  
 525 specified in TSD 10-002. These criteria provide the removable contamination levels and contact  
 526 exposure rates that will allow structures to be safely demolished without containment. Prior to  
 527 demolition, a contamination verification survey (CVS) will be performed to identify areas

528 ~~requiring remediation to meet the open-air demolition limits. The CVS will also be used to~~  
529 ~~identify areas on surfaces to remain at license termination (i.e., at least three feet below grade)~~  
530 ~~that could potentially result in a FSS measurement (using ISOCS) to exceed the Basement~~  
531 ~~DCGLs (DCGL<sub>B</sub>) listed in LTP Chapter 5, Table 5-3. The dose rate target for this objective will~~  
532 ~~be lower than that required for open-air demolition. Identified areas will be remediated to~~  
533 ~~provide high confidence that no FSS ISOCS measurement will exceed the DCGL<sub>B</sub>. These~~  
534 ~~conditions or indicators are designations used to characterize the acceptable removable~~  
535 ~~contamination and contact exposure rates that will safely allow structures to be demolished~~  
536 ~~without containment. The limits are based upon re-suspension factors and ground level release~~  
537 ~~and dispersion models. Public dose is calculated at the site boundary using Off Site Dose~~  
538 ~~Calculation Manual (ODCM) methodologies for a ground level airborne radioactivity release.~~  
539 ~~The objectives of the open air demolition limits are:~~

540 ~~To ensure ground level airborne radioactivity levels remain ALARA and within regulatory limits~~  
541 ~~(note that in this case, ALARA refers to operational ALARA and not 10 CFR 20.1402~~  
542 ~~compliance).~~

543 ~~To ensure demolition liquid concentrations remain at levels which can be collected, processed~~  
544 ~~and released using plant water treatment systems and discharge points.~~

545 ~~To minimize the spread of contamination within the site boundary such that there is not~~  
546 ~~significant effect on groundwater or the scope of soil remediation required for License~~  
547 ~~Termination.~~

548 ~~To ensure open air demolition activities can be conducted using conventional demolition~~  
549 ~~techniques with minimal radiological restrictions or controls.~~

550 ~~Based upon the calculations, comparison and conclusions documented in TSD 10-002, the~~  
551 ~~following open air demolition limits will be implemented:~~

552 ~~Less than 2 mR/hr beta-gamma total contamination on contact with structural concrete.~~

553 ~~Less than 1,000 dpm/100cm<sup>2</sup> beta-gamma loose surface contamination.~~

554 ~~All structural surfaces will be remediated to the open air demolition limits prior to demolition.~~  
555 ~~Confirmatory surveys will be performed using approved procedures following remediation and~~  
556 ~~prior to demolition to ensure that contamination levels are at or below the open air demolition~~  
557 ~~criteria. It is expected that remediation to open air demolition criteria will reduce the structure~~  
558 ~~source terms to level below that corresponding to 25 mrem/yr. If not, additional remediation will~~  
559 ~~be performed to meet the 25 mrem/yr dose limit. Once remediation is complete structural~~  
560 ~~surfaces located above the 588 foot elevation and non-load-bearing interior concrete walls below~~  
561 ~~the 588 foot elevation will be demolished, reduced in size, packaged and shipped off-site to a~~  
562 ~~licensed disposal facility.~~

563 All concrete inside the liner above the 541-565 foot elevation will be removed from the interiors  
564 of both Containment Buildings prior to demolition. This includes all activated and contaminated  
565 concrete. Only the concrete below the 541-565 foot elevation in the In-core Instrument Shaft  
566 leading to and including the area under vessel (or Under-Vessel area) will remain. The source  
567 term in the Containment Basements remaining after demolition will be consist of the concrete in  
568 the Under-Vessel area(s) and low levels of surface contamination on the exposed liner surfaces.  
569 There is currently minimal contamination in the Turbine Building, Crib House/Forebay, and

570 Circulating Water Piping at levels that are expected to be well below the open air demolition  
571 criteria and below ~~the DCGL<sub>B</sub> listed in LTP Chapter 5, Table 5-3, contamination levels~~  
572 ~~corresponding to 25 mrem/yr dose limit in the BFM (see Chapter 6 for a detailed description of~~  
573 ~~the BFM).~~ The only portion of the Fuel Handling Building Basement that will remain following  
574 building demolition is the lower 13 foot (~4 m) concrete bottom of the Spent Fuel Pool (SFP)  
575 and the Transfer Canal, which is located at the 575 foot elevation. The steel liner will be  
576 removed from both the SFP and the Transfer Canal. After the liner is removed and the  
577 underlying concrete exposed, ~~additional continuing~~ characterization surveys will be performed ~~to~~  
578 ~~assess the radiological condition of the underlying concrete pad and remaining pool walls.~~  
579 Continuing characterization will consist of scanning of the exposed concrete surfaces and the  
580 acquisition of concrete core sample(s) at the location of highest activity. Contamination is  
581 expected below the liner but an estimate of levels cannot be made until characterization is  
582 completed.

583 In summary, the vast majority of residual radioactivity remaining in the structures after the open  
584 air demolition criteria is met and after ~~the majority of all~~ concrete is removed from the  
585 Containment Building basements will be located in the 542 foot elevation floor of the Auxiliary  
586 Building. Therefore, the ALARA assessment for the remediation of basement structures will  
587 focus on the 542 foot elevation floor of the Auxiliary Building as this is the location where the  
588 greatest benefit of concrete remediation could be achieved. An ALARA assessment of the  
589 542 foot elevation floor of the Auxiliary Building will bound ALARA assessments for the other  
590 buildings which would use the same methods (and cost estimate) but remove less contamination.  
591 If continuing characterization indicates significant concentrations of residual radioactivity  
592 remaining in other end-state structures (e.g., Under-Vessel area, SFP/Transfer Canal, Auxiliary  
593 Building embedded drains), then ZSRP will perform and document a separate ALARA analysis  
594 or, provide evidence that the ALARA analysis of the 542 foot floor of the Auxiliary Building is  
595 still bounding.

596 The Auxiliary Building basement concrete at the 542 foot elevation is volumetrically  
597 contaminated. A total of twenty (20) concrete core samples were collected in the Auxiliary  
598 Building during characterization. The sample analysis of these concrete core samples indicates  
599 that the majority of the radionuclide inventory resides within the first ½-inch of concrete.  
600 However, several core samples show detectable Cs-137 and Co-60 at depths in excess of six  
601 inches.

#### 602 4.4.2.1. ALARA Analysis Equation for Remediation of Basement Structures

603 For the ALARA analysis for the remediation of basement structures, the equation from section  
604 4.4.1.5 ~~for the ratio of the concentration to the DCGL<sub>w</sub> when the total cost (Cost<sub>T</sub>) is set equal to~~  
605 ~~the dose averted~~ is modified as follows. The BFM DFs DCGLs for concrete are expressed in  
606 units of mrem/yr per mCi total activity pCi/m<sup>2</sup>. The denominator must be summed and the  
607 individual dose contribution normalized to account for the multiple detectable radionuclides that  
608 are present in the radionuclide distribution for the Auxiliary Building. The equation from  
609 NUREG-1757 therefore becomes:

Equation 4-10

$$\frac{Conc}{DCGL_w} = \frac{(Cost_T)(r + \lambda_i \lambda)}{\sum (\$2,000) (P_D) (f_i) (DOSE_{AMCG} 0.025) (F) (A) (1 - e^{-(r + \lambda_i \lambda) N})}$$

where:

$f_i$  = the normalized product of the Basement Inventory Levels radionuclide fraction for the Auxiliary Building for each individual Radionuclides of Concern (ROC) (from Chapter 5, Table 5-92) ~~normalized to one~~

$DOSE_{AMCG}$  = averted dose to the AMCG (rem).

The total cost for the remedial action when divided by the total benefit of averted dose determines the cost effectiveness of the remedial action. Values greater than unity demonstrate that no further remediation is necessary beyond that required to meet the 25 mrem/yr dose criterion and are ALARA. Values less than one provide the fraction of the 25 mrem/yr dose criterion where it is necessary to remediate to achieve ALARA.

4.4.2.2. Remedial Action Costs

The only structures that will remain as potential candidate surfaces for remediation are the concrete walls and floors from the Auxiliary Building, the Under-Vessel area(s), Turbine Building, Crib House/Forebay, WWTF, the lower 13 foot concrete bottom of the SFP, the Circulating Water Intake Piping and Circulating Water Discharge Tunnels. With the exception of some sections of buried and embedded pipe, all impacted systems, components as well as all structures above the 588 foot elevation will be removed during the decommissioning process and disposed of as a waste stream. The current decommissioning approach for ZSRP also calls for the beneficial reuse of concrete from building demolition as clean fill. As discussed above, the vast majority of contamination to remain after removal of containment concrete will be in the 542 foot elevation floor of the Auxiliary Building.

Prior to building demolition, all structures will be remediated to meet the open air demolition limits specified in TSD 10-002 and, to provide high confidence that ISOCS measurements taken during FSS will not exceed the DCGL<sub>B</sub> from Table 5-3. All loose surface contamination greater than 1,000 dpm/100cm<sup>2</sup> will be removed. The remediation techniques most likely to be implemented to perform this work are vacuuming, pressure washing and hand-wiping. ~~In addition, TSD 10-002 calls for structural surfaces that exhibit fixed contamination in excess of 2 mR/hr beta gamma total surface contamination on contact to be remediated. The remediation approach used to accomplish this action will likely be~~ concrete scabbling or concrete shaving. As these efforts will occur prior to evaluating the remaining structural surfaces for acceptable concentrations of residual activity, this remediation action will not be evaluated for ALARA.

The remediation action evaluated for the ALARA analysis for the remediation of basement structures is scabbling the concrete surface of the 542 foot elevation floor of the Auxiliary Building. Concrete core samples indicate that the majority of the radionuclide source inventory in the 542 foot elevation concrete floor resides within the first ½-inch of concrete. For the purposes of the ALARA evaluation, it is conservatively assumed that 100% of the contamination resides in the first ½ inch. In accordance with the guidance in section G.3.1 of NUREG/CR-

650 5884, “Revised Analyses of Decommissioning for the Reference Pressurized Water Reactor  
651 Power Station” Volume 2 (Reference 4-1314), one pass of scabbling is assumed to remove  
652 0.125 inches (0.635 cm) of concrete. In accordance with ZionSolutions TSD 14-013, “Zion  
653 Auxiliary Building End State Estimated Concrete Volumes, Surface Areas, and Source Terms”  
654 (Reference 4-1415), the 542 foot elevation floor of the Auxiliary Building has a surface area of  
655 2,543 m<sup>2</sup>. This is the surface area which will be evaluated for the remediation cost  
656 determination.

#### 657 4.4.2.2.1. Remediation Activity Rates

658 The remediation activity rates that were used for this evaluation were based on previous  
659 experience, from published literature, or from groups or vendors currently performing these or  
660 similar activities. Current project labor costs and past operational experience were also used in  
661 developing these rates.

662 In accordance with NUREG/CR-5884, an assumed crew size for performing concrete scabbling  
663 or shaving activities is three full-time laborers, a supervisor at a ¼-time involvement and a  
664 Radiation Protection Technician (RPT), also at a ¼-time involvement. Using the current project  
665 labor rates for these positions of \$66.78 per hour for a laborer, \$90.00 per hour for a supervisor  
666 and \$55.59 per hour for a RPT, the hourly unit rate that will be used for the evaluation is  
667 \$236.74.

668 Using the guidance found in NUREG/CR-5884 it is assumed that the concrete scabbling or  
669 shaving activity will remove approximately 0.125 inches of concrete per pass and the effective  
670 nominal removal rate is approximately 12.07 m<sup>2</sup> per hour. The ALARA evaluation assumes that  
671 100% of the radioactive contamination resides within the first ½ inch. Consequently, removing  
672 ½ inch of concrete over an assumed reference area of 2,543 m<sup>2</sup>, scabbling at a nominal rate of  
673 12.07 m<sup>2</sup> per hour to a depth of 0.125 inch per pass, equates to approximately 836.5 man-hours  
674 of work.

675 Also in accordance with NUREG/CR-5884 it is assumed that the actual remediation time in a  
676 typical eight-hour shift is 5.33 hours. To account for non-remediation work hours for work  
677 preparation, donning and removing protective clothing and work breaks, the total man-hours  
678 were increased by a factor of 33% which equates to 1,112 man-hours. In addition, a contingency  
679 of 25% was added to the manpower hours. This equates to a total ~~man-hours~~ of 1,390.61 man-  
680 hours, which is multiplied times the hourly unit rate of \$236.74 to equal the labor cost for this  
681 evaluation of \$329,209.54.

#### 682 4.4.2.2.2. Equipment Costs

683 Using the guidance found in NUREG/CR-5884, equipment costs are based on the rental of  
684 commercially available scabbling equipment, a compressor, a vacuum unit and consumables such  
685 as cutting bits, vacuum filters and waste drums for containing waste debris. At 40-hours per  
686 work week, 1,391 man-hours equates to approximately 35 work-weeks. This evaluation assumes  
687 that two different commercially available concrete removal units will be procured, the Pentek  
688 Squirrel Scabbler & Vacuum System with a nominal rental rate of \$685.00 per week and a  
689 Pentek Moose Scabbler & Vacuum System with a nominal rental rate of \$950.00 per week. The  
690 compressor required for pneumatic equipment operation can be rented at a nominal rate of  
691 \$115.00 per week. The cutting bits for the units are assumed to be replaced every 80 hours of

692 operation, for an equivalent cost of about \$13.00 per hour of operation. Additional costs include  
693 filter replacements at about \$2.50 per hour of operation and waste drums for the collected debris.  
694 A 55-gallon drum holds approximately 7 ft<sup>3</sup> of waste and cost approximately \$100.00 per drum.  
695 As it is assumed that the scabbing activity will generate approximately 1,132 ft<sup>3</sup> (32 m<sup>3</sup>) of  
696 concrete waste, this will require the procurement of approximately 162 drums at a total cost of  
697 \$16,171.49. The mobilization and demobilization costs associated with procuring this equipment  
698 would be approximately \$2,200.00 per piece of equipment for a total of approximately  
699 \$6,600.00. The total equipment costs assumed for this evaluation is approximately \$98,975.87.

700 4.4.2.2.3. Total Remediation Action Cost ( $Cost_R$ )

701 For the evaluation of the remediation activity of concrete scabbling or shaving, the sum of the  
702 labor cost of \$329,209.54 plus the equipment cost of \$98,975.87 results in a total remediation  
703 action cost ( $Cost_R$ ) for this activity of \$428,185.41.

704 4.4.2.3. Transport and Disposal of the Waste ( $Cost_{WD}$ )

705 As previously described in section 4.4.1.4.1, the cost of waste transport and disposal ( $Cost_{WD}$ ) is  
706 expressed as follows:

707 **Equation 4-11**

$$708 \quad Cost_{WD} = V_A \times Cost_V$$

709 Disposal costs for generated waste were based on an average total disposal cost of \$2,500/m<sup>3</sup>.  
710 This average cost includes packaging, transportation and disposal fees. The transportation  
711 component of this average cost is based on the average transportation cost of using either rail or  
712 highway hauling from the Zion site to Clive, Utah (EnergySolutions radioactive waste disposal  
713 facility). Based upon an assumed waste volume of 32 m<sup>3</sup>, a value of \$80,000.00 is calculated for  
714 the  $Cost_{WD}$  variable.

715 4.4.2.4. Non-Radiological Risks ( $Cost_{ACC}$ )

716 The cost of non-radiological workplace accidents ( $Cost_{ACC}$ ) was calculated using Equation N-5  
717 of NUREG-1757, Appendix N which is expressed as follows:

718 **Equation 4-12**

$$719 \quad Cost_{ACC} = \$3,000,000.00 \times F_W \times T_A$$

720 where:

721  $\$3,000,000$  = monetary value of a fatality equivalent to \$2000/person-  
722 rem (NUREG-1530)

723  $F_W$  = workplace fatality rate in fatalities/hour worked;

724  $T_A$  = worker time required for remediation in units of worker-  
725 hours.

726 In accordance with NUREG-1496, Appendix B, Table A.1, a value of 4.2 E-08/hr was used for  
727  $F_W$ . For  $T_A$ , in accordance with NUREG-1757 the same hours that was determined for labor cost

728 (1,391 man-hours) was used for worker accident cost. Subsequently, a value of \$175.27 is  
729 calculated for the  $Cost_{ACC}$  variable.

730 4.4.2.5. Transportation Risks ( $Cost_{TF}$ )

731 As previously described in section 4.4.1.4.2, the cost of traffic fatalities incurred during the  
732 transportation of waste ( $Cost_{TF}$ ) is expressed as follows:

733 **Equation 4-13**

734 
$$Cost_{TF} = \$3,000,000.00 \times \frac{V_A}{V_{SHIP}} \times F_T \times D_T$$

735 For this evaluation, the waste volume ( $V_A$ ) is assumed to be 32 m<sup>3</sup> and the haul volume of an  
736 overland truck shipment per NUREG-1757 is assumed to be 13.6 m<sup>3</sup> ( $V_{SHIP}$ ).

737 In accordance with NUREG-1496, Volume 2, Appendix B, Table A.1, a value of 3.8 E-08/hr  
738 was used for  $F_T$ .

739 The Clive, Utah round trip distance from the Zion site by highway is 1,463 miles (2,355 km).  
740 The distance for rail shipments is further than that for highway shipments because of the route  
741 rail shipments must follow, however the difference as it pertains to the calculation is  
742 insignificant. The highway shipment distance of 2,355 km ( $D_T$ ) was used for the calculation of  
743  $Cost_{TF}$ . For this evaluation, the value for the  $Cost_{TF}$  variable is \$631.69.

744 4.4.2.6. Worker Dose Estimates ( $Cost_{WDose}$ )

745 The cost of remediation worker dose ( $Cost_{WDose}$ ) was calculated using Equation N-7 of NUREG-  
746 1757, Appendix N which is expressed as follows:

747 **Equation 4-14**

748 
$$Cost_{WDose} = \$2,000.00 \times D_R \times T$$

749 where:

750  $D_R$  = total effective dose equivalent (TEDE) rate to remediation  
751 workers in units of Remrem/hr;

752  $T$  = time worked (site labor) to remediate the area in units of  
753 person-hour.

754 Costs associated with worker dose are a function of the hours worked and the workers' radiation  
755 exposure for the task. A value of 3 mrem per man-hour was used for  $D_R$ . This assumes that a  
756 majority of the source inventory will be removed prior to performing the concrete scabbling or  
757 shaving activity. The time worked to remediate the area in units of person-hour calculated for  
758 this activity ( $T$ ) was 1,391 man-hours. For this evaluation, the value for the  $Cost_{WDose}$  variable is  
759 \$8,346.00.

760 4.4.2.7. Monetary Cost of Dose to the Public ( $Cost_{PDose}$ )

761 The cost of remediation worker dose ( $Cost_{PDose}$ ) was calculated using Equation N-7 of NUREG-  
762 1757, Appendix N which is expressed as follows:

Equation 4-15

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$$Cost_{PDose} = \$2,000.00 \times D_R \times T$$

where:

- $D_R$  = total effective dose equivalent (TEDE) rate to public in units of Remrem/hr;
- $T$  = time spent near waste shipments in parking lots in units of person-hour.

For this equation, a “worst-case” value of 0.5 mrem/hr was used for  $D_R$ . This assumes that the shipment is classified as Limited Specific Activity (LSA) in accordance with 49 CFR 173.427 and the package meets the Zion specific administrative limit of 0.5 mrem/hr on the exterior of the shipment. The exposure time ( $T$ ) used for this calculation is based upon a transit time of 23 hours driving from Zion to the disposal site in Clive Utah times three shipments, for a total of 69 hours. For this evaluation, the value for the  $Cost_{PDose}$  variable is \$69.00.

4.4.2.8. Total Cost ( $Cost_T$ )

The total cost, ( $Cost_T$ ) assumed for this evaluation is \$517,407.37

4.4.2.9. Residual Radioactivity in Basement Structures that are ALARA

The following parameters were used for performing the ALARA calculation using the equation from NUREG-1757 and presented in section 4.4.2.1:

- Population density ( $P_D$ ) for the critical group (persons/m<sup>2</sup>) - 0.0004 person/m<sup>2</sup> for soil (per NUREG-1496, Appendix B, Table A.1)
- Fraction of residual radioactivity removed by the remedial action ( $F$ ) – 1 (Removal of desired concrete volume is assumed 100% effective)
- Area ( $A$ ) used to calculate the population density (m<sup>2</sup>) –
  - Groundwater scenario – 10,000 m<sup>2</sup> (size of resident farmer reference area)
  - Drilling Spoils scenario – 100 m<sup>2</sup> is assumed in order to allow the calculation to generate a population of 1 person exposed to drilling spoils. The actual surface area of the drilling spoils is much smaller at 0.46 m<sup>2</sup> (see LTP Chapter 6)
- Monetary discount rate ( $r$ ) - 0.00 yr<sup>-1</sup> for soil

(Note: This variable was established at 0.03 yr<sup>-1</sup> for soil in Table N.2 of Appendix N of NUREG-1757. The monetary discount for the ALARA analysis was removed from the equation through Federal Register Notice 72 FR 46102 – August 16, 2007. Consequently, the  $r$  variable has been conservatively set at 0.00 yr<sup>-1</sup> for soil, i.e., no monetary discount for soils as well as basements.)~~Monetary discount rate ( $r$ ) – 0.03 yr<sup>-1</sup> for soils (per NUREG/BR-0058)~~
- Number of years ( $N$ ) over which the collective averted dose is calculated (yr) - 1,000 yrs (per NUREG-1496, Appendix B, Table A.1)

799 4.4.2.9.1. Radionuclides Considered for ALARA Analysis

800 The radionuclide mixture for contaminated concrete developed in ZionSolutions TSD 14-019,  
 801 “Radionuclides of Concern for Soil and Basement Fill Model Source Terms” (Reference 4-~~15~~16)  
 802 was used for the ALARA analysis. The ~~Basement Inventory Levels~~DCGL<sub>B</sub> for the Auxiliary  
 803 Building for each individual ROC from Chapter 5, Table 5-9-3 were used for the calculation of *f*.  
 804 DCGLs, in units of pCi/m<sup>2</sup> of basement surface area, are presented in Chapter 6, section 6.6.8.1  
 805 for the Basement Fill Model (BFM) Groundwater and BFM Drilling Spoils scenarios  
 806 individually and are designated as the DCGL<sub>BS</sub> (Basement Scenario DCGLs). The  
 807 ~~DCGL<sub>BS</sub>Basement Inventory Levels~~ for the Auxiliary Building are reproduced in Table 4-1.  
 808 The values for half-life, radiological decay constants ( $\lambda$ ) and the radionuclide mixture fractions  
 809 are presented in Table 4-2. The mixture fractions are based on the analysis of the concrete core  
 810 samples taken on the Auxiliary Building 542 foot elevation and presented in TSD 14-019,  
 811 Table 17.

812 The ALARA calculation was performed in two parts, the first representing the Groundwater  
 813 scenario and the second representing the Drilling Spoils scenario. Two dose values were  
 814 required to accurately calculate the averted dose because the compliance dose is based on the  
 815 sum of both scenarios. In addition, each scenario is applicable to a different area. The  
 816 Groundwater dose applies to the full 10,000 m<sup>2</sup> site area, the Drilling Spoils dose applies only to  
 817 the area of material brought to the surface by the well drilling action.

818 The actual dose from each scenario, assuming a summation of the dose from both scenarios  
 819 equaled 25 mrem/yr is presented in Table 4-3. Therefore, the dose values for each ROC from  
 820 Table 4-3 were used to derive the AMCG (DOSE<sub>AMCG</sub>) variable in Equation 4-10 for each  
 821 scenario.

822 **Table 4-1 Basement ~~Inventory Levels~~DCGL<sub>BS</sub> for the Auxiliary Building**

<b>Radionuclide</b>	<b><del>Inventory Limit</del>Groundwater Scenario DCGL (mCi) (pCi/m<sup>2</sup>)</b>	<b><del>Drilling Spoils Scenario</del> DCGL (pCi/m<sup>2</sup>)</b>
Co-60	<del>3.28E+102.28</del> E+03	<u>3.07E+08</u>
Ni-63	<del>1.15E+108.76</del> E+04	<u>1.02E+14</u>
Sr-90	<del>9.98E+067.50</del> E+01	<u>5.25E+10</u>
Cs-134	<del>3.55E+081.59</del> E+03	<u>5.23E+08</u>
Cs-137	<del>1.25E+088.35</del> E+02	<u>1.02E+09</u>

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824

825 **Table 4-2 Radionuclide Half-Life(s), Decay Constant(s) and ~~Dose Factors~~Mixture**

Radionuclide <sup>(a)</sup>	Half-Life (yrs)	$\lambda$ (yr <sup>-1</sup> )	Radionuclide Mixture <sup>(b)</sup>
Co-60	5.27 E 00	1.31 E-01	0.92%
Ni-63	9.60 E+01	7.22 E-03	23.71%
Sr-90	2.91 E+01	2.38 E-02	0.05%
Cs-134	2.06 E+00	3.36 E-01	0.01%
Cs-137	3.02 E+01	2.30 E-02	75.32%

- 826 (a) Dose significant ROC for the Auxiliary Building in accordance with TSD 14-019.  
 827 (b) Normalized radionuclide mixture for dose significant ROC for Auxiliary Building from Table 20 of  
 828 TSD 14-019.

829  
 830 **Table 4-3 Dose for Individual Scenarios (DOSE<sub>AMCG</sub>)**

	<u>Auxiliary Building</u>	
	<u>Groundwater</u> (mrem/yr)	<u>Drilling Spoils</u> (mrem/yr)
<u>Co-60</u>	<u>0.232</u>	<u>24.768</u>
<u>Ni-63</u>	<u>24.997</u>	<u>0.003</u>
<u>Sr-90</u>	<u>24.995</u>	<u>0.005</u>
<u>Cs-134</u>	<u>14.892</u>	<u>10.108</u>
<u>Cs-137</u>	<u>22.271</u>	<u>2.729</u>

831  
 832 4.4.2.9.2. ALARA Calculation  
 833 The ALARA calculations performed to evaluate the concrete scabbling or shaving remediation  
 834 activity is presented in Table 4-3-4 for the Auxiliary Building 542 foot elevation. A result for the  
 835 Conc/DCGL ratio that is less than one would justify remediation whereas a result greater than  
 836 one would demonstrate that residual radioactivity is ALARA. The Conc/DCGL ratio calculated  
 837 for the summation of In-Situ Scenarios (Groundwater + Drilling Spoils) was 2.87.

838 4.4.2.10. Conclusion  
 839 Concrete structural surfaces below the 588 foot elevation will remain in place after license  
 840 termination. The site dose contribution from remaining residual radioactivity remaining in these  
 841 buried plant structures will be accounted for by the BFM. The ALARA analysis based on cost  
 842 benefit analysis shows that further remediation of concrete beyond that required to demonstrate  
 843 compliance with the 25 mrem/yr dose criterion is not justified.

844 **Table 4-4 ALARA Analysis for Volumetrically Contaminated Subsurface Structures – Auxiliary Building 542 ft.**

845 Cost (in dollars) of remedial action (Cost<sub>r</sub>) = \$517,407.37

846 Summation of In-Situ Scenarios (Groundwater + Drilling Spoils)

847 (Groundwater Scenario)

848 A = 10,000 m<sup>2</sup>, r = 0.00 yr<sup>-1</sup>, N = 1,000 yr, P<sub>D</sub> = 0.01 person/m<sup>2</sup> Fraction of Activity removed by remedial action (F) = 1

Column A	Column B	Column C	Column D	Column E	Column F	Column G	Column H	Column I	Column J	Column K	Column L	Column M	
Nuclide	Half-Life (yrs) <sup>b</sup>	λ (yr <sup>-1</sup> ) <sup>b</sup>	(r+λ)	(r+λ)N	e <sup>-(r+λ)N</sup>	1-e <sup>-(r+λ)N</sup>	[1-e <sup>-(r+λ)N</sup> ]/(r+λ)	Mixture <sup>b</sup>	GW DCGL <sub>BS</sub> <sup>a</sup>	(Columns I*J)	f <sub>i</sub> Column K divided by sum	Cost Benefit	
Co-60	5.27E+00	1.31E-01	1.31E-01	1.31E+02	7.77E-58	1.00E+00	7.60E+00	0.92%	3.28E+10	3.02E+08	9.66E-02	\$ 179.22	
Ni-63	9.60E+01	7.22E-03	7.22E-03	7.22E+00	7.33E-04	9.99E-01	1.38E+02	23.71%	1.15E+10	2.73E+09	8.73E-01	\$ 174,620.71	
Sr-90	2.91E+01	2.38E-02	2.38E-02	2.38E+01	4.54E-11	1.00E+00	4.20E+01	0.05%	9.98E+06	4.99E+03	1.60E-06	\$ 0.32	
Cs-134	2.06E+00	3.36E-01	3.36E-01	3.36E+02	7.94E-147	1.00E+00	2.97E+00	0.01%	3.55E+08	3.55E+04	1.14E-05	\$1.35	
Cs-137	3.02E+01	2.29E-02	2.29E-02	2.29E+01	1.08E-10	1.00E+00	4.36E+01	75.31%	1.25E+08	9.41E+07	3.01E-02	\$ 5,371.22	
							Check Sum	100%	Sum	3.12E+09	1.00E+00	\$ 180,172.82	Σ(Cost <sub>B</sub> )

849 (Drilling Spoils Scenario)

850 A = 100.00 m<sup>2</sup>(c), r = 0.00 yr<sup>-1</sup>, N = 1,000 yr, P<sub>D</sub> = 0.01 person/m<sup>2</sup> Fraction of Activity removed by remedial action (F) = 1

Column A	Column B	Column C	Column D	Column E	Column F	Column G	Column H	Column I	Column J	Column K	Column L	Column M	
Nuclide	Half-Life (yrs) <sup>b</sup>	λ (yr <sup>-1</sup> ) <sup>b</sup>	(r+λ)	(r+λ)N	e <sup>-(r+λ)N</sup>	1-e <sup>-(r+λ)N</sup>	[1-e <sup>-(r+λ)N</sup> ]/(r+λ)	Mixture <sup>b</sup>	DS DCGL <sub>BS</sub> <sup>a</sup>	(Columns I*J)	f <sub>i</sub> Column K divided by sum	Cost Benefit	
Co-60	5.27E+00	1.31E-01	1.31E-01	1.31E+02	7.77E-58	1.00E+00	7.60E+00	0.92%	3.07E+08	2.82E+06	1.17E-07	\$ 0.00	
Ni-63	9.60E+01	7.22E-03	7.22E-03	7.22E+00	7.33E-04	9.99E-01	1.38E+02	23.71%	1.02E+14	2.42E+13	1.00E+00	\$ 0.23	
Sr-90	2.91E+01	2.38E-02	2.38E-02	2.38E+01	4.54E-11	1.00E+00	4.20E+01	0.05%	5.25E+10	2.63E+07	1.09E-06	\$ 0.00	
Cs-134	2.06E+00	3.36E-01	3.36E-01	3.36E+02	7.94E-147	1.00E+00	2.97E+00	0.01%	5.23E+08	5.23E+04	2.16E-09	\$ 0.00	
Cs-137	3.02E+01	2.29E-02	2.29E-02	2.29E+01	1.08E-10	1.00E+00	4.36E+01	75.31%	1.02E+09	7.68E+08	3.18E-05	\$ 0.01	
							Check Sum	100%	Sum	2.42E+13	1.00E+00	\$ 0.23	Σ(Cost <sub>B</sub> )

**Summation of In-Situ In Situ Cost Benefit (Groundwater + Drilling Spoils)**

**Conc/-DCGL (A result < 1 would justify remediation whereas a result > 1 would demonstrate that residual radioactivity is ALARA)**

**2.87**

851 (a) From Table 4-1

852 (b) From Table 4-2

853 (b)(c) Actual drilling spoils area 0.457 m2, 100 m2 used in calculation to ensure 1 person exposed

854 **4.5. References**

- 855 4-1 U.S. Nuclear Regulatory Commission Regulatory Guide 1.187 “Guidance for  
856 Implementation of 10 CFR 50.59 Changes, Tests and Experiments” – November 2000
- 857 4-2 U.S. Nuclear Regulatory Commission Regulatory Guide 1.179, “Standard Format and  
858 Content of License Termination Plans for Nuclear Power Reactors” – January 1999
- 859 4-3 Zion Station, “Defueled Safety Analysis Report” (DSAR) – September 2014
- 860 4-4 “Zion Nuclear Power Station, Units 1 and 2 Asset Sale Agreement” – December 2007
- 861 4-5 *ZionSolutions* Technical Support Document 10-002, “Technical Basis for Radiological  
862 Limits for Structure/Building Open Air Demolition”
- 863 4-6 U.S. Nuclear Regulatory Commission NUREG-1575, Revision 1, “Multi-Agency  
864 Radiation Survey and Site Investigation Manual (MARSSIM)” – August 2000
- 865 4-7 U.S. Nuclear Regulatory Commission Docket Number 50-295, “Facility Operating  
866 License Number DPR-39 (for Unit One)”
- 867 4-8 U.S. Nuclear Regulatory Commission Docket Number 50-304, “Facility Operating  
868 License Number DPR-48 (for Unit Two)”
- 869 4-9 U.S. Nuclear Regulatory Commission NUREG-1757, Volume 2, Revision 1,  
870 “Consolidated Decommissioning Guidance - Characterization, Survey, and  
871 Determination of Radiological Criteria, Final Report” – September 2003
- 872 4-10 U.S. Nuclear Regulatory Commission, NUREG/BR-0058, Revision 4, “Regulatory  
873 Analysis Guidelines of the U.S. Nuclear Regulatory Commission” – September 2004
- 874 4-11 U.S. Nuclear Regulatory Commission, NUREG-1496, Volume 2, “Generic  
875 Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for  
876 License Termination of NRC-Licensed Nuclear Facilities” – July 1997
- 877 4-12 U.S. Nuclear Regulatory Commission, NUREG-1530, “Reassessment of NRC’s Dollar  
878 per Person-Rem Conversion Factor Policy” – December 1995
- 879 4-13 *ZionSolutions* Technical Support Document 14-016, “Description of Embedded Pipe,  
880 Penetrations, and Buried Pipe to Remain in Zion End State”
- 881 4-134-14 U.S. Nuclear Regulatory Commission, NUREG/CR-5884, Volume 2, “Revised  
882 Analyses of Decommissioning for the Reference Pressurized Water Reactor Power  
883 Station” – November, 1995
- 884 4-144-15 *ZionSolutions* Technical Support Document 14-013, “Zion Auxiliary Building  
885 End State Estimated Concrete Volumes, Surface Areas, and Source Terms”

886 ~~4-154-16~~ ZionSolutions Technical Support Document 14-019, “Radionuclides of Concern  
887 for Soil and Basement Fill Model Source Terms”