ZION STATION RESTORATION PROJECT
LICENSE TERMINATION PLAN
CHAPTER 4, REVISION 2
REMEDIATION PLAN

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LIST OF ACRONYMS AND ABBREVIATIONS

AF	Area Factor
ALARA	As Low As Reasonably Achievable
AMCG	Average Member of the Critical Group
BFM	Basement Fill Model
CFR	Code of Federal Regulations
CVS	Contamination Verification Survey
DCGL	Derived Concentration Guideline Levels
DSAR	Defueled Safety Analysis Report
EMC	Elevated Measurement Comparison
FSS	Final Status Survey
HEPA	High Efficiency Particulate Air
ISOCS	*In Situ* Object Counting System
LLRW	Low Level Radioactive Waste
LSA	Limited Specific Activity
LTP	License Termination Plan
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
NRC	Nuclear Regulatory Commission
ODCM	Off Site Dose Calculation Manual
ROC	Radionuclides of Concern
RPT	Radiation Protection Technician
SAFSTOR	SAFeSTORage
SFP	Spent Fuel Pool
TEDE	Total Effective Dose Equivalent
WWTF	Waste Water Treatment Facility
ZNPS	Zion Nuclear Power Station
ZSRP	Zion Station Restoration Project

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4. SITE REMEDIATION PLAN

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

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

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

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

4.1. <u>Remediation Actions and ALARA Evaluations</u>

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

The ALARA evaluation calculates the concentration at which the averted collective radiation dose, converted into dollars, is equal to the costs of continued remediation (e.g., risk of transportation accidents converted into dollars, worker and public doses associated with the remediation action converted into dollars, and the actual costs to perform the remediation activity). If this concentration is below the concentrations that correspond to the maximum annual dose criterion, then further reduction of residual radioactivity is justified by ALARA.

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

4.2. Remediation Actions

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

4.2.1. Structures

The general approach to structure remediation at Zion Station Restoration Project (ZSRP) is driven by section 8.5 of Exhibit C, Lease Agreement, “Removal of Improvements; Site Restoration” integral to the *“Zion Nuclear Power Station, Units 1 and 2 Asset Sale Agreement”* (Reference 4-4) which requires the demolition and removal of all on-site buildings, structures, and components to a depth of at least three feet below grade. Consequently, the only structures that will remain at license termination are the concrete walls and floors below 588 foot elevation in the Unit 1 Containment Building, Unit 2 Containment Building, Auxiliary Building, Turbine Building, Fuel Handling Building, Crib House/Forebay, Waste Water Treatment Facility (WWTF), Circulating Water Intake Piping and Circulating Water Discharge Tunnels. All impacted systems, components and 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 clean concrete from building demolition as clean fill. The only concrete structures that will be considered are those where the probability of the presence of residual contamination is minimal and surveys demonstrate that the concrete is free of plant derived radionuclides and hazardous paint coatings.

The remaining structural surfaces that will remain at ZNPS following the termination of the license are solid concrete structures which will be covered by at least three 3 feet of soil and physically altered to a condition which would not allow the remaining structural surfaces, if excavated, to be realistically occupied.

Scan measurements, static measurements and/or the analysis of volumetric sample(s) will be used to calculate the remaining total concentration of residual activity. The concrete walls and floors of the basements will be remediated to levels that will provide high confidence that FSS measurements with ISOCS will not exceed radionuclide-specific DCGLs that represent the annual dose criterion for unrestricted use specified in 10 CFR 20.1402.

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

4.2.1.1. Scabbling and Shaving

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

4.2.1.2. Needle Guns

A second method of scabbling is accomplished using needle guns. The needle gun is a pneumatic air-operated tool containing a series of tungsten-carbide or hardened steel rods enclosed in housing. The rods are connected to an air-driven piston to abrade and fracture the media surface. The media removal depth is a function of the residence time of the rods over the surface. Typically, one to two millimeters are removed per pass. Generated debris collection, transport and dust control are accomplished in the same manner as other scabbling methods. Use of needle guns for removal and chipping of media is usually reserved for areas not accessible to normal scabbling operations. These include, but are not limited to, inside corners, cracks, joints and crevices. Needle gunning techniques can also be applied to painted and oxidized surfaces.

4.2.1.3. Chipping

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

4.2.1.4. Sponge and Abrasive Blasting

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

4.2.1.5. Pressure Washing

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

4.2.1.6. Washing and Wiping

Washing and wiping decontamination techniques are actions that are typically performed during the course of remediation activities for housekeeping and to minimize the spread of loose surface contamination. ZSRP will implement good housekeeping throughout decommissioning to ensure ALARA, to reduce the residual activity in structural surfaces to comply with the open air demolition criteria in Zion*Solutions* TSD 10-002, *"Technical Basis for Radiological Limits for Structure/Building Open Air Demolition"* (Reference 4-5) and, to ensure that loose surface contamination is removed prior to evaluating the surface for acceptable concentrations of residual activity.

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

4.2.1.7. High-Pressure Water Blasting

Most contaminated piping will be removed and disposed of as radioactive waste. Any pipe systems or sections of pipe systems that reside below the 588 foot elevation that will be abandoned in place will be inspected and surveyed as described in Chapter 5. If radiological conditions inside the pipe are in excess of the release criteria, then *in situ* remediation will be performed. One method that may be used to remediate the pipe interior surfaces is high pressure water blasting. A High-Pressure Liquid-Jetting System has a high pressure water pump capable of producing a water pressure of 10,000 psi to 20,000 psi at an actual flow rate that ranges from

44 gallons per minute at 10,000 psi to 23 gallons per minute at 20,000 psi. A rotating jet-mole tip is used for 360 degree coverage of pipe interiors. The jet-mole is attached to a lance and high-pressure hose. The lance is manually advanced through the interior of the pipe. As the lance is advanced, the high-pressure water abrades the interior surface of the pipe, removing the corrosive layer, internal debris and radiological contamination. The waste water containing the removed contamination is then collected and stored for processing as liquid radiological waste.

4.2.1.8. Grit Blasting

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

4.2.1.9. Removal of Activated/Contaminated Concrete

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

4.2.1.10. Additional Remedial Actions

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

4.2.2. Soil

The surface and subsurface soil $DCGL_W$ that will be used to demonstrate compliance with the dose-based criteria of 10 CFR 20, Subpart E for the unrestricted release of open land survey units are provided in Tables 5-5 and 5-6 of Chapter 5. Section 2.5.1.1 of NUREG-1575, *"Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM)*"* (Reference 4-6) addresses the concern for the presence of small areas of elevated radioactivity. A simple comparison to an investigation level is used to assess the dose impact of potential elevated areas. This is referred to as the Elevated Measurement Comparison (EMC). The investigation level for this comparison is the $DCGL_{EMC}$, which is the $DCGL_w$ modified by an Area Factor (AF) to account for the small area of the elevated radioactivity. Any radiological contamination in soils identified in concentrations greater than the $DCGL_{EMC}$ will be removed and disposed of as radioactive waste.

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

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

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

4.3. Remediation Activities Impact on the Radiation Protection Program

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

The current approved Radiation Protection Program at ZSRP is adequate to comply with all federal and state regulatory requirements for the protection of occupational personnel from radiological hazards encountered or expected to be encountered during the decommissioning of a two unit commercial reactor facility. In addition, the program ensures the protection of the public from radiological hazards and ensures occupational, effluent and environmental dose from exposure to radioactive materials is, and remains ALARA. To ensure that adequate and proper engineering controls and hazard mitigation techniques are employed, work control programs and procedural requirements allow radiation protection personnel to integrate radiation protection and radiological hazard mitigation measures directly into the work planning and scheduling process. Consequently, the necessary radiological controls are correctly implemented to accommodate each remediation technology as appropriate.

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

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

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

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

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

The decommissioning organization is experienced in and capable of applying these remediation techniques on contaminated systems, structures or components during decommissioning. The Radiation Protection Program is adequate to safely control the radiological aspects of this work. Because the activities expected during decommissioning are the same or similar to those encountered during operations, as described above, the approval of any changes to the existing approved Radiation Protection Program as described in the Nuclear Regulatory Commission (NRC) Docket Number 50-295, *"Facility Operating License Number DPR-39 (for Unit One)"* (Reference 4-7), NRC Docket Number 50-304, *"Facility Operating License Number DPR-48 (for Unit Two)"* (Reference 4-8) is not requested in this LTP.

4.4. ALARA Evaluation

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

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

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

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

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

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

4.4.1. ALARA Analysis of Soil Remediation

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

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

4.4.1.1. Calculation of Benefits

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

Equation 4-1

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

where;

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

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

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

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

Equation 4-2

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

where;

P_D = population density for the critical group scenario in people/m^2,

A = area being evaluated in square meters (m^2),

0.025 = annual dose to an AMCG from residual radioactivity at the DCGL$_w$ concentration in rem/yr,

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

Conc = average concentration of residual radioactivity in the area being evaluated in units of activity per unit volume (pCi/g),

$DCGL_w$ = derived concentration equivalent to the average concentration of residual radioactivity that would give a dose of 25 mrem/yr to the AMCG (pCi/g),

r = monetary discount rate in units per year (yr^{-1}),

λ = radiological decay constant for the radionuclide in units per year and,

N = number of years over which the collective dose will be calculated.

4.4.1.2. ALARA Analysis Parameters

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

- Dollars per person-rem - $2,000.00/person-rem (per NUREG/BR-0058, *"Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission"* [Reference 4-10])
- Population density (P_D) for the critical group (persons/m^2) - 0.0004 person/m^2 for land (per NUREG-1496, *"Final Generic Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for License Termination of NRC-Licensed Nuclear Facilities,"* Volume 2, [Reference 4-11] Appendix B, Table A.1)
- Monetary discount rate (r) - 0.00 yr^{-1} for soil

  (Note: This variable was established at 0.03 yr^{-1} 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^{-1} for soil, i.e., no monetary discount for soils as well as basements.)
- Area (A) used to calculate the population density (m^2) – 10,000 m^2 (size of reference area that was evaluated)
- Number of years (N) over which the collective averted dose is calculated (yr) - 1,000 yrs (per NUREG-1496, Volume 2, Appendix B, Table A.1)

4.4.1.3. Calculation of Costs

The total cost, ($Cost_T$) which is balanced against the benefits; has several components and may be evaluated according to Equation N-3 of NUREG-1757, Appendix N below:

Equation 4-3

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

where:

$Cost_R$ = monetary cost of the remediation action (including mobilization costs);

$Cost_{WD}$ = monetary cost for transport and disposal of the waste generated by the action;

$Cost_{ACC}$ = monetary cost of worker accidents during the remediation action;

$Cost_{TF}$ = monetary cost of traffic fatalities during transportation of the waste;

$Cost_{WDose}$ = monetary cost of traffic fatalities during transportation of the waste;

$Cost_{PDose}$ = monetary cost of dose to the public from excavation, transport and disposal of the waste;

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

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

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

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

Equation 4-4

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

where:

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

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

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

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

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

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

Equation 4-5

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

where:

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

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

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

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

D_T = distance traveled in km.

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

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

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

4.4.1.4.3. Total Cost ($Cost_T$)

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

4.4.1.5. Residual Radioactivity in Soils that are ALARA

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

Equation 4-6

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

Assuming the following values for the remaining variables;

- the default parameter values from section 4.4.1.2,
- a value of one for remediation effectiveness (F), assuming all residual radioactivity is removed during the excavation,
- a surface soil $DCGL_w$ of 14.18 pCi/g for Cs-137 from Table 5-5 of Chapter 5,

Equation 4-7

$$\frac{Conc}{DCGL_w} = \frac{(\$3{,}779{,}610.66)\left(0.00 + \frac{0.693}{30.17}\right)}{(\$2{,}000)(0.0004)(0.025)(1)(10{,}000)\left(1 - e^{-\left(0.00+\frac{0.693}{30.17}\right)1{,}000}\right)}$$

the ratio of the concentration to the DCGL$_w$ when the total cost ($Cost_T$) is equal to the dose averted is 434.08.

Assuming a concentration set at 50% of the DCGL$_w$ (based on the investigation level for a Class 3 area), the present worth of future collective averted dose PW(AD$_{Collective}$) can be calculated as follows;

Equation 4-8

$$PW(AD_{Collective}) = (0.0004)(10{,}000)(0.025)(1)\left(\frac{7.09}{14.2}\right)\left(\frac{1 - e^{-\left(0.00+\frac{0.693}{30.17}\right)(1{,}000)}}{0.00 + \frac{0.693}{30.17}}\right)$$

resulting in a value for PW(AD$_{Collective}$) of 2.18 person rems. The benefit from collective averted dose (B_{AD}) is then calculated as follows;

Equation 4-9

$$B_{AD} = \$2{,}000 \times 2.18 = \$4{,}353.54$$

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

4.4.2. ALARA Analysis for Remediation of Basement Structures

With the exception of some penetrations, embedded and buried piping, all contaminated and non-contaminated systems will be disassembled, removed, packaged and shipped off-site as a waste stream commodity. The list of penetrations and embedded piping to remain is provided in Zion*Solutions* TSD 14-016, 14-016, "*Description of Embedded Pipe, Penetrations, and Buried Pipe to Remain in Zion End State*" (Reference 4-13). Once commodity removal is complete, structural surfaces will be remediated as necessary to meet the open air demolition criteria specified in TSD 10-002. These criteria provide the removable contamination levels and contact exposure rates that will allow structures to be safely demolished without containment. Prior to demolition, a contamination verification survey (CVS) will be performed to identify areas requiring remediation to meet the open-air demolition limits. The CVS will also be used to identify areas on surfaces to remain at license termination (i.e., at least three feet below grade) that could potentially result in a FSS measurement (using ISOCS) to exceed the Basement DCGLs (DCGL$_B$) listed in LTP Chapter 5, Table 5-4. The dose rate target for this objective will be lower than that required for open-air demolition. Identified areas will be remediated to provide high confidence that no FSS ISOCS measurement will exceed the DCGL$_B$. Once remediation is complete structural surfaces located above the 588 foot elevation and non-load-bearing interior concrete walls below the 588 foot elevation will be demolished, reduced in size, packaged and shipped off-site to a licensed disposal facility.

All concrete inside the liner above the 565 foot elevation will be removed from the interiors of both Containment Buildings prior to demolition. This includes all activated and contaminated concrete. Only the concrete below the 565 foot elevation in the In-core Instrument Shaft leading to and including the area under vessel (or Under-Vessel area) will remain. The source term in the Containment Basements remaining after demolition will consist of the concrete in the Under-Vessel area(s) and low levels of surface contamination on the exposed liner surfaces. There is currently minimal contamination in the Turbine Building, Crib House/Forebay, and Circulating Water Piping at levels that are expected to be well below the open air demolition criteria and below the $DCGL_B$ listed in LTP Chapter 5, Table 5-4. The only portion of the Fuel Handling Building Basement that will remain following building demolition is the lower 13 foot (~4 m) concrete bottom of the Spent Fuel Pool (SFP) and the Transfer Canal, which is located at the 575 foot elevation. The steel liner will be removed from both the SFP and the Transfer Canal. After the liner is removed and the underlying concrete exposed, continuing characterization surveys will be performed. Continuing characterization will consist of scanning of the exposed concrete surfaces and the acquisition of concrete core sample(s) at the location of highest activity. Contamination is expected below the liner but an estimate of levels cannot be made until characterization is completed.

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

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

4.4.2.1. ALARA Analysis Equation for Remediation of Basement Structures

For the ALARA analysis for the remediation of basement structures, the equation from section 4.4.1.5 is modified as follows. The DCGLs for concrete are expressed in units of pCi/m^2. The denominator must be summed and the individual dose contribution normalized to account for the multiple detectable radionuclides that are present in the radionuclide distribution for the Auxiliary Building. The equation from NUREG-1757 therefore becomes:

Equation 4-10

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

where:

f_i = the normalized radionuclide fraction for the Auxiliary Building for each individual Radionuclides of Concern (ROC) (from Chapter 5, Table 5-2)

$DOSE_{AMCG}$ = 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 $DCGL_B$ from Table 5-4. All loose surface contamination greater than 1,000 dpm/100cm^2 will be removed. The remediation techniques most likely to be implemented to perform this work are vacuuming, pressure washing and hand-wiping, 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-

5884, *"Revised Analyses of Decommissioning for the Reference Pressurized Water Reactor Power Station"* Volume 2 (Reference 4-14), one pass of scabbling is assumed to remove 0.125 inches (0.635 cm) of concrete. In accordance with Zion*Solutions* TSD 14-013, *"Zion Auxiliary Building End State Estimated Concrete Volumes, Surface Areas, and Source Terms"* (Reference 4-15), the 542 foot elevation floor of the Auxiliary Building has a surface area of 2,543 m^2. This is the surface area which will be evaluated for the remediation cost determination.

4.4.2.2.1. Remediation Activity Rates

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

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

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

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

4.4.2.2.2. Equipment Costs

Using the guidance found in NUREG/CR-5884, equipment costs are based on the rental of commercially available scabbing equipment, a compressor, a vacuum unit and consumables such as cutting bits, vacuum filters and waste drums for containing waste debris. At 40-hours per work week, 1,391 man-hours equates to approximately 35 work-weeks. This evaluation assumes that two different commercially available concrete removal units will be procured, the Pentek Squirrel Scabbler & Vacuum System with a nominal rental rate of $685.00 per week and a Pentek Moose Scabbler & Vacuum System with a nominal rental rate of $950.00 per week. The compressor required for pneumatic equipment operation can be rented at a nominal rate of $115.00 per week. The cutting bits for the units are assumed to be replaced every 80 hours of operation, for an equivalent cost of about $13.00 per hour of operation. Additional costs include filter replacements at about $2.50 per hour of operation and waste drums for the collected debris. A 55-gallon drum holds approximately 7 ft^3 of waste and cost approximately $100.00 per drum. As it is assumed that the scabbing activity will generate approximately 1,132 ft^3 (32 m^3) of concrete waste, this will require the procurement of approximately 162 drums at a total cost of $16,171.49. The mobilization and demobilization costs associated with procuring this equipment would be approximately $2,200.00 per piece of equipment for a total of approximately $6,600.00. The total equipment costs assumed for this evaluation is approximately $98,975.87.

4.4.2.2.3. Total Remediation Action Cost ($Cost_R$)

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

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

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

Equation 4-11

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

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

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

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

Equation 4-12

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

where:

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

F_W = workplace fatality rate in fatalities/hour worked;

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

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

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

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

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

Equation 4-13

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

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

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

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

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

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

Equation 4-14

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

where:

D_R = total effective dose equivalent (TEDE) rate to remediation workers in units of rem/hr;

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

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

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

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

Equation 4-15

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

where:

D_R = total effective dose equivalent (TEDE) rate to public in units of rem/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^2) - 0.0004 person/m^2 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^2)
    - Groundwater scenario –10,000 m^2 (size of resident farmer reference area)
    - Drilling Spoils scenario – 100 m^2 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^2 (see LTP Chapter 6)
- Monetary discount rate (r) - 0.00 yr^{-1} for soil

  (Note; This variable was established at 0.03 yr^{-1} 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^{-1} for soil, i.e., no monetary discount for soils as well as basements.)
- Number of years (N) over which the collective averted dose is calculated (yr) - 1,000 yrs (per NUREG-1496, Appendix B, Table A.1)

4.4.2.9.1. Radionuclides Considered for ALARA Analysis

The radionuclide mixture for contaminated concrete developed in Zion*Solutions* TSD 14-019, *"Radionuclides of Concern for Soil and Basement Fill Model Source Terms"* (Reference 4-16) was used for the ALARA analysis. The $DCGL_B$ for the Auxiliary Building for each individual ROC from Chapter 5, Table 5-3 were used for the calculation of f_i for the Auxiliary Building ROC's identified in Table 6-5. DCGLs, in units of pCi/m^2 of basement surface area, are presented in Chapter 6, section 6.6.8.1 for the Basement Fill Model (BFM) Groundwater and BFM Drilling Spoils scenarios individually and are designated as the $DCGL_{BS}$ (Basement Scenario DCGLs). The $DCGL_{BS}$ for the Auxiliary Building are reproduced in Table 4-1. The values for half-life, radiological decay constants (λ) and the radionuclide mixture fractions are presented in Table 4-2. The mixture fractions are based on the analysis of the concrete core samples taken on the Auxiliary Building 542 foot elevation and presented in TSD 14-019, Table 17.

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

The actual dose from each scenario, assuming a summation of the dose from both scenarios equaled 25 mrem/yr is presented in Table 4-3. Therefore, the dose values for each ROC from Table 4-3 were used to derive the AMCG ($DOSE_{AMCG}$) variable in Equation 4-10 for each scenario.

Table 4-1 Basement $DCGL_{BS}$ for the Auxiliary Building

Radionuclide	Groundwater Scenario DCGL (pCi/m^2)	Drilling Spoils Scenario DCGL (pCi/m^2)
Co-60	3.28E+10	3.07E+08
Ni-63	1.15E+10	1.02E+14
Sr-90	9.98E+06	5.25E+10
Cs-134	3.55E+08	5.23E+08
Cs-137	1.25E+08	1.02E+09

Table 4-2 Radionuclide Half-Life(s), Decay Constant(s) and Mixture

Radionuclide [(a)]	Half-Life (yrs)	λ (yr^{-1})	Radionuclide Mixture[(b)]
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%

(a) Dose significant ROC for the Auxiliary Building in accordance with TSD 14-019.

(b) Normalized radionuclide mixture for dose significant ROC for Auxiliary Building from Table 20 of TSD 14-019.

Table 4-3 Dose for Individual Scenarios ($DOSE_{AMCG}$)

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

4.4.2.9.2. ALARA Calculation

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

4.4.2.10. Conclusion

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

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

Cost (in dollars) of remedial action (*$Cost_T$*) = $517,407.37

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

(Groundwater Scenario)

A = 10,000 m^2, r = 0.00 yr^{-1}, N = 1,000 yr, P_D = 0.01 person/m^2

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)^b	λ (yr^{-1})^b	$(r+\lambda)$	$(r+\lambda)N$	$e^{-(r+\lambda)N}$	$1-e^{-(r+\lambda)N}$	$[1-e^{-(r+\lambda)}N]$ $/(r+\lambda)$	Mixture ^{b}	GW $DCGL_{BS}$ ^{a}	(Columns I*J)	f_i 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	$\sum(Cost_B)$

(Drilling Spoils Scenario)

A = 100.00 m$^{2\,(c)}$, r = 0.00 yr^{-1}, N = 1,000 yr, P_D = 0.01 person/m^2

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)^b	λ (yr^{-1})^b	$(r+\lambda)$	$(r+\lambda)N$	$e^{-(r+\lambda)N}$	$1-e^{-(r+\lambda)N}$	$[1-e^{-(r+\lambda)}N]$ $/(r+\lambda)$	Mixture ^{b}	DS $DCGL_{BS}$ ^{a}	(Columns I*J)	f_i 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	$\sum(Cost_B)$

Summation of *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**

(a) From Table 4-1
(b) From Table 4-2
(c) Actual drilling spoils area 0.457 m2, 100 m2 used in calculation to ensure 1 person exposed

4.5. References

4-1 U.S. Nuclear Regulatory Commission Regulatory Guide 1.187 “Guidance for Implementation of 10 CFR 50.59 Changes, Tests and Experiments” – November 2000

4-2 U.S. Nuclear Regulatory Commission Regulatory Guide 1.179, “Standard Format and Content of License Termination Plans for Nuclear Power Reactors” – January 1999

4-3 Zion Station, “Defueled Safety Analysis Report” (DSAR) – September 2014

4-4 “Zion Nuclear Power Station, Units 1 and 2 Asset Sale Agreement” – December 2007

4-5 Zion*Solutions* Technical Support Document 10-002, Revision 1,“Technical Basis for Radiological Limits for Structure/Building Open Air Demolition”

4-6 U.S. Nuclear Regulatory Commission NUREG-1575, Revision 1, “Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)” – August 2000

4-7 U.S. Nuclear Regulatory Commission Docket Number 50-295, “Facility Operating License Number DPR-39 (for Unit One)”

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