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TABLES

APPENDICES

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4.0 SITE REMEDIATION PLAN

4.1 Remediation Actions and ALARA Evaluations

This chapter of the LTP describes various remediation actions that may be used during the decommissioning of Rancho Seco. In addition, the methods used to reduce residual contamination to levels that comply with the NRC's annual dose limit of 25 mrem plus ALARA are described. Finally, the Radiation Protection Program requirements for the remediation are described.

4.2 Remediation Actions

Remediation actions are performed throughout the decommissioning process. The remediation action taken is dependent on the material contaminated. The principal materials that may be subjected to remediation are hardened structural surfaces and soils. Appendix 4-A of this LTP chapter describes the equipment, personnel, and waste costs used to generate a unit cost basis for the remediation actions discussed below.

4.2.1 Structures

Following the removal of equipment and components, structures will be surveyed as necessary and contaminated materials will be remediated or removed and disposed of as radioactive waste. Contaminated structural surfaces will be remediated to a level that will meet the established radiological criteria provided in Chapter 5 of this LTP.

Remediation techniques that may be used for the structural surfaces include washing, wiping, pressure washing, vacuuming, scabbling, chipping, and sponge or abrasive blasting. Washing, wiping, abrasive blasting, vacuuming and pressure washing techniques may be used for both metal and concrete surfaces. Scabbling and chipping are mechanical surface removal methods that are intended for concrete surfaces. Activated 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 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 0.25 inches at a rate of about 20 ft^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 HEPA (high efficiency particulate air filter) filtration devices. Dust and generated debris are collected and controlled during the operation.

4.2.1.2 Needle Guns

A second form 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 a 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 for scabbling. 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 but may also be used in lieu of concrete saws to remove pedestal bases or similar equipment platforms. 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 washed from the medium for reuse.

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. Abrasive blasting is evaluated as a remediation action and the cost is comparable to sponge blasting with an abrasive media.

4.2.1.5 Pressure Washing

Pressure washing uses a hydrolazer-type nozzle of intermediate water pressure to direct a jet of pressurized water that removes surficial 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 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 are performed. Washing and wiping techniques used as a housekeeping or good practice measure will not be evaluated. Examples of washing and wiping activities for which ALARA evaluations would be performed include:

- Decontamination of stairs and rails,
- Decontamination of structural materials, metals or media for which decontamination reagents may be required, or
- Structure areas that do not provide sufficient access for utilization of other decontamination equipment such as pressure washing.

4.2.1.7 Grit Blasting

Most contaminated piping will be removed and disposed of as radioactive waste. Any remaining contaminated piping buried or embedded in concrete may be remediated using methods such as 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.

4.2.1.8 Removal of Activated/Contaminated Concrete

Removal of concrete may be accomplished using a machine mounted, remote-operated articulating arm with exchangeable actuated hammer and bucket (sawing, impact hammering and expansion fracturing may also be employed). As concrete is fractured and rebar exposed, the metal is cut using flame cutting (oxygen-acetylene or other) equipment. Bulk concrete such as walls or floors may be removed as intact sections after sawing with blades, wires or other cutting methods. Removal may also be accomplished by demolition using power impact tools or explosives.

The debris media are transferred into containers for later disposal. Dusts, fumes and generated debris are collected locally or in bulk room exhaust and as necessary, controlled using temporary enclosures coupled with close-capture HEPA filtration systems and controlled water misting. Any remaining loose media are removed by pressure washing or dry vacuuming using a HEPA filter equipped wet-dry vacuum.

4.2.2 Soil

Soil contamination above the site specific DCGL will be removed and disposed of as radioactive waste. 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. The site characterization process established the location, depth and extent of soil contamination. As needed, additional investigations will be performed to ensure that any changing soil contamination profile during the remediation actions is adequately identified and addressed. It should also be noted that soil remediation volume estimates in the LTP may vary from section to section, as appropriate, depending on their use, e.g., decommissioning cost estimates, ALARA evaluations, or dose assessment. Section 5.4.1.2 of this LTP discusses soil sampling and survey methods.

Soil remediation equipment will include, but not be limited to, back and track hoe excavators. 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 include the use of established Excavation Safety and Environmental Control procedures. Additionally, soil handling procedures and work package instructions will augment the above guidance and procedural requirements 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 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. The techniques used during operations are the same or similar to the techniques used during decommissioning to reduce personnel exposure to radiation and contamination and to prevent the spread of contamination from established contaminated areas.

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.

Low levels of surface contamination are expected to be remediated by washing and wiping. These techniques have been used throughout the operational history of the facility. Water washing with detergent has been the method of choice for large area decontamination. Wiping with detergent soaked or oil-impregnated media has been used on small items, overhead spaces and small hand tools to remove surface contaminants. These same techniques will be applied to remediation of lightly contaminated structure surfaces during remediation actions.

Intermediate levels of contamination and contamination on the internal surfaces of piping or components have been subjected to high-pressure washing, hydrolazing or grit blasting in the past. The refueling cavity has been decontaminated by both pressure washing and hydrolazing. Pipes, surfaces and drain lines have been cleaned and hot spots removed using hydrolazing, sponge blasting or grit blasting. Small tools, hoses and cables have been pressure washed in a self-contained glove box to remove surface contamination. These methods will be used to reduce contamination on moderately contaminated exterior surfaces as well as internal surfaces of pipes during decommissioning.

Scabbling or other surface removal techniques will reduce high levels of contamination, including that present on contaminated concrete. Concrete cutting or surface scabbling has been used at Rancho Seco in the past during or prior to installation of new equipment or structures both outside and inside the RCA.

Abrasive water jet cutting will be used to section the reactor vessel and mechanical cutting was be used to section reactor internals. Abrasive water jet cutting uses actions similar to hydrolazing and grit blasting that have been used at the site in the past. Mechanical cutting was used at this facility during past operations. The current Radiation Protection Program provides adequate controls for these actions.

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, no changes to the program are necessary in order to ensure the health and safety of the workers and the public.

4.4 ALARA Evaluation

As described in Chapter 6 of this LTP, dose assessment scenarios were evaluated for the residual contamination that could remain on structural surfaces and soils. The ALARA analysis is based on the same industrial worker, industrial worker building occupancy and containment building renovation/demolition scenarios used for RESRAD and RESRAD-BUILD derivation of single nuclide DCGLs.

4.4.1 Dose Models

To calculate the cost and benefit of averted dose for the ALARA calculation, certain parameters such as size of contaminated area and population density are required. This information was developed as a part of the dose models described in Chapter 6 and the Final Status Survey Program in Chapter 5 and is summarized below.

4.4.1.1 Industrial Worker Scenario for Surface and Subsurface Soil Exposure

The average member of the critical group is defined as a District employee or contractor who is allowed occupational access to areas of the site (which were classified as impacted prior to license termination) over the course of his/her employment. The assumption is made that occupancy would be limited to a 50-workweek year (2,000 hours per year). It was further assumed that the industrial worker would spend 50 percent of his/her time indoors and 50 percent outdoors while onsite.

The drinking water pathway is not suppressed – there are currently four potable water wells existing on the 2,480-acre site. Three of these wells are upgradient of the impacted area; however, the fourth well is in the northern portion of the impacted area and is used for potable water purposes.

4.4.1.2 Industrial Worker Scenario for Building Occupancy Exposure

The average member of the critical group is defined as a District employee or contractor who is allowed occupational access to structures (which were classified as impacted prior to license termination) of the site over the course of his/her employment. The occupancy assumed is the 45 hours per week used in NUREG/CR-5512, Volume 3, "Residual Radioactive Contamination from Decommissioning – Parameter Analysis," [Reference 4-1].

The building occupancy survey unit floor area size is 137 m^2 based on the probabilistic sensitivity analysis derivation found in LTP Section 6.7.3. ALARA cost analyses are based on an assumption that only the 137 m^2 floor area requires remediation. This is conservative since including the walls would increase remediation cost without significantly increasing the benefit of averted dose.

4.4.2 Methods for ALARA Evaluation

The ALARA evaluations were performed in accordance with the guidance in Appendix N to NUREG-1757, Volume 2, "Consolidated NMSS Decommissioning Guidance - Characterization, Survey, and Determination of Radiological Criteria," [Reference 4-2]. The principal equations used for the calculations are presented in Section 4.5. The evaluation determines if the benefit of the dose averted by the remediation is greater or less than the cost of the remediation. When the benefit is greater than the cost, additional remediation is required. Conversely when the benefit is less than the cost, additional remediation is not required.

4.4.3 Remediation Methods and Cost

For the Rancho Seco facility the remediation techniques examined are scabbling, pressure water washing, wet and dry wiping, grit blasting for embedded and buried piping, grit blasting of surfaces and soil excavation. The principal remediation method expected to be used is scabbling, which is intended to include needle guns and chipping. The total cost of each remediation method is provided in Appendix 4-A. The cost inputs are defined in Section 4.5.1, Calculation of Total Cost.

4.4.3.1 Concrete Surfaces

The characterization data for concrete surfaces at the Rancho Seco facility indicates that a major fraction of the contamination occurs in the top ten millimeters of the concrete. The ALARA evaluation was performed by bounding the cost estimate for a scabbled depth of 0.125 and 0.25 inches. For each evaluation the same manpower cost is used. However, the manpower and equipment costs for the lower bounding depth do not include compressor and consumable supply costs which adds some conservatism to the cost estimate, i.e., biases the cost low. The major variables for the bounding conditions are the costs associated with manpower and waste disposal.

4.4.3.2 Structure Activated Concrete

Concrete activation is associated with the containment building. Characterization of the reactor bioshield and loop area concrete has provided information regarding the identification, concentration, and distribution of the radionuclides. In addition to the observed concrete activation products, the concrete surfaces in the containment structure are radioactively contaminated by the deposition and transport of fluids and airborne distribution that occurred during plant operation. Based upon the difficulty that these activated and contaminated characteristics have raised in demonstrating compliance with the dose criteria in 10 CFR 20, Subpart E at other commercial reactor decommissioning projects; Rancho Seco has decided to remove and dispose of all containment building interior concrete without having performed an ALARA analysis.

4.4.4 Remediation Cost Basis

The cost of remediation depends on several factors such as those listed below. This section describes the attributes of each remediation method that affect cost. The detailed cost estimates for each method are provided in Appendix 4-A.

- Depth of contaminants;
- Surface area(s) of contamination relative to total;
- Types of surfaces: vertical walls, overhead surfaces, media condition;
- Consumable items and equipment parts;
- Cleaning rate and efficiency (decontamination factor);
- Work crew size;

- Support activities such as, waste packaging and transfer, set up time and interfering activities for other tasks; and
- Waste volume.

4.4.4.1 Scabbling

NUREG/CR-5884, Volume 2, "Revised Analyses of Decommissioning for the Reference Pressurized Water Reactor Power Station," [Reference 4-3] states that scabbling can be effectively performed on smooth concrete surfaces to a depth of 0.125 inches at a rate of 115 ft^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. The waste media and dust are deposited into a sealed removable container. The exhaust air passes through both roughing and absolute HEPA filtration devices. Dust and generated debris are collected and controlled during the operation.

The unit cost is presented in Table 4-2. Scabbling the room assumes that 100% of the concrete surface contains contamination at levels equal to the DCGL and that 12.5% of this residual activity is removed by each pass and that it takes eight passes to effectively remove all the residual activity. The debris is vacuumed into collectors that are transferred to containers for truck or rail shipments. For the evaluation, the truck container is assumed to carry 13.5 m^3 of concrete per shipment based on the NUREG-1757, Volume 2 guidance contained in Table 4-1.

Based on evaluation of concrete core samples, scabbling is expected to be the principal method used for remediation of concrete surfaces. The cost elements used to derive the unit costs for the ALARA evaluation are listed in Appendix 4-A. The methods for calculating total cost are provided in Section 4.5.1.

4.4.4.2 Pressure Water Washing

The unit costs provided in Table 4-2 for pressure water washing were established by assuming that 20,312 m^2 of the site structures' surface area is pressure washed using the surface area example of NUREG/CR-5884, Volume 1, "Revised Analyses of Decommissioning for the Reference Pressurized Water Reactor Power Station," [Reference 4-4], Table 3.22. This information was used to provide a cost per square meter factor. Appendix 4-A provides the cost details. The equipment consists of a hydrolazer and when used, a header assembly. The hydrolazer type nozzle directs the jet of pressurized water that removes surficial materials from the concrete. The header minimizes over-spray. A wet vacuum system is used to suction the potentially contaminated water into containers for filtration or processing. The cleaning speed is approximately 240 ft^2 (22.3 m^2) per hour and the process generates about 5.4 liters of liquid per square meter as discussed in NUREG/CR-5884, Volume 2. The contamination reduction rates are dependent on the media in which the contaminants are fixed, the composition of the contaminants, cleaning reagents used and water jet pressure. Mitigation of loose contaminants is high. Reduction of hard-to-remove surface contamination is approximately 25% for the jet pressure and cleaning speed used. The use of reagents and slower speeds can provide better contamination reduction rates but at proportionally higher costs. The formula associated with the cost elements is provided in Section 4.5.1 and the cost elements are provided in Appendix 4-A.

4.4.4.3 Wet and Dry Wiping

The unit costs provided in Table 4-2 for washing and wiping assume the same 20,312 m^2 of the site structures' surface area as discussed in Section 4.4.4.2 is washed and wiped. The information is used to develop a cost per square meter. Appendix 4-A provides the detailed costs. Wet wiping consists of using a cleaning reagent and wipes on surfaces that cannot be otherwise cleaned or decontaminated. Dry wiping includes the use of oil-impregnated media to pick up and hold contaminants. The cleaning rate of these actions is estimated at 2.8 m^2/hr (~2 min per ft^2), based on industry experience such as that described in the Maine Yankee License Termination Plan [Reference 4-5]. This action is labor intensive. The action is effective for the removal of loose contaminants and reduction of surface contaminants, especially when cleaning reagents are used. Waste generation is about 0.005 m^3 per hour (NUREG-5884, Volume 2). Decontamination factors vary and are dependent on factors such as the reagents that are used, the level of wiping effort and the chemical and physical composition of the contaminant. The contamination reduction efficiency used for wet and dry wiping is 20 percent. Removal of loose contaminants, oil and grease is very effective (100 percent). The formula associated with the cost elements is provided in Section 4.5.1. Appendix 4-A lists the cost elements used for the evaluation.

4.4.4.4 Grit Blasting (Embedded Piping)

The cost for grit blasting was established by assuming that 5,354 linear feet, which is the estimated total of embedded piping to remain at Rancho Seco, is decontaminated. For the evaluation, the entire interior surface is assumed to require decontamination and the internal diameter is assumed at 4 inches (typical drain line dimensions). The grit blasting system is comprised of a hopper assembly that delivers a grit medium (garnet or sand) at intermediate air pressures through a nozzle that is pulled at a fixed rate (~1 ft/min) through the piping. A HEPA vacuum system maintains the piping system under a negative pressure and collects the grit for reuse (cyclone separator) or disposal. Usually several passes are required to effectively clean the piping to acceptable residual radioactivity levels. The contamination reduction efficiency used for grit blasting is 95 percent. This reduction rate can vary depending on radial bends in piping, reduction and expansion fittings, pipe material composition, physical condition and the plate-out mechanisms associated with the contaminants and effluents. The final pass is made with clean grit to mitigate the possibility of loose residual contaminants associated with previous cleaning passes. Grit decontamination factors are related to pressure, nozzle size, grit media and the number of passes made. A nominal grit usage rate of one pound per linear foot is used in the calculation. This cost unit information is provided as cost per linear foot factor and is also converted to m^2 for evaluation. Appendix 4-A provides the cost details used to derive unit cost. The formula associated with the cost elements is provided in Section 4.5.1.

4.4.4.5 Sponge and Abrasive Blasting

Sponge and abrasive blasting uses media or materials coated with abrasive compounds such as silica sands, garnet, aluminum oxide and walnut hulls. The operation uses intermediate air pressures as that described for grit blasting. The operation uses a closed-capture system and air filtration system to mitigate loose and airborne radioactivity. The system includes a cyclone or similar separation system to collect the generated media. The operation is intended for removal of surficial films. The removal efficiency and depth are a function of the surface, abrasive mix, air pressure, grit media, and speed or number of passes performed over the suspect surface. Surface cleaning rates are about 30 ft^2/hr (2.8 m^2/hr). For the rate given, the removal depth using aluminum oxide grit will range from less than 1 to as much as 3 millimeters. Abrasive blasting techniques are often used for film and paint removal and are less aggressive than scabbling.

4.4.4.6 Soil Excavation

The unit costs provided in Table 4-2 for soil excavation were established by assuming 52,972 ft^3 (1,500.0 m^3) of soil is excavated from the site. This information was used to generate a cost per cubic meter for soil remediation. The equipment consists of an excavator that first moves the soil at the contaminated depth interface into a container or if necessary, a pile that is scooped into a staged shipping container. When filled, the container is moved from the excavation area with a forklift. Contamination reduction is assumed at 95%. The operation is performed using two equipment operators and two laborers. Costs for radiation protection support activities and supervision are also included. The formula associated with the cost elements is provided in Section 4.5.1 and the cost elements are provided in Appendix 4-A.

4.5 Unit Cost Estimates

In order to effectively perform ALARA evaluations and remediation actions, unit cost values are required. These values are used to perform the NUREG-1757, Volume 2 cost-benefit analysis. Table 4-2 lists the unit costs of the remediation methods anticipated to be used at Rancho Seco.

4.5.1 Calculation of Total Cost

In order to evaluate the cost of remediation actions NUREG-1757, Volume 2, Appendix N provides the elements necessary to derive the costs that are compared to the benefits. The total cost, $Cost_T$, which is balanced against the benefits, has several components defined as follows in Appendix N, Equation (N-3):

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

Equation 4-1

where:

$Cost_R$	=	monetary cost of the remediation action (may include "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 transporting of the waste;
$Cost_{WDose}$	=	monetary cost of dose received by workers performing the remediation action and transporting waste to the disposal facility;
$Cost_{PDose}$	=	monetary cost of the dose to the public from excavation, transport, and disposal of the waste; and
$Cost_{other}$	=	other costs as appropriate for the particular situation.

4.5.1.1 Transport and Disposal of the Waste

In accordance with the guidance provided in NUREG-1757, Volume 2, the cost of waste transport and disposal, $Cost_{WD}$, may be evaluated according to Equation 4-2 below:

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

Equation 4-2

where:

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

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

4.5.1.2 Nonradiological Risks

Also in accordance with the guidance provided in NUREG-1757, Volume 2, the cost of nonradiological workplace accidents, $Cost_{ACC}$, may be evaluated using Equation 4-3 below:

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

Equation 4-3

where:

\$3,000,000 = monetary value of a fatality equivalent to \$2,000/person-rem (see pages 11-12 of NUREG-1530, "Reassessment of NRC's Dollar per Person-Rem Conversion Factor Policy," [Reference 4-6]);

F_W = workplace fatality rate in fatalities/hour worked; and

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

4.5.1.3 Transportation Risks

Also, the cost of traffic fatalities incurred during the transportation of waste, $Cost_{TF}$, may be calculated using Equation 4-4 below:

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

Equation 4-4

where:

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, and

D_T = distance traveled in km.

The actual parameters will depend on Rancho Seco's planned method of waste transport. This may include a mix of trucking and rail transport to get the waste to the disposal site. In these cases, the cost would be equivalent to the total fatalities likely from the rail transport and the limited trucking, not just the trucking alone.

4.5.1.4 Worker Dose Estimates

The cost of the remediation worker dose, $Cost_{WDose}$, can be calculated as shown in Equation 4-5 below:

$$Cost_{WDose} = \$2{,}000 \times D_R \times T$$

Equation 4-5

where:

D_R = total effective dose equivalent (TEDE) rate to remediation workers in units of rems/hr, and

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

4.5.1.5 Default Parameter Values

In accordance with the guidance provided in NUREG-1757, Volume 2, parameter values found acceptable by the NRC for performing the calculations provided in Equations 4-2 through 4-5 and the source of the parameter values, are provided in Table 4-1.

Table 4-1
Acceptable Parameter Values for Use in ALARA Analyses

Parameter	Parameter Value	Reference Source
Workplace accident fatality rate, F_W	4.2E-08/hr	NUREG–1496, Volume 1 [Reference 4-7] and NUREG–1496, Volume 2 [Reference 4-8], Appendix B, Table A.1
Transportation fatal accident rate, F_T	Trucks: 3.8E-08/km	NUREG–1496, Volume 2, Appendix B, Table A.1
Dollars/person-rem	$2,000	NUREG/BR–0058 [Reference 4-9], Section 4.3.5
Monetary discount rate, r	0.07/y for the first 100 years and 0.03/y thereafter, or 0.07 for buildings and 0.03 for soil	NUREG/BR–0058, Section 4.3.5
Number of years of exposure, N	Buildings: 70 years Soil: 1000 years	NUREG–1496, Volume 2, Appendix B, Table A.1
Population density, P_D	Building: 0.09 person/m^2 Land: 0.0004 person/m^2	NUREG–1496, Volume 2, Appendix B, Table A.1
Excavation, monitoring, packaging, and handling soil	Soil: 1.62 person-hours/m^3 of soil	NUREG–1496, Volume 2, Appendix B, Table A.1
Waste shipment volume, V_{SHIP}	Truck: 13.6 m^3/shipment	NUREG–1496, Volume 2, Appendix B, Table A.1

4.5.2 Calculation of Benefits

In order to evaluate the benefits of remediation actions NUREG-1757, Volume 2, Appendix N provides the elements necessary to derive the benefits that are compared to the total cost. As discussed in Section 4.4.1, calculation of the benefits of remediation actions is based on an industrial worker scenario for surface and subsurface soil exposure and for building occupancy exposure. The benefit from collective averted dose, B_{AD}, is calculated by determining the present worth of the future collective averted dose and multiplying it by a factor to convert the dose to monetary value:

$$B_{AD} = \$2{,}000 \times PW\left(AD_{collective}\right)$$

Equation 4-6

where:

B_{AD} = benefit from an avoided dose for a remediation action, in current U.S. dollars;

\$2,000 = value in dollars of a person-rem averted (see NUREG/BR–0058); and

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

A value acceptable to the NRC for a collective dose is \$2,000 per person-rem averted, discounted for a dose averted in the future (see Section 4.3.5 of NUREG/BR–0058, Revision 4). For doses averted within the first 100 years (applicable to structural surfaces), a discount rate of 7 percent was used. For doses averted beyond 100 years (applicable to surface and subsurface soil), a 3 percent discount rate was used.

The present worth of the future collective averted dose can be estimated from Equation 4-7, for relatively simple situations:

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

Equation 4-7

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 average member of the critical group from residual radioactivity at the Derived Concentration Guideline Level ($DCGL_W$) concentration in rem/y;

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 area for buildings or activity per unit volume for soils;

$DCGL_W$ = derived concentration guideline equivalent to the average concentration of residual radioactivity that would give a dose of 25 mrem/y to the average member of the critical group, in the same units as "*Conc*";

r = monetary discount rate in units per year;

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

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

The present worth of the benefit calculated by Equation 4-7, above, assumes that the peak dose occurs in the first year. The $DCGL_W$ used is the single nuclide $DCGL_W$ derived in LTP Chapter 6 to show compliance with the 25 mrem/y dose limit. The population density, P_D, is based on the dose scenario used to demonstrate compliance with the dose limit. The factor at the far right of the equation, which includes the exponential terms, accounts for both the present worth of the monetary value and radiological decay.

4.5.3 Residual Radioactivity Levels that are ALARA

NUREG-1757, Volume 2, Appendix N, also provides the guidance necessary to determine if residual levels of radioactivity are ALARA. The residual radioactivity level that is ALARA is the concentration, *Conc*, at which the benefit from removal equals the cost of removal. If the total cost, $Cost_T$, is set equal to the present worth of the collective dose averted in Equation 4-7, the ratio of the concentration, *Conc*, to the $DCGL_W$ can be determined from Equation 4-8 below (derivation shown in NUREG-1757, Volume 2, Section N.5).

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

Equation 4-8

All the terms in Equation 4-8 are as defined previously.

Equation 4-9 may be derived from Equation 4-8 to perform the ALARA evaluation in the presence of multiple radionuclides as follows:

$$\frac{Conc}{DCGL_W} = \frac{Cost_T}{\$2{,}000 \times P_D \times 0.025 \times F \times A} \times \left[\frac{\frac{r+\lambda}{1-e^{-(r+\lambda)N}}}{1}\right]$$

The right term of the above equation is then multiplied by 1 as follows:

$$\frac{Conc}{DCGL_W} = \frac{Cost_T}{\$2{,}000 \times P_D \times 0.025 \times F \times A} \times \left[\frac{\frac{r+\lambda}{1-e^{-(r+\lambda)N}}}{1}\right] \times \left[\frac{\frac{1-e^{-(r+\lambda)N}}{r+\lambda}}{\frac{1-e^{-(r+\lambda)N}}{r+\lambda}}\right]$$

Equation 4-8 is then expressed as:

$$\frac{Conc}{DCGL_W} = \frac{Cost_T}{\$2{,}000 \times P_D \times 0.025 \times F \times A \times \left[\frac{1-e^{-(r+\lambda)N}}{r+\lambda}\right]}$$

For multiple radionuclides the denominator must be summed over all radionuclides as shown below:

$$\frac{Conc}{DCGL_W} = \frac{Cost_T}{\sum_i^n \$2{,}000 \times P_D \times 0.025 \times Df_i \times F \times A \times \left[\frac{1-e^{-(r+\lambda_i)N}}{r+\lambda_i}\right]}$$

Equation 4-9

where:

i = radionuclide "i",

n = total of all radionuclides, and

Df_i = dose fraction of radionuclide "i"

and:

$$Df_i = \frac{\frac{nf_i}{DCGL_{W_i}}}{\sum_i^n \frac{nf_i}{DCGL_{W_i}}}$$

where:

nf_i = nuclide fraction of the mixture radionuclide

4.6 Radionuclides Considered for ALARA Calculations

As discussed in LTP Chapter 6, Section 6.4.1, the site-specific suite of radionuclides identified for use at Rancho Seco contains 26 radionuclides. Only six of these radionuclides have been identified above minimum detectable concentration (MDC) levels in soil samples while 21 have been identified at least one time in structural surface samples. For purposes of the ALARA calculations, only Co-60 and Cs-137 were used along with their associated DCGL values (adjusted DCGL value for Co-60 and surrogate DCGL value for Cs-137) and nuclide fractions. Cs-137 was used as a surrogate radionuclide for the other 19 radionuclides with the surrogate DCGL value used to classify survey units. Rancho Seco Decommissioning Technical Basis Document DTBD-05-015, "Rancho Seco Nuclear Generating Station Structure Nuclide Fraction and DCGLs," [Reference 4-10] provides the bases for the structural surface nuclide fractions and the surrogate DCGL value. Rancho Seco DTBD-05-014, "Rancho Seco Nuclear Generating Station Surface Soil Nuclide Fraction and DCGL," [Reference 4-11] provides the bases for the surface soil nuclide fractions and the surrogate DCGL value.

4.7 ALARA Calculation Results

The final ALARA calculations were performed by comparing the total remediation cost to the benefit of averted dose using Equation 4-9. The calculations were described in detail in Sections 4.5.1, 4.5.2 and 4.5.3. The results for each remediation method, for both the Industrial Worker (for soils) and (Industrial Worker) Building Occupancy scenarios, are provided in Table 4-2. Since the $Conc/DCGL_W$ values are greater than 1 for all remediation methods and scenarios, no remediation below the NRC 25 mrem/y dose limit is required.

Table 4-2
ALARA Evaluation Results

Remediation Action	Unit Costs ($ per ft, m^2 or m^3)	$Conc/DCGL_W$ Ratio
Pressure Washing and Vacuuming	15.31	1.31
Wiping/Washing	58.87	6.31
Concrete Scabbling(Upper Bound)	67.02	5.75
Concrete Scabbling (Lower Bound)	33.36	5.72
Grit Blasting Surfaces (Upper Bound)	96.88	2.19
Grit Blasting Surfaces (Lower Bound)	80.58	1.82
Grit Blasting Embedded/Buried Piping	27.39	42.77
Soil Excavation	2,679.82	1142.00

4.8 References

4-1 U.S. Nuclear Regulatory Commission NUREG/CR-5512, Volume 3, "Residual Radioactive Contamination from Decommissioning – Parameter Analysis, Draft Report for Comment," October 1999

4-2 U.S. Nuclear Regulatory Commission, NUREG-1757, Volume 2, Final Report, "Consolidated NMSS Decommissioning Guidance - Characterization, Survey, and Determination of Radiological Criteria," September 2003

4-3 U.S. Nuclear Regulatory Commission, NUREG/CR-5884, Volume 2, "Revised Analyses of Decommissioning for the Reference Pressurized Water Reactor Power Station," Draft Report for Comment, October 1993

4-4 U.S. Nuclear Regulatory Commission, NUREG/CR-5884, Volume 1, "Revised Analyses of Decommissioning for the Reference Pressurized Water Reactor Power Station," Draft Report for Comment, October 1993

4-5 "License Termination Plan," submitted by Maine Yankee Atomic Power Company, Revision 3, October 15, 2002

4-6 U.S. Nuclear Regulatory Commission, NUREG-1530, "Reassessment of NRC's Dollar per Person-Rem Conversion Factor Policy," December 1995

4-7 U.S. Nuclear Regulatory Commission, NUREG–1496, Volume 1, Final Report, "Final Generic Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for License Termination of NRC-Licensed Nuclear Facilities," July 1997

4-8 U.S. Nuclear Regulatory Commission, NUREG–1496, Volume 2, Final Report, "Final Generic Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for License Termination of NRC-Licensed Nuclear Facilities," July 1997

4-9 U.S. Nuclear Regulatory Commission, NUREG/BR–0058, Revision 4, "Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission," September 2004

4-10 Rancho Seco Decommissioning Technical Basis Document DTBD-05-015, Revision 0, "Rancho Seco Nuclear Generating Station Structure Nuclide Fraction and DCGLs"

4-11 Rancho Seco Decommissioning Technical Basis Document DTBD-05-014, Revision 0, "Rancho Seco Nuclear Generating Station Surface Soil Nuclide Fraction and DCGL"

A.1 General

This Appendix provides the unit cost values used to develop the total cost C_T as defined in Section 4.5.1.

Remediation Activity Rates

Remediation activity rates were provided based on previous experience, from published literature, or from groups or vendors currently performing these or similar activities. Past operational experience was also used in developing the rates.

Contingency

A contingency of 0.25 was added to the manpower hours. Scabbling (the primary activity) was bounded using cost and manpower associated with the volume of concrete (disposal cost) for remediation of 0.125 inches versus using a compressor, consumable materials and the volume of concrete (disposal cost) for remediation of 0.25 inches of concrete.

Equipment

Equipment costs were developed based on the cost of buying specific equipment and whenever possible prorating the cost over the task activities. Rental rates are also included for specific equipment such as forklifts and excavators. Consumable supplies and parts were included in the cost for equipment. Shipping containers were included with shipment costs.

Mobilization and Demobilization Costs

Costs were conservatively included for delivery and pick up of equipment. Anticipated costs to stage and move equipment from location to location were also included.

Waste Disposal Cost

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 Rancho Seco site to Clive, Utah (Energy*Solutions*[1] site). The details of the average total disposal cost of $2,500 are considered proprietary values defined by negotiated contract.

The Clive, Utah round trip distance from the Rancho Seco site by highway is 1,223 miles (1,968 km). The distance for rail shipments is considerably further than that for highway shipments because of the route rail shipments must follow. The highway shipment distance of 1,968 km (D_T) was used as a conservative value for the calculation of C_T since it results in a lower transportation cost.

The volume for highway hauling (V_{SHIP}) used for the calculation of C_T was 13.6 m^3 as specified in Table 4-1. The distance and haul volume are used for determining transport accident cost in

[1] Energy*Solutions* was previously Envirocare of Utah

accordance with NUREG-1757, Volume 2 and Section 4.5.1.3. The impact to total cost of this item is minimal.

Worker Accident Costs

To determine worker accident cost in accordance with NUREG-1757, Volume 2 and Section 4.5.1.2, the same hours input for labor cost were used for worker accident cost.

Worker Dose

Costs associated with worker dose are a function of the hours worked and the workers' radiation exposure for the task. A value of 2 mrem/hr per work crew or 3 mrem/hr per work crew for work crew dose depending upon remediation action was based on the assumed dose rate used for worker dose calculations in NUREG/CR-5884 Volume 2.

Labor Costs

The individual cost for the applicable disciplines, e.g., laborer, equipment operator, health physics technicians, were developed into an hourly crew rate for the task and based on guidance provided by NUREG/CR-5884, Volumes 1 and 2. Manpower costs assumptions were also based on NUREG/CR-5884. The NUREG/CR-5884 manpower cost assumptions are based on 1993 dollars and were not escalated to the projected time remediation activities would occur for the following C_T calculations. This is considered a conservative approach because escalating manpower costs or using current contracted rates would only raise C_T, thus raising the $Conc/DCGL_W$ ratio. It is important to note that the total work hours for a normal day were used and not adjusted for personnel breaks, ALARA meetings or ingress and egress from an area.

Unit Cost

The sum of all the cost elements was divided by the applicable unit (m^2, m^3 or linear feet) to provide a unit cost for the activity. Other cost units for cost per hour or linear foot were also developed in the same fashion. The tables to follow provide the crew cost per hour but do not provide the individual hourly rates for individual disciplines. These values are however included in the supporting calculation.

A.2 Pressure Water Washing And Vacuuming

Area Evaluated For Unit Cost Determination:	20,312 m^2 (218,636 ft^2) per NUREG/CR-5884, Volume 1, Table 3.22
Crew Composition	2 Laborers, 1 Craft, 0.5 HP Technician and 0.5 Crew Leader per NUREG/CR-5884, Volume 2, Appendix C
Hourly Crew Cost:	$148.27 per NUREG/CR-5884, Volume 2, Appendix C without escalation from 1993 labor costs
Cleaning Rate:	22.3 m^2/h (240 ft^2/hr) per NUREG/CR-5884, Volume 2, Appendix C

Contamination Removed:	25% based on industry experience
Hours:	1,139 [(20,312 m^2/22.3 m^2/h)(1.25 contingency)]
Mobilization Costs	$600
Labor Cost:	$168,815
Equipment Costs:	$3,480 per NUREG/CR-5884, Volume 2, Appendix C
Liquid Processing Costs:	$34,276 [($1.00/g)(1.35g/m^2)(20,312 m^2) (1.25 liquid contingency)]
Waste Disposal Cost ($Cost_{WD}$):	$101,500 [Solids estimated at 0.002 m^3/m^2 = 40.6 m^3 ($ 2,500/m^3)]
Worker Accident Cost ($Cost_{ACC}$):	$574 per Equation 4-3
Transportation Accident Cost ($Cost_{TF}$):	$670 per Equation 4-4
Worker Dose Cost ($Cost_{WDose}$):	$1,139 at NUREG/CR-5884, Volume 2, Appendix C, dose rate of 0.002 rem/crew-hour using Equation 4-5
Total Costs ($Cost_T$):	$311,053
Cost ($Cost_T$) per m^2:	$15.31

A.3 Washing and Wiping Remediation Actions

Area Evaluated For Unit Cost Determination:	20,312 m^2 (218,636 ft^2) per NUREG/CR-5884, Volume 1, Table 3.22
Crew Composition	2 Laborers, 0.5 HP Technician and 0.5 Crew Leader
Hourly Crew Cost:	$98.57 per NUREG/CR-5884, Volume 2, Appendix C without escalation from 1993 labor costs
Cleaning Rate:	2.8 m^2/h based on industry experience
Contamination Removed:	20% based on industry experience
Hours:	9,975 [(20,312 m^2/2.8 m^2//h) + 4 h/40 h set up)(1.25 contingency)]
Mobilization Costs	$600

Labor Cost:	$983,200
Equipment Costs:	$21,571 based on industry experience
Waste Generation:	68.9 m^3 (3.39E-03 m^3/m^2) based on industry experience
Waste Disposal Cost ($Cost_{WD}$):	$172,250 ($ 2,500/m^3)
Worker Accident Cost ($Cost_{ACC}$):	$3,770 per Equation 4-3
Transportation Accident Cost ($Cost_{TF}$):	$1,137 per Equation 4-4
Worker Dose Cost ($Cost_{WDose}$):	$13,300 at NUREG/CR-5884, Volume 2, Appendix C, dose rate of 0.002 rem/crew-hour using Equation 4-5
Total Costs ($Cost_T$):	$1,195,828
Cost ($Cost_T$) per m^2:	$58.87

A.4.a Scabbling Remediation Action (Bounding Condition 0.635 cm (0.25 in) Concrete)*

Area Evaluated For Unit Cost Determination:	2,007 m^2 (21,598 ft^2) per NUREG/CR-5884, Volume 1, Table 3.22
Crew Composition	3 Laborers, 0.25 HP Technician and 0.25 Crew Leader per NUREG/CR-5884, Volume 2, Appendix C
Hourly Crew Cost:	$102.02 per NUREG/CR-5884, Volume 2, Appendix C without escalation from 1993 labor costs
Cleaning Rate:	4.65 m^2/h per NUREG/CR-5884, Volume 2, Appendix C removal rate is 9.29 m^2/h per pass with two passes required to remove 0.25 inches
Contamination Removed:	25% per NUREG/CR-5884, Volume 2, Appendix C removal of 12.5% per pass
Hours:	540 [(2,007 m^2/4.65 m^2//h)(1.25 contingency)]
Mobilization Costs	$7,100 based on industry experience
Labor Cost:	$55,041

Equipment Costs:	\$39,549.60 (\$73.24/hr) based on current industry experience*
Waste Generation:	12.7 m^3 = (2,007 m^2)(6.35E-3 m)
Waste Disposal Cost ($Cost_{WD}$):	\$31,750 (\$2,500/m^3)
Worker Accident Cost ($Cost_{ACC}$):	\$238 per Equation 4-3
Transportation Accident Cost ($Cost_{TF}$):	\$210 per Equation 4-4
Worker Dose Cost ($Cost_{WDose}$):	\$617 at NUREG/CR-5884, Volume 2, Appendix C, dose rate of 0.003 rem/crew-hour using Equation 4-5
Total Costs ($Cost_T$):	\$134,505
Cost ($Cost_T$) per m^2:	\$67.02*

*Bounding condition includes cost for air compressor, consumables at 10% of the base equipment costs and the waste volume of 0.25 inch (0.635 cm) concrete depth.

A.4.b <u>Scabbling Remediation Action (Bounding Condition 0.32 cm (0.125 in) Concrete)</u>*

Area Evaluated For Unit Cost Determination:	2,007 m^2 (21,598 ft^2) per NUREG/CR-5884, Volume 1, Table 3.22
Crew Composition	3 Laborers, 0.25 HP Technician and 0.25 Crew Leader per NUREG/CR-5884, Volume 2, Appendix C
Hourly Crew Cost:	\$102.02 per NUREG/CR-5884, Volume 2, Appendix C without escalation from 1993 labor costs
Cleaning Rate:	9.29 m^2/h per NUREG/CR-5884, Volume 2, Appendix C removal rate is 9.29 m^2/h per pass with one pass required to remove 0.125 inches
Contamination Removed:	12.5% per NUREG/CR-5884, Volume 2, Appendix C removal of 12.5% per pass
Hours:	270 [(2,007 m^2/9.29 m^2//h)(1.25 contingency)]
Mobilization Costs	\$7,100 based on industry experience
Labor Cost:	\$27,550

Equipment Cost:	\$15,827.40 (\$58.62/hr) based on current industry experience*
Waste Generation:	6.38 m^3 = (2,007 m^2)(3.18E-3 m)*
Waste Disposal Cost ($Cost_{WD}$):	\$15,950 (\$2,500/m^3)
Worker Accident Cost ($Cost_{ACC}$):	\$119 per Equation 4-3
Transportation Accident Cost ($Cost_{TF}$):	\$105 per Equation 4-4
Worker Dose Cost ($Cost_{WDose}$):	\$309 at NUREG/CR-5884, Volume 2, Appendix C, dose rate of 0.003 rem/crew-hour using Equation 4-5
Total Costs ($Cost_T$):	\$66,961
Cost ($Cost_T$) per m^2:	\$33.36

*Bounding condition uses: (1) base equipment cost , (2) assumes an on-site air compressor, (3) no added consumables, and (4) the waste volume is relative to 0.125 inches (0.32 cm) depth of concrete, i.e., one-half of that assumed in A.4.a.

A.5 Grit Blasting (Embedded/Buried Piping) Remediation Action

Length Evaluated For Unit Cost Determination:	5,354 linear feet (LF) – total of embedded piping to remain at Rancho Seco
Crew Composition	2 Laborers, 1 Craft, 0.5 HP Technician and 0.5 Crew Leader based on NUREG/CR-5884, Volume 2, Appendix C crew for pressure washing
Hourly Crew Cost:	\$148.27 per NUREG/CR-5884, Volume 2, Appendix C without escalation from 1993 labor costs
Cleaning Rate:	60 LF/h based on recent industry experience
Hours:	112 [(5,354 LF/60 LF/hr)(1.25 contingency multiplier)]
Mobilization Costs	\$4,000 based on recent industry experience
Labor Cost:	\$16,538
Equipment Costs:	\$123,311 based on recent industry experience

Waste Generation:	1.05 m^3 = (5,354 LF x 1.96E-04 m^3/LF at ~ 1.0 lb. per linear foot)
Waste Disposal Cost ($Cost_{WD}$):	$2,625 ($ 2,500/m^3)
Worker Accident Cost ($Cost_{ACC}$):	$56 per Equation 4-3
Transportation Accident Cost ($Cost_{TF}$):	$17 per Equation 4-4
Worker Dose Cost ($Cost_{WDose}$):	$112 at NUREG/CR-5884, Volume 2, Appendix C, dose rate of 0.002 rem/crew-hour for pressure washing using Equation 4-5
Total Costs ($Cost_T$):	$146,659
Cost ($Cost_T$) per linear foot:	$27.39

A.6.a <u>Grit Blasting (Surfaces) Remediation Action (Bounding Condition 1.25 Contingency)</u>

Area Evaluated For Unit Cost Determination:	2,007 m^2 (21,598 ft^2) per NUREG/CR-5884, Volume 1, Table 3.22 for scabbling evaluation
Crew Composition:	3 Laborers, 0.25 HP Technician and 0.25 Crew Leader as in the NUREG/CR-5884, Volume 2, Appendix C, evaluation for scabbling remediation action
Hourly Crew Cost:	$102.02 per NUREG/CR-5884, Volume 2, Appendix C without escalation from 1993 labor costs
Cleaning Rate:	2.79 m^2/hr based on recent industry experience
Hours:	899 [(2,007/2.79 m^2/h) x 1.25 contingency]
Mobilization Costs	$7,339 [(2,007/2.79 m^2/h) x 0.10 set up x $102.02/crew hour]
Labor Cost:	$91,736
Equipment Costs:	$51,315 based on recent industry experience
Grit/Consumables	$17,984 based on recent industry experience
Waste Generation:	9.59 m^3 = (2,007 m^2 x 3.0E-03 m + 3.57 m^3 for grit)

Waste Disposal Cost ($Cost_{WD}$):	\$23,975 (\$2,500/m^3)
Worker Accident Cost ($Cost_{ACC}$):	\$397 per Equation 4-3
Transportation Accident Cost ($Cost_{TF}$):	\$158 per Equation 4-4
Worker Dose Cost ($Cost_{WDose}$):	\$1,541 at NUREG/CR-5884, Volume 2, Appendix C, dose rate of 0.003 rem/crew-hour for scabbling using Equation 4-5
Total Costs ($Cost_T$):	\$194,445
Cost ($Cost_T$) per m^2	\$96.88

A.6.b <u>Grit Blasting (Surfaces) Remediation Action (Bounding Condition No Contingency)</u>

Area Evaluated For Unit Cost Determination:	2,007 m^2 (21,598 ft^2) per NUREG/CR-5884, Volume 1, Table 3.22 for scabbling evaluation
Crew Composition:	3 Laborers, 0.25 HP Technician and 0.25 Crew Leader as in the NUREG/CR-5884, Volume 2, Appendix C, evaluation for scabbling remediation action
Hourly Crew Cost:	\$102.02 per NUREG/CR-5884, Volume 2, Appendix C without escalation from 1993 labor costs
Cleaning Rate:	2.79 m^2/hr based on recent industry experience
Hours:	719 (2,007 m^2/2.79 m^2/hr)
Mobilization Costs	\$7,339 [(2,007/2.79 m^2/h) x 0.10 set up x \$102.02/crew hour]
Labor Cost:	\$73,389
Equipment Costs:	\$37,320 based on recent industry experience
Grit/Consumables	\$17,984 based on recent industry experience
Waste Generation:	9.59 m^3 = (2,007 m^2 x 3.0E-03 m + 3.57 m^3 for grit)
Waste Disposal Cost ($Cost_{WD}$):	\$23,975 (\$2,500/m^3)
Worker Accident Cost ($Cost_{ACC}$):	\$317 per Equation 4-3

Transportation Accident Cost ($Cost_{TF}$):	\$158 per Equation 4-4
Worker Dose Cost ($Cost_{WDose}$):	\$1,233 at NUREG/CR-5884, Volume 2, Appendix C, dose rate of 0.003 rem/crew-hour for scabbling using Equation 4-5
Total Costs ($Cost_T$):	\$161,715
Cost ($Cost_T$) per m^2	\$80.58

A.7 Soil Excavation Remediation Action

Volume Evaluated For Unit Cost Determination:	1,500 m^3 (52,972 ft^3) based on top 15 cm of soil removed from a 10,000 m^2 area
Crew Composition	2 Laborers, 2 Craft, 0.25 HP Technician and 0.25 Crew Leader based on recent industry experience
Hourly Crew Cost:	\$175.06 per NUREG/CR-5884, Volume 2, Table B.1 labor costs without escalation from 1993 labor costs
Cleaning Rate:	3.06 m^3/h based on recent industry experience
Hours:	980 [(1,500 m^3/3.06 m^3/h)(2.0 contingency multiplier for restaging and articulation)]
Mobilization Costs	\$700 based on recent industry experience
Labor Cost:	\$171,627
Equipment Costs:	\$71,228 (consumables \$9,291)
Waste Generation:	1,500 m^3 based on volume of soil removed
Waste Disposal Cost ($Cost_{WD}$):	\$3,750,00 (\$2,500/m^3)
Worker Accident Cost ($Cost_{ACC}$):	\$556 per Equation 4-3
Transportation Accident Cost ($Cost_{TF}$):	\$24,745 per Equation 4-4
Worker Dose Cost ($Cost_{WDose}$):	\$871 at NUREG/CR-5884, Volume 2, Appendix C, dose rate of 0.002 rem/crew-hour for pressure washing using Equation 4-5
Total Costs ($Cost_T$):	\$4,019,727

Cost ($Cost_T$) per m^3: $2,679.82